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RESEARCH ON POTATO (*SOLANUM TUBEROSUM* L.) GENETIC RESOURCES IN LITHUANIA

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Abstract

Research on the Lithuanian potato gene bank's genetic diversity was carried out at the Vokė Branch of the Lithuanian Institute of Agriculture during the period 1990–2006. The experimental plots were established on sandy loam on carbonaceous fluvial-glacial gravel eluviated soil (IDp), according to FAO-UNESCO classification *Haplic Luvisols* (*LVh*). It involved a potato collection including 247 varieties and hybrids from the main potato origin and growing regions and selection material bred in Lithuania. A great genetic diversity was determined. Potato varieties varied according to morphological, physiological, immunological, and agronomic features within the different maturity groups and between groups. Research data on the genetic diversity of the potato collection are directly used in the breeding programs. Potato varieties of Lithuanian origin were developed using a transgenic hybridization method and genetic material of the local potato collection.

Key words: potato, breeding, varieties, collection.

Introduction

Cultivated potatoes come from South America. *Andigena* and *Tuberosa* potato species have been grown in Latin America countries since olden times. Seedlings of different *Solanum tuberosum L. ssp. Chilotanum* and *S.andigenum* potato species were introduced to Europe and later to the United States. From hybrids from Chile there were produced potato varieties that belong to *Solanum tuberosum L. ssp. Europaem Buk. Et Lechn*. subspecies. Wild species such as *S.demissum, S.stoloniferum, S.acaule* and others are also used in the breeding work /Hijmans, 2001/.

S.tuberosum and *S.andigenum* potato species are tetraploids (2n = 48), therefore potatoes inherit many features at the tetrasomic level. *S.demissum* species of Mexico origin are allelohexaploids (2n = 72). They have resistance to the late blight *Phytophthora infestans (Mont.) de Bary*. It is widely used in the Lithuanian potato breeding programs and due to this local potato cultivars possess high resistance to the late blight. *S.andigenum* potatoes are donors of resistance to the PVX virus and potato cyst nematode Ro1. The local potato cultivar 'Aista' has parents from these species' hybrid crosses /Staniulis, Ražukas, 2003/.

Potatoes are usually bred using hybridization method. The most valuable in the breading work are paternal plants which have desirable quality features such as high yielding, earliness, disease and pest resistance, dry matter content and others. In the

potato breeding process the most important are varieties and hybrids which belong to or have progeny of nine systematic groups: *Comersoniana, Glabresantia, Acaulia, and Transa equaatorialia, Andigena, Tuberosa*, *Longipedicellata*, *Demissa* and *Pinnatisecta*. They give proper genetic diversity for the cultivated potato varieties /Lough et al., 2001/.

Potato breeding and primary seed production from the meristem tissue programs in Lithuania are performed at the Voke Branch of the Lithuanian Institute of Agriculture. Gene bank of potato genetic resources is collected and stored here. Research on over 247 potato varieties and hybrids selected all over the world is done at the breeding depart.-ment. Potato breeding is one of the main ways to develop strong cultivars with good resistance to unfavourable climatic conditions, diseases and pests /Razukas, 2002; Razukas et al., 2003/. High quality potato seed, high yielding varieties demonstrate the results of many years' breeding work /Ražukas, Jundulas, 2005/. In the world of variability, the influence of human and ecological factors on the new varieties' breeding is one of the most effective ways to solve quality, disease, and ecological tasks. One of the objectives of the present work was to study potato genetic collection, to select genetically valuable genotypes and introduce them in the breeding program /Chauvin et al., 2003, Asakaviciute et al., 2006/.

Materials and methods

Research was performed on 247 potato cultivars and hybrids. Genetic potato material was collected from all over the world. Potato genetic collection trials were planted at the breeding department of the Vokė Branch of the Lithuanian Institute of Agriculture during the period 1990–2006. The experimental plots were established on sandy loam on carbonaceous fluvial-glacial gravel eluviated soil (IDp), according to FAO-UNESCO classification *Haplic Luvisols* (*LVh*). The trials were performed on a soddy podzolic sandy loam soil (Haplic Luvisols (LVh)) in a crop rotation field. Soil natural fertility was medium: humus content up to 2.0 %, pH_{KCl} 5.1–5.5, amount of available phosphorus – P_2O_5 180–240 mg kg^{-1} and of available potassium – K_2O 150–190 mg kg^{-1}. Potato varieties and seedlings were planted in the separate 4.9 m^2 field plots. In every field plot there were 2 rows, the number of tubers – 20. Potato tubers were planted when the soil temperature had increased to 7–10 ^oC. Planting was done by hand into hilled rows. Fertilization was local $N_{90}P_{90}K_{90}$ during potato planting. Potato trial plot was twice hilled and harrowed before sprouting and twice hilled during potato plants growing. Fungicides against late blight were applied annually once during the growing season, insecticides against Colorado beetles and aphids were applied depending on their infestation level in the field. Potato trials were harvested by hand at the end of the growing period. Tubers were stored during the winter season in the potato storage with an air temperature of +2 ^oC and air humidity of 80–90 %.

Gene bank's potato varieties and seedlings during the growing season are tested for disease resistance. The potato plant features were recorded according to BBCH scale. It covers over 50 parameters. The main ones are beginning of sprouting, plant exuberance, flowering period, flower colour, stem number, disease development on plants, beginning of foliage destruction, and end of growing season. Depending on the plant growing season, potato varieties are divided into five maturity groups: first early, second early, maincrop, late and last late. Plant foliage resistance to bacteria, fungi and viruses

was determined during flowering period. Potato yield quality features depend on total yield, marketing tuber yield, tuber number, tuber shape, eye depth, skin and flesh colour, dry matter content , cooking and technological features /Ražukas et al., 2001/.

Results and discussion

One of the main features of cultivated plants is length of the growing period. Research carried out during potato growing period leads to the better use of the plant potential in a specific geographical zone. Day length has direct influence on potato variety growing period and yielding. Potato varieties originated from South America belong to the short day (13–14 h) geographical zone /Bradshaw et al., 2006/. Therefore all potato varieties in the potato gene bank collection are divided into five maturity groups. Our experimental data suggest that the first early maturity potato group includes potato varieties whose growing period from sprouting to foliage death lasts for 52–58 days in South East of Lithuania. To this maturity group were attributed 49 varieties. The second early potato group includes potatoes, whose growing period is 59–68 days. There are 62 varieties in this group. Maincrop maturity group's potato growing period is 69–75 days, and there are 42 varieties. There are 20 varieties in the late maturity group; it covers 76–85 days. Last late potatoes' growing period is 86–101 days, and 27 varieties are in this group.

A very important factor in potato breeding using hybrid cross method is flowering and berry production. Experimental data show that modern potato varieties that digress greatly from progenitors produce fewer berries. During the last ten years 120 varieties exhibited stable flowering period and only 57 varieties and hybrids without special intervention ripened seeds naturally in the field conditions. One of the main reasons for absence of berries and seeds is sterility. In some cases there was no flowering start because flowers did not evolve. They dropped down to the size 0.5–1 cm. In other cases phenotypical stamen sterility was observed. It can be invoked by factors such as unfavourable weather conditions when, for example, air temperature during potato flowering period increases up to 25–30 ^{o}C. Phenotypical sterility can be eliminated in wet and cool medium. In those conditions potatoes flower well and produce seeds. Potato variety that naturally has stamen sterility can be used in the breeding practice as a mother plant. While producing hybrids by crossing sterile varieties with fertile, a split into sterile and fertile is observed. For varieties and hybrids that flower and produce berries classical methods are used. They can be used as gene donors when working with protoplasts in the laboratory.

Tubers with light yellow skin and flesh colour dominate in the Lithuanian potato genetic collection. 135 potato varieties have light yellow tuber skin colour, 112 varieties of them have light yellow flesh. Light yellow tuber colour and flesh dominates in potato tubers which are resistant to Ro1 potato nematode pathotype.

One of the most important factors is potato tuber shape, uniformity, and eye depth. Potato hybrids that produce in the breeding work improper shape and uniformity have no agronomic value. Potato tubers shape degradation from uniform to irregular is found with increasing population age. Older varieties have higher virus infection and their plant and tuber shape recede from cultural variety parameters. That can be discussed as entropy expression in the populations of cultural potatoes.

Maincrop varieties produce the highest potato yield in Lithuania. There are no donors with resistance to late blight in this group. Genetic material of early and late maturity groups is used for breeding maincrop maturity potato varieties. Special methods were used to prevent discrepancy of flowering time. Lithuanian potato gene bank research generated considerable amount of data based on which all Lithuanian potato varieties have been bred: 'Aistės' (('Olympia' x 'Olev') x ('Severnaja' x 'Sagitta')), 'Aista' (N 263 x N 476-9), 'Goda' ('Ausonia' x 'Franci'), 'Liepa' (N 34/36 x 'Pirmūnės'), 'Mėta' ('Saggita' x 'Comtesa'), 'Mirta' ('Fryla' x No 17/6), 'Nida' ('Amaryl' x ('Sagitta' x 'Olev')), 'Pirmūnės' ('Pepo' x VIR), 'Rasa' ('Cardinal' x Viola'), 'Vokė' ('Majestic' x No 323), 'Vilnia' ('Sagitta' x 'Neringa'), 'Vaiva' ('Hanibal' x 'Anosta'), 'Venta' ('Priekulu visagrie' x 'Pirmūnės') (Table).

Table. The main biological characteristics of the potato varieties in the competitive variety trials

Lentelė. *Bulvių veislių svarbiausi biologiniai rodikliai konkursiniuose veislių bandymuose*

T. Vokė, 2001–2006

Variety *Veislė*	Morphology of tuber *Gumbo morfologinės savybės*				Resistance to diseases and pests *Atsparumas ligoms ir kenkėjams*			
	Shape *Forma*	Color of skin *Odelės spalva*	Color of flesh *Minkštimo spalva*	Time of maturity *Vegetacija*	Nematode R_{01} *Nematodai* R_{01}	Wart *Vėžys*	Late blight, leaf, % *Bulvienojų maras*	Late blight, tuber, % *Gumbų maras*
Aista	Round *Apvali*	Yellow *Geltona*	White *Balta*	Very late *Lv*	r	o	87 ± 2.1	97 ± 2.1
Goda	Round *Apvali*	Yellow *Geltona*	Yellow *Geltona*	Early *Va*	r	o	50 ± 4.5	95 ± 3.5
Liepa	Round *Apvali*	Yellow *Geltona*	Light yellow *Šviesiai geltona*	Early *Va*	r	o	0	91 ± 4.9
Mėta	Round *Apvali*	Yellow *Geltona*	Yellow *Geltona*	Early *Va*	r	o	85 ± 6.0	92 ± 3.3
Mirta	Round *Apvali*	Yellow *Geltona*	Light yellow *Šviesiai geltona*	Early *Va*	r	o	10 ± 1.3	70 ± 6.2
Nida	Short-oval *Silpnai ovali*	Yellow *Geltona*	Light yellow *Šviesiai geltona*	Medium *Vv*	r	o	45 ± 2.7	96 ± 8.4
Rasa	Oval *Ovali*	Red *Raudona*	Yellow *Geltona*	Very late *Lv*	r	o	80 ± 5.4	93 ± 7.5
Vokė	Oval *Ovali*	Yellow *Geltona*	Light yellow *Šviesiai geltona*	Early *Va*	4	o	10 ± 2.1	99 ± 8.8
Vilnia	Oval *Ovali*	Red *Raudona*	Yellow *Geltona*	Late *V*	r	o	47 ± 2.9	98 ± 9.7
Vaiva	Oval *Ovali*	Red *Raudona*	Yellow *Geltona*	Early *Va*	r	o	0	93 ± 4.6
Venta	Round *Apvali*	Yellow *Geltona*	Light yellow *Šviesiai geltona*	Very early *La*	4	o	0	80 ± 6.7

Note. / *Pastaba*. r – resistant / *atsparus*, 4 – susceptible to nematode / *jautrus nematodams*, o – immune / *neimlus*

High attention is given to the disease and pest resistance of natural potato resources. Such disease as wart, also nematodes and viruses can be eliminated partially or fully by producing new potato varieties using genetic material which has high resistance or are immune to one or another disease and pest. All potato varieties and hybrids stored in the gene bank are immune to the wart disease. 75 varieties in the gene bank collection were found to be resistant to Ro1 potato nematode pathotype. While crossing varieties when both parent plants possess resistance to this pest, progeny hybrids are almost always immune. When one of the parents is not immune, progeny hybrids can be selected with negative or positive response.

Viruses and virus diseases cause great problems in potatoes. One of the main problems is potato tuber yield and quality deterioration. There are no potato varieties or hybrids that have complete resistance to the number of viruses. All new selected potato varieties during their growing period get virus infection. Therefore it is of prime importance to use primary breeding material with tolerance to virus diseases in the breeding work. Virus infection development is fast in potato varieties which have no tolerance; it causes plant degradation, increases penetration possibility for fungal and bacterial infection to the plant. It leads to the death of plants. In the plants which have tolerance to virus infection, viruses cause low injuries which at good growing conditions may not be observed at all. Such variety is 'Dietskosielskij'. In the Lithuanian breeding program tolerant varieties from the gene bank are used. Tolerance to viruses in newly bred varieties can be achieved using classical breeding methods.

In Lithuania the most harmful potato disease is late blight *Phytophthora infestans*. The disease decreases plant leaf assimilation area and destroys potato foliage at potato tuberization. Virus infection affects potato yield and during storage period causes different rots. Fifteen years of testing of potato genetic collection led to the conclusion that there was no variety with full resistance to *Phytophthora infestans*. First early, second early and maincrop maturity groups' potato varieties and hybrids possess low resistance to late blight. Comparatively late maturity potato varieties such as 'Aistės', 'Vilnia', 'Kuras', 'Olev', 'Danve' exhibited the highest resistance to late blight.

The data of the quality of the selected Lithuanian potato varieties are presented in Figure a, b. All varieties depending on the genetic diversity of features produced high seed potato yield.

According to their progeny, starch content and dry matter were different. Potato varieties with shorter growing period produced lower contents of starch and dry matter, whereas late varieties such as 'Vilnia' and 'Aista' had the highest contents. Tuber number per potato plant depended on the varietal genetic features.

The variety 'Goda' produced the highest number of potato tubers. Early and maincrop varieties produced bigger size tubers than the late maturity varieties. This potato variety quality indicator depended on potato growing period. The largest tubers were produced by the varieties 'Venta', 'Nida' and 'Goda'. The varieties differed in susceptibility to diseases, which depended on their genetic progeny.

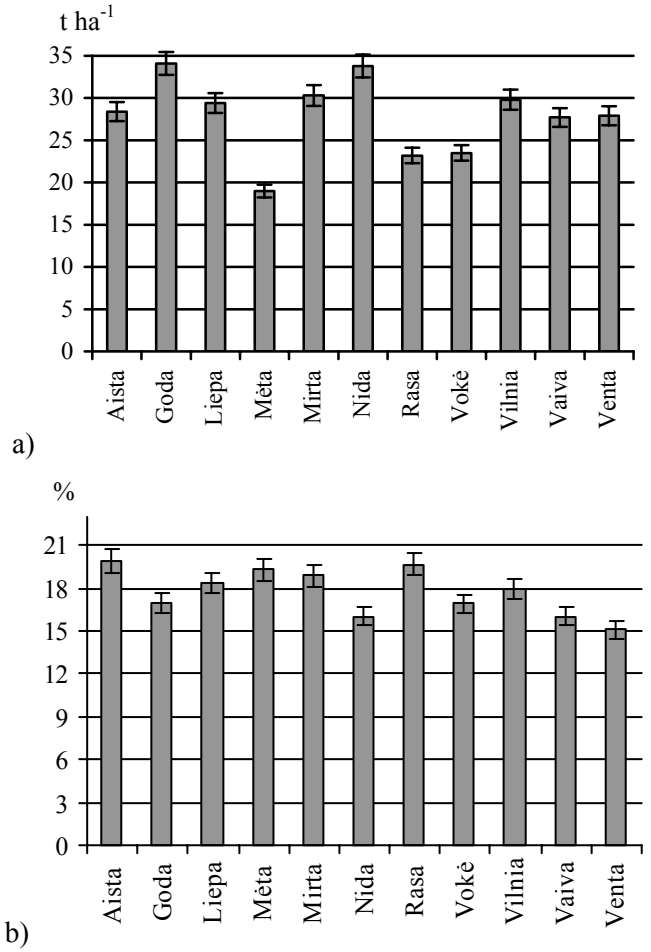

Figure. The most important economic parameters (a – yield of tubers and b – starch content) of various Lithuanian potato varieties. Each value is the mean of three replicates ± standard error

Paveikslas. *Lietuviškos selekcijos bulvių veislių svarbiausi ekonominiai rodikliai (a – derlingumas ir b – krakmolingumas) konkursiniuose veislių bandymuose*

T. Vokė, 2001–2006

Conclusions

The following conclusions were drawn from the research on the collections of potato varieties and breeding lines, conducted in Lithuania:

1. Potato genetic bank collection includes over 247 potato varieties and hybrids from the main potato origin and growing regions and selection material bred in Lithuania.

2. Studies of potato gene bank generated significant data about each variety and hybrid. Abundant genetic material was used in the breeding work to produce local potato varieties and hybrid crosses for further breeding.

3. All potato varieties tested are immune to wart disease, 75 varieties and hybrids possess resistance genes to potato cyst nematode pathotype Ro1. Virus resistant potato varieties as donors were not found. There were identified only a few tolerant to virus infection potato gene donors. Late maturity potato varieties genetically have higher resistance to late blight than early varieties.

4. Research data show that of the 11 Lithuanian breeding potato varieties tested the highest potato yield was determined for 'Goda' (34.1 t ha^{-1}) and 'Nida' (33.8 t ha^{-1}). The lowest potato tuber yield was produced by the old Lithuanian variety 'Mėta' (19.0 t ha^{-1}). The highest starch contents were determined for late maturity Lihuanian varieties 'Aista' (19.9 %) and 'Rasa' (19.7 %). The lowest starch content was in first early variety 'Venta' (15.1 %).

5. Genetic material of the Lithuanian potato gene bank used for hybrid crossings enabled us to develop new potato varieties.

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GENETINIŲ BULVIŲ (*SOLANUM TUBEROSUM* L.) RESURSŲ TYRIMAI LIETUVOJE

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Santrauka

Lietuvoje bulvės selekcionuojamos Lietuvos žemdirbystės instituto Vokės filiale. Selekciniam darbui būtinas bulvių genetinis bankas palaikomas veislių ir hibridų kolekcijoje. 1990–2006 m. buvo atlikti išsamūs bulvių kolekcijos tyrimai. Tyrimai atlikti LŽI Vokės filiale priesmėlio ant karbonatingo fliuvioglacialinio žvyro paprastajame išplautžemyje (IDp), pagal FAO-UNESCO klasifikaciją – *Haplic Luvisols* (*LVh*). Bulvių genų banke ištirta 247 veislių ir hibridų iš tėvyninių bulvių kilmės centrų bei pasaulinių bulvių auginimo regionų. Nustatyta didelė jų genetinė įvairovė. Bulvių veislės ir hibridai suskirstyti į ankstyvumo grupes, atlikti morfologiniai, fiziologiniai, imunologiniai ir ūkinio vertingumo tyrimai. Nustatytos gumbų odelės ir minkštimo spalvos, gumbų formos, atsparumo bulviniams nematodams, vėžiui, virusams, bulvių marui ir kitiems požymiams bulvių veislių ir hibridų požymių dominavimo ir jų perdavimo palikuonims selekcinio darbo procese galimybės. Visi kolekcijoje tirti pavyzdžiai yra atsparūs bulvių vėžiui, daugiau negu pusė visų saugomų veislių ir hibridų turi atsparumo Ro_1 bulvinių nematodų patotipui genus, keletas veislių pasižymėjo tolerantiškumu virusinei infekcijai, ilgesnės vegetacijos bulvių veislės pasižymėjo didesniu atsparumu marui. Pagal minėtus požymius ištirta bulvių kolekcija yra tiesiogiai panaudojama selekcinėse programose. Tarpveislinės hibridizacijos metodais, naudojant bulvių genų banke sukauptą medžiagą, sukurtos lietuviškos slekcijos bulvių veislės.

Reikšminiai žodžiai: bulvės, selekcija, veislės, kolekcija.