YIELD AND QUALITY OF WINTER RYE IN TRIALS AT THE JÕGEVA PBI

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Abstract
Rye bread has been a staple food for centuries in Estonia, Latvia, and Lithuania. The aim of the study was to compare the yield and quality of winter rye varieties and breeds from all the three countries in Estonian climatic and soil conditions at the Jõgeva Plant Breeding Institute (PBI). The varieties Elvi (Estonia), Kaupo (Latvia), and Joniai (Lithuania) and the breeds J 92-5 (Estonia), LAT 9504 (Latvia), and LIA 426 (Lithuania) were sown using conventional cultivation in three series of trials (2005–2007). Weather conditions of the trial years were relatively similar. No significant winter damage was observed. All the varieties and the breeds demonstrated high yielding potential. Comparing the three-year averages, the variety Elvi and the breed J 92-5 had the highest yields. The thousand-kernel weight (TKW) exceeded 30 g in all the trial years and the average was the highest in 2005. The falling number (FN) was generally suitable for bread baking on average, Joniai and breed LIA 426 had the lowest FN in all the years. In wet conditions, the harvest of this variety and breed must be completed fast.

Key words: winter hardiness, yield components, yield, thousand-kernel weight, quality

Introduction
Rye bread is a valuable component in the human diet, and the consumption of the bread in physiologically reasonable quantities may make us feel good as well as protect us against health problems (Kann, 2002). In 2005, the area under winter rye in Estonia was rather small: only 7.4 thousand hectares. By 2007 it had increased to 16.2 thousand hectares (www.stat.ee). The climatic conditions of Estonia are suitable for the cultivation of winter rye but it is important to find an appropriate variety. The success of rye cultivation depends on the climatic conditions and the adaptation of varieties to variable growing conditions (Tupits and Kukk, 2000). Experiments with different rye varieties, investigating development, winter hardiness, yield formation and quality in Finland, showed that both the yield and the quality depended mostly on local climatic conditions (Pahkala *et al*., 2004).
Chmielewski (1992) admits relying on his long-term study, that even relatively small climate change can affect crop yields. Climate change towards warming can also be observed in Estonia (Jaagus, 1999). Because of climate change, there is a need for new rye varieties that would be suitable for cultivation in changeable conditions, have good yielding capacity, are resistant to plant diseases, and have a high bread baking quality (Hakala and Pahkala, 2003). The aim of this study was to compare the yield and the quality of the new local breeding material with the breeding material from neighbouring countries and with the best varieties from Estonia, Latvia and Lithuania. Foreign winter rye varieties suitable for the Estonian climatic and soil conditions are also a good source of initial material for rye breeding.

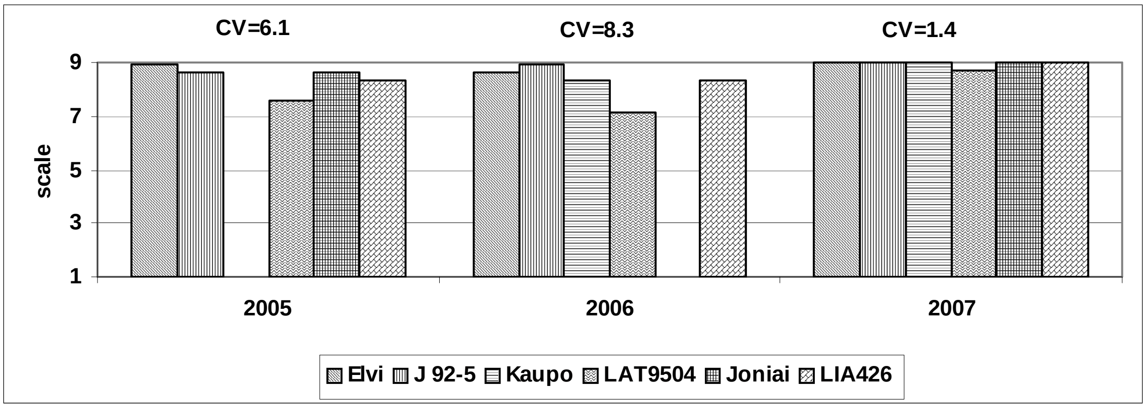
Material and Methods
The study involves three growing seasons (2005–2007). By FAO-UNESCO classification, the Jõgeva PBI trial area is located on podzolized soddy-calsareous soil (Kask, 1995). Based on soil analyses (pH_{KCl} 6.5), 290 kg ha^{-1} of the complex fertilizer Kemira Skalsa ($N_0P_{12}K_{24}$) was applied before sowing. In spring, after the onset of plant growth, 150 kg ha^{-1} of ammonium nitrate (N_{51}) was added. Non-treated seeds were sown on black fallow in three replications, using a completely randomized block design according to the Nearest Neighbour Analyses method (NNA). The trial plots were 5 square meters each. The sowing rate was 500 germinating seeds per square meter and the sowing time was the first decade of September. The optimal sowing time of winter rye in Estonia is from August 25 to September 10. The following varieties and breeds were included in the trials: Elvi and J 92-5 (Estonia), Kaupo and LAT 9504 (Latvia), Joniai and LIA 426

(Lithuania). The determined grain yields (kg ha^{-1}) describe the weight of dried and cleaned seeds calculated to 14% moisture content. Winter hardiness was assessed on a 1–9 scale (1–poor winter hardiness, 9–winter hardy) by the visual inspection of all the trial plots. The yield components were determined from samples, compiled from 25 randomly picked plants, by counting the tillers per plant and the kernels per head, and weighing the kernels. The falling numbers (FN) were determined according to the standard method of AACC 56-81A with the Falling Number 1800 equipment. The yield data were statistically analysed using the database management and analysis system Agrobase (Agrobase^{TM} 20, 1999) ($LSD_{0.05}$). The coefficient of variation (CV) was used as a basis for the comparison between different trial years.

In Estonia, the vegetation period of rye usually begins in the middle of April and the harvest at the end of July or in early August. Meteorological data from the beginning of the vegetation period to the harvest were recorded by the field meteorological weather station Metos Compact. The long-term (1922–2007) average sum of precipitation of the vegetation period of rye at Jõgeva is 255 mm, and the long-term average cumulative sum of effective (over +5° C) air temperatures is 994 degrees. The vegetation periods of 2005, 2006 and 2007 were considerably drier and warmer than the long-term average. For yield and for quality in general, not only the amount, but also the distribution of precipitation during the vegetation period is important. The beginning of the 2005 vegetation period was cool but from the end of May to the end of July the air temperature was above the long-term average (sum – 1024 degrees). In May it was wet, in June and July there was drought and rain started again just before harvesting. The sum of precipitation of the 2005 vegetation period was 287 mm. The vegetation periods of 2006 and 2007 were dry (precipitation 111 and 214 mm respectively) and warm (1006 and 1010 degrees respectively) from the beginning and the rye seeds reached the hard dough development stage about two weeks earlier than usual. In 2007 it started to rain shortly before harvesting.

Results and Discussion

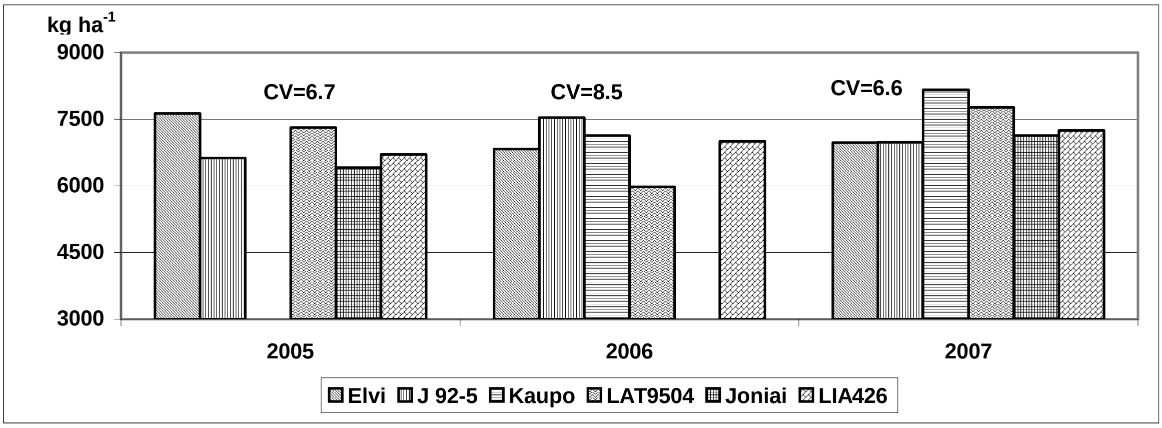
In general, winter hardiness in the trials was high (Figure 1). The highest winter hardiness during all the trials was assessed in 2007 (CV 1.4). In 2005 and 2006, the average winter hardiness was lower than in 2007 (CV 6.1 and 8.3 respectively). In all the trial years, the Estonian variety and breed were the most winter hardy, followed by the breed from Lithuania. The Latvian breed had the lowest winter hardiness.



($LSD_{0,05}$ for 2005=0.8; 2006=0.65; 2007=0.2)

Figure 1. Winter hardiness of the rye varieties and breeds in the trials at the Jõgeva PBI

The highest average yield of the trial years was in 2007 – 7,377 kg ha^{-1} (CV 6.6), in 2006 6,977 kg ha^{-1} (CV 8.5) and in 2005 6,940 kg ha^{-1} (CV 6.7) (Figure 2). Elvi had the highest three-year average yield: 7,280 kg ha^{-1}, followed by the yield of J 92-5 (7,050 kg ha^{-1}), LAT 9504 (7,020 kg ha^{-1}), and LIA 426 (6,980 kg ha^{-1}). The lowest single yield was produced by LAT 9504 (5,980 kg ha^{-1}) in 2006. Kaupo and Joniai were included in the trials in 2006 and 2007, and in 2005 and 2007, respectively. In the two-years average the yield of Kaupo was 7,645 kg ha^{-1} and that of Joniai 6,770 kg ha^{-1}. In 2007, Kaupo produced the highest yield of the whole trial period (8,160 kg ha^{-1}). The two-year average yield of LAT 9504 was lower in comparison with Kaupo. The two-year average yield of Joniai was lower than that of LIA 426, which showed a good yielding capacity. The three-year average yield of Elvi exceeded that of J 92-5. The yield of LAT 9504 varied significantly (CV 18.0) during the trial period, followed by the yield of Kaupo (CV 9.5), Joniai (CV 7.5), J 92-5 (CV 5.6), LIA 426 (CV 3.9) and Elvi (CV 2.6).



($LSD_{0.05}$ for 2005=996; 2006=1006; 2007=1080)

Figure 2. Yield of the winter rye varieties and breeds in trials at the Jõgeva PBI

The analysis of the yield components of the breeds showed, that on the average LAT 9504 had 6.5 productive tillers per plant, 56 kernels per head and the weight of kernels in 2005 was 2.4 g. LIA 426 had 5.4 tillers, 52 kernels and the weight of kernels was 2.2 g. J 92-5 had 4.5 tillers, 59 kernels per head and in 2005, the kernels weighed 2.2 g in 2005 (Table 1). In 2006, when the plant density on the plots of LAT 9504 was low, the number of tillers was high – 11.7, the number of kernels per head was 57, and the kernels were heavy – 2.3 g. There were only small differences in the yield components of Elvi, J 92-5 and Kaupo.

Table 1. Yield components in the trials at the Jõgeva PBI

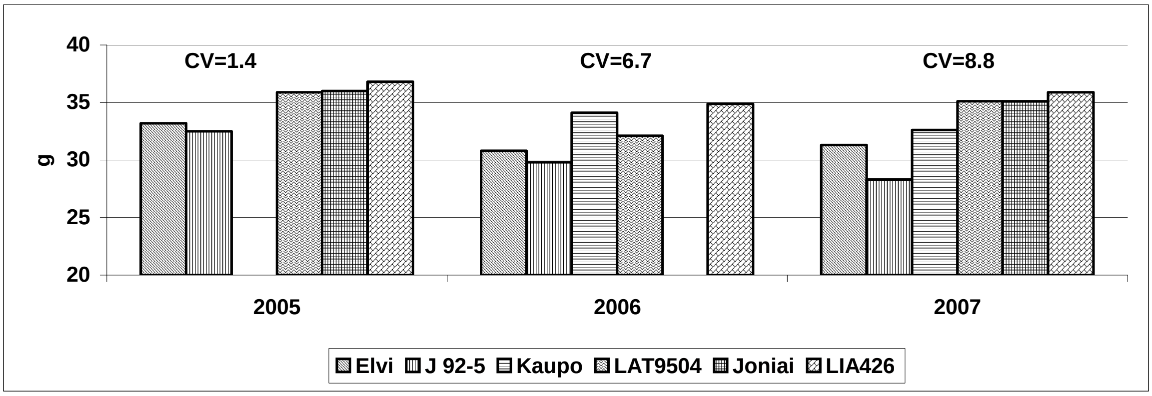
Variety/	Tillers/plant			Kernels/head			Kernel weight,g		
Breed	2005	2006	2007	2005	2006	2007	2005	2006	2007
Elvi	4.1	6.6	4.9	53	56	64	2.2	1.7	2.2
J 92-5	4.5	6.6	4.2	59	53	56	2.2	1.7	1.7
Kaupo		6.9	5.5		54	57		1.8	2.0
LAT 9504	6.5	11.7	5.1	56	57	59	2.4	2.3	1.9
Joniai	4.6		4.2	50		58	2.0		2.3
LIA 426	5.4	4.8	4.1	52	50	60	2.2	1.9	2.2

LIA 426 had 4.8 tillers per plant, 50 kernels per head and the weight of kernels was 1.9 g on the average. In 2007, Kaupo had the highest number of tillers per plant (5.5) whereas LIA 426 had the smallest (4.1). Elvi had the highest number of kernels per plant (64) and J 92-5, the smallest (58). On the average Joniai had the heaviest kernels (2.3 g) and J 92-5 the most and lightweight kernels (1.7 g). On the average, the thousand-kernel weight (TKW) was the highest in 2005 – 35 g (CV 1.4), in 2007 – 33 g (CV 8.8) and in 2006 – 32 g (CV 6.7) (Figure 3).

The highest three-year average TKW was demonstrated by Joniai – 35.6 g and LIA 426 – 35.9 g, followed by the TKW of LAT 9504 – 34.4 g, Kaupo – 33.3 g, and the lowest TKW-s of Elvi – 31.8 g and J 92-5 – 30.3 g.

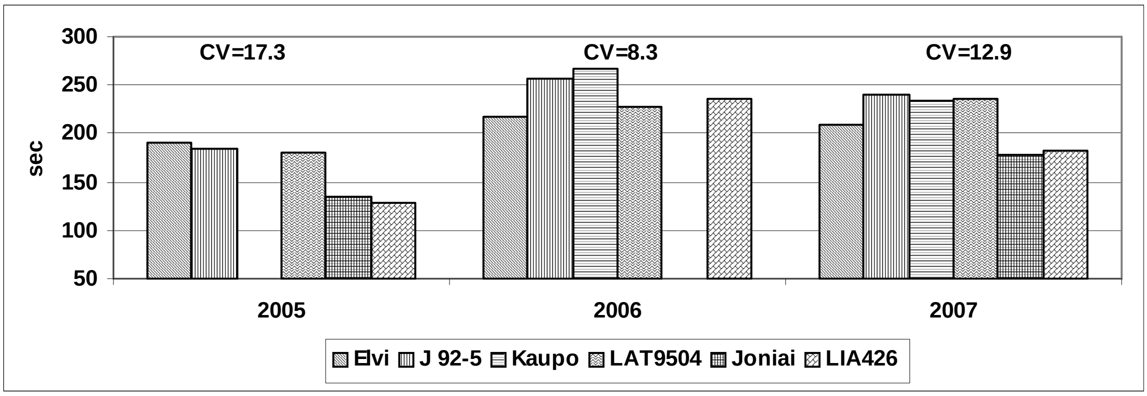
The two-year average thousand-kernel weights of Kaupo and LAT 9504 were equal. Comparing the TKW of Joniai and LIA 426, the kernels of LIA 426 were larger and heavier.

In 2005, the falling numbers were the lowest, the average of the trial was 164 sec (CV 17.3), followed by 213 sec (CV 12.9) in 2007, and the highest 241 sec (CV 8.3) in 2006 (Figure 4). The highest single FN of all the trials was demonstrated by Kaupo by 266 sec, followed by J 92-5 by 257 sec, both in 2006. The lowest FN occurred in 2005, LIA 426 by 129 sec and Joniai by 135 sec. The three-year average FN of the mentioned breed was 182 seconds and it varied the most (CV 29.4) during the years. The two-year average FN of Joniai was the lowest –156 seconds (CV 19.5).



($LSD_{0.05}$ for 2005=1.66; 2006=1.0; 2007=2.27)

Figure 3. Thousand-kernel weight of the winter rye varieties and breeds in the trials at the Jõgeva PBI



($LSD_{0.05}$ for 2005=32.0; 2006=28.7; 2007=36.8)

Figure 4. Falling number of the winter rye varieties and breeds in the trials at the Jõgeva PBI

The long-term yield variation is associated with climate changes, which occurred from years to decades and influenced vegetation (Chmielewski, 1992). Estonian climate data testify that the average air temperature is increasing, especially in spring. For example, the average air temperature in March is 1° C higher than in mid-sixties and the snow melts about a week earlier. At the same time, the amount of precipitation has increased by 50 mm, mostly in autumn and early winter (Jaagus, 1999). During the described trial years, the snow cover of the fields was scanty and the plants of winter cereals were exposed to rain, ice cover and cold (Keppart, 2007).

The most essential characteristic of winter rye is winter hardiness. For winter hardiness, the duration of the vegetation period in autumn is important. When the autumn growing season is short, plant development will be insufficient and rye may be killed off during the winter (Chmielewski, 1992). In long-term trials in Germany, it was found that warm and sunny autumn weather had a positive influence on the density of winter rye plants and the number of kernels per head (Chmielewski and Köhn, 2000). The data on cumulative air temperature in autumn demonstrates an increase in our region, which means that the growing season is more than two weeks longer than in the 1990-ies (Keppart, 2008).

In all the trial years, the autumns were warm and air temperatures dropped and persisted below zero in the middle of January. In the trials, all the varieties and breeds developed well in autumn, five out of six showed high winter hardiness, and only the breed LAT 9504 had lower resistance to cold. In 2005 and 2007, winters were mild after a prolonged autumn. In February 2006, the winter was harsh and a number of killed off LAT 9504 plants were seen in spring. There was no snow mould in the trials.

Grain yield is the sum of the three yield components, number of heads per m^{-2}, kernels per head and weight of kernels (Fowler, 2002). In 2005, visual assessment suggested no big differences in plant density but LAT 9504 had the highest yield among breeds, followed by LIA 426 and J 92-5. The yield of Elvi exceeded the yield of Joniai. Next year, the plant density on plots of LAT 9504 was low, and although the number of kernels and the weight of kernels were the highest, the yield was small. At the same time, the number of kernels per head and the weight of kernels of J 92-5 were the lowest. The average yield of this breed was the highest of all the trial years. In 2007, the plant density on plots was equal and number of tillers per plants was analogous but there were differences between the numbers of kernels per head and kernel weights, which resulted in differences in the yields.

Winter rye needs about 20-30% less water for seed formation compared to wheat (Starzycki, 1976, Кобылянский, 1982). In drought years, winter rye yields are usually bigger than those of spring cultivars (Häusler, 1996) because rye has a bigger and deeper root system (Kutschera, 1960). In all three years, the yields of winter rye exceeded the yields of spring cereals at Jõgeva (Keppart and Tupits, 2008). During trials in the Czech Republic it was found that high air temperature and precipitation before heading had a good influence on the yield formation of rye varieties, but after heading, high air temperature decreased the yield (Petr *et al*., 1985). Chmielewski and Köhn (2000) have also found that high temperatures and drought during the ripening stage may have a negative influence on the kernel weight. The thousand-kernel weights of Elvi and J 92-5 were lower than those of the Latvian and Lithuanian varieties and breeds, which were probably more resistant to drought.

Rye is very sensitive to pre-harvest sprouting (Drews *et al*., 1976; Salmenkallio-Martila *et al*., 1998). Due to unsuitable weather conditions during grain maturation and harvesting, sprouting may reduce the end-use quality of winter rye. The years of the trials were dry and warm, but just before the 2005 and 2007 harvestings, heavy showers occurred and high humidity influenced the activity of ferments that dissolve starch. According to the quality requirements of the Tartu Grain Mill Ltd., the main purchaser of rye grain in Estonia (www.tartuveski.ee), the minimum falling number of rye for bread baking is 160 sec for the first bread quality category, and 120 sec for the second category. The falling numbers of the trials fulfilled these requirements. The lowest falling numbers of the trial period were in 2005, however the Estonian variety and breed and the Latvian breed had much higher falling numbers than those from Lithuania. The same situation recurred in 2007, although the values were higher than in 2005. In Estonian conditions, not only the high value of the falling number, but also long-term stability is important. A special test in artificial conditions in the moisture chamber was arranged in 2000–2006 (Tupits, 2007). The results concerning the germination starting time of the 63 breeds was follows the first – high, but quickly starting germination, the second – high and moderately starting germination, and the third – high and slowly starting germination. The second and third categories included varieties from Germany, Sweden, Finland, Latvia and Estonia, the first, different breeds and the variety Joniai from Lithuania. The falling numbers of ripe grain remained high enough for bread baking just for one day in highly humid conditions.

Conclusions

All the breeds included is the trials had high yielding potential, medium to good winter hardiness, and medium to good quality. The plants of LAT 9504 were more sensitive to cold and a number of plants were killed off during the harsh winter. The plants on sparser plots had twice as many tillers as on dense plots, the size and the weight of the kernels of these plants were bigger, but the total yield was small all in all.

In comparison with Latvian and Lithuanian varieties and breeds, J 92-5 had bigger-size kernels, but thousand-kernel weights and kernel weights per head were smaller. These traits need improvement during breeding in coming years.

In rainy or foggy conditions before and during harvest, the sprouting of kernels may occur often. Joniai and LIA 426 had high falling numbers in droughty year, but if rain occurred before harvesting, the values dropped quicker than these of the other varieties or breeds.

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ZIEMAS RUDZU RAŽA UN KVALITĀTE IZMĒĢINĀJUMOS JÕGEVA PBI

Tupits I.
Rudzu maize gadsimtiem bijis pamatēdiens Igaunijā, Latvijā un Lietuvā. Pētījuma mērķis bija salīdzināt visās trijās valstīs izveidotu ziemas rudzu šķirņu un hibrīdu ražu un kvalitāti Igaunijas klimatiskajos un augsnes apstākļos Jegevas selekcijas institūtā (Jogeva PBI). Trīs gadu izmēģinājumā (2005.-2007.) konvencionāli saimniekojot tika sētas šādas šķirnes un hibrīdi: ‘Elvi’ (Igaunija), ‘Kaupo’ (Latvija), ‘Joniai’ (Lietuva), J 92-5 (Igaunija), LAT 9504 (Latvija) un LIA 426 (Lietuva). Laika apstākļi izmēģinājumu gados bija līdzīgi. Netika novēroti būtiski ziemošanas bojājumi. Visas šķirnes un hibrīdi uzrādīja augstu ražas potenciālu. Salīdzinot trīs gadu rezultātus, augstākās ražas bija šķirnei Elvi un hibrīdam J 92-5. Tūkstoš graudu masa (TKW) pārsniedza 30 g visos pētījuma gados, vidēji augstākais tika novērots 2005. gadā. Krišanas skaitlis (FN) kopumā bija atbilstošs maizes cepšanai, zemākais FN visos pētījuma gados bija ‘Joniai’ un LIA 426. Mitros apstākļos šīs šķirnes un hibrīda raža vākšana jāveic ātri.

CHARACTERIZATION OF LATVIAN POTATO GENETIC RESOURCES BY DNA FINGERPRINTING WITH SSR MARKERS

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Abstract
SSR (Simple Sequence Repeats) markers have been broadly applied in plant material identification, genetic diversity evaluation, in various gene banks for collections maintenance and in breeding programs for the monitoring of elite alleles and material exchange, as well as in ploidy level prediction, construction of genetic maps, evolutionary and population studies. The high polymorphism level and the co-dominance of SSR markers allow for efficient cultivar characterization and can discriminate even closely related cultivars. However, several factors must be considered when applying SSR markers to polyploid plant species.
After initial optimization and the pre-screening of 15 SSR markers, all potato (*Solanum tuberosum* L. subsp. *tuberosum*) cultivars listed in the Latvian Plant Genetic Resource database were analyzed using eight SSR markers that were found to be most polymorphic. Cultivar fingerprinting, genetic distance evaluation and cluster analyses were performed. Two pairs of the tested cultivars were identical in all screened loci and couldn’t be discriminated; the remaining potato cultivars could be discriminated using a minimum of 4 SSR markers. Similar genetic relationships were observed in the potato cultivar collection when analysed with different phylogenetic methods. An increase in the genetic diversity of the newly bred potato cultivars was identified when compared to the older cultivars.

Key words: genotyping, potato, SSR, cultivar identification

Introduction
Potato cultivars are vegetatively reproduced every year for distribution and breeding purposes. Currently the identification of potato cultivars is based on phenotypic characteristics, which are difficult to distinguish, time-consuming and can be affected by environmental factors all of which results in a high risk of misclassification. The autotetraploid genome of cultivated potato (2n=4x=48) and their outcrossing nature makes them a difficult candidate for genetic studies. A narrow genetic base has lead to a high genetic similarity in European cultivated potatoes (Gebhardt *et al*., 2004; Simko *et al*., 2006).