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Breeding and Productivity Aspects of Narrow-leaved Lupine and Buckwheat in Lithuania

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Abstract

The research of narrow-leaved lupine (*Lupinus angustifolius* L.) and buckwheat (*Fagopyrum esculentum* Moench) were carried out in Voke Branch of the Lithuanian Research Centre for Agriculture and Forestry. The individual selection method developed two narrow-leaved lupine varieties 'VB Derliai' and 'VB Ugniai' intended for green manure and two narrow-leaved forage varieties 'VB Vilniai' and 'VB Antaniai'. All selected lines have high resistance to fungal diseases, good growing speed at all plant development phases and high seed yield. The main aim in the buckwheat research work was to select good yielding varieties of different maturity, suitable for the local agroclimatic conditions. During the research a new buckwheat variety 'VB Vokiai' was selected. The selected material is highly valuable as genetic, breeding and farming material. It will be useful in further narrow-leaved lupine and buckwheat breeding programs and seed production of new varieties.

Keywords: breeding, lupine, anthracnose, buckwheat

Introduction

The breeding of lupine and buckwheat and seed production are carried out at the Voke Branch of Lithuanian Institute of Agriculture. Development of novel, high-yielding, high-quality, disease resistant varieties of narrow-leaved lupine and buckwheat those are suitable for organic production on less productive, light-textured soils receives particular attention.

Breeding program of narrow-leaved lupines was started in 1995. Breeding work is done in three directions. First – breeding of low alkaloid narrow-leaved lupine varieties for food industry. Second – breeding of low alkaloid narrow-leaved lupines for animal feeding. Third – breeding of narrow-leaved lupines for the green manure. During the period of 1995 – 2012, using the individual selection method, four narrow-leaved lupine varieties were developed: two narrow-leaved lupine varieties 'VB Derliai' and 'VB Ugniai' for green manure, and two narrow-leaved forage lupine varieties 'VB Vilniai' and 'VB Antaniai'. 'VB Derliai' and 'VB Vilniai' were registered in EU catalog of varieties in 2006. 'VB Ugniai' was registered in 2007 and 'VB Antaniai' was registered in 2010 in EU catalog of varieties.

Lupine has been grown in Lithuania since olden times; however, the area sown with this crop is not large. The chief reason why the area sown with lupine is declining is the spread of new fungal diseases. Lupine anthracnose (*Colletotrichtum gloesporoides* (Penz.) Penz & Sass.) (Huyen *et al*., 2007) is one of the most harmful lupine fungal diseases, which occurs on all lupine species.

Breeding program of buckwheat was started in 1999. During the period of 1999 – 2002 was developed buckwheat varieties 'VB Vokiai'. Buckwheat varieties 'VB Vokiai' has passed DUS (distinctness, uniformity and stability) tests in Poland as well as quality tests at varieties research stations of Lithuanian Variety Testing Centre. Variety 'VB Vokiai' was included into Lithuanian Variety List from 2006 year.

Buckwheat is one of the main cereal plants grown on the light soils in Lithuania. The land area for the buckwheat covers over 21000 ha in Lithuania (Batulevičiūtė, 2006). The economical importance of buckwheat increases every year as more and more attention is given to human health problems. Due to this buckwheat scientific research work and the breeding of new buckwheat varieties started to increase at the world wide level (Campbell, 2003).

The main objective of the present work was to explore new narrow-leaved lupine and buckwheat breeding lines at the selection process for the high yielding, early maturity, resistance to fungal diseases and suitability for forage and food industry.

Materials and Methods

Site and soil. Investigations were conducted in the crop rotation of the Voke Branch of the Lithuanian Research Centre for Agriculture and Forestry (54°63' N, 25°10' E) during 2008-2012. The experimental plots were established on sandy loam on carbonaceous fluvial-glacial gravel eluviated soil (IDp), according to FAO-UNESCO classification *Haplic Luvisols* (*LVh*) (Buivydaitė, 2005). Soil agrochemical characteristics: pH_{KCl} – 5.2–6.2, humus – 2.11–2.18%, mobile P_2O_5 – 108–152 mg kg^{-1}, mobile K_2O – 150–165 mg kg^{-1}.

Experimental design and management. Lupine and buckweat varieties carried out in two separate competitive variety trials.

Narrow-leaved lupine (*Lupinus angustifolius* L.). For the primary material breeding of narrow-leaved lupines we used the methods of intervariety straight and reversible crossing and individual selection. Backross was used to intensify one hybrid feature. First generation hybrids were crossed with one of the patents components. Individual plant selection

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was used for estimation of the selected material (selection lines N1575, N1579, N1670, N1675 and N1702). The lupine varieties 'VB Vilniai' and 'VB Derliai' were used as a control. During the vegetative growth period various assessment methods (Cristofolini and Chiapella, 1984) were applied in all stages of breeding work for the identification of resistance to fungal diseases at three plant growth stages: seedling, bud formation-flowering and shiny pods. 1 to 9 point scale was used: 1 – very low resistance, over 50% of diseased plants, 3 – low resistance, 26–50% of diseased plants, 5 – moderate resistance, 11–25% of diseased plants, 7 – high resistance, 2.5–10% of diseased plants, 9 – very high resistance, less than 2. 5% of diseased plants. With this end in view, at complete emergence plants were counted in A and C replications, at seedling, bud formation-flowering and shiny pods stages anthracnose and fusarium-affected plants were counted and removed from the plot. At the complete maturity stage healthy plants were counted and their productivity was estimated. The percent of fungal-disease affected plants was identified according to the formula: P = (n / N) x100, where n – number of affected plants, N – number of assessed plants.

Buckwheat (*Fagopyrum esculentum* Moench). The hybridization and selection methods were used in buckwheat breeding. The best buckwheat genotypes were assessed for grain yield and size, plant resistance to lodging and other valuable features. Varieties of buckwheat 'VB Vokiai' (from Lithuania), 'Volma' (from Belarus), 'Smuglianka' (from Belarus) and 'Anita Belaruskaya' (from Belarus) were tested in competitive varieties trials. The buckwheat variety 'VB Vokiai' was used as a control. Soil for buckwheat trials was ploughed in the autumn, two times cultivated and harrowed in the spring. Fertilization – $N_{60}P_{50}K_{40}$. Test field area for competitive varieties trials – 10 m^2 in 4 replications. Planting rate – 3 mln ha^{-1} of fertile seeds.

Meteorological conditions. The weather conditions varied among experimental years; however, all the five growth seasons were relatively warm and abundant in rainfall (Table 1). Thermal and irrigation conditions during the growth season could be described by a widely used Selianinov's hydrothermal coefficient HTC = Σp / 0.1 Σt, where: Σp – total precipitation (mm) sum during the given period; Σt – total sum active temperatures (°C) of the same period. If HTC > 1.6 – the irrigation is excessive, HTC = 1.0…1.5 – optimal irrigation, HTC = 0.9…0.8 – weak drought, HTC = 0.7…0.6 – moderate drought (arid), HTC = 0.5…0.4 – heavy drought, HTC < 0.4 – very heavy drought (Dirsė, Taparauskienė, 2010).

Meteorological conditions during vegetation periods of the 2008–2012 were not always optimal for the growth of narrow-leaved lupine and buckwheat. Rating of meteorological conditions by hydrothermal coefficient showed that entire vegetation period of two years (2008 and 2012) was favorable for plant growth (*Fig. 1*). In other years vegetation periods were too wet.

Statistical analyses. The experimental were statistically processed using analysis of variance and correlation – regression analyses methods employing software *Anova,* software package *Selekcija* (Tarakanovas 2002). The treatment effect was tested by the least significant differences LSD_{05}. Significance levels: * - $p < 0.05$, ** - $p < 0.01$.

Results

Research results of narrow-leaved lupine (*Lupinus angustifolius* L.). Narrow-leaved forage lupine variety 'VB Vilniai' (2006) was produced by the individual selection method. According to the test data, yield of green mass ranges from 41 to 79 t ha^{-1}, and yield of seeds – 1.8 ± 0.05 t ha^{-1} depending on the agro-meteorological conditions. Growth period is 98 days, variety is of seed type, resistant to fungal diseases (Table 2).

Variety 'VB Antaniai' (2010) is a biochemical consequence of mutation. The selected genotypes differed in flowers, seed color, low alkaloid content (0.054%), high resistance to fungal diseases. According to the test data, yield of green mass ranges from 26 to 55 t ha^{-1}, of seeds – 2.1 ± 0.07 t ha^{-1} depending on the agro-meteorological conditions. This variety is of a short growing season (90 days), of seed type, with a fast growth rate at all growth stages, resistant to fungal diseases.

Variety 'VB Derliai' (2006) was produced from the variety Deter-3. The variety Deter-3 is of a determinant type, very early, low-yielding, with low alkaloid content and a low resistance to fungal diseases. The variety 'VB Derliai' significantly differs in morphological and biochemical properties from the parental variety. This variety is characterized by monopodic branching, high seed yield (3.2 ± 0.08 t ha^{-1}) and green mass yield (54.0 – 75.0 t ha^{-1}), and high resistance to fungal diseases.

Variety 'VB Ugniai' (2007) was produced from the variety DM-15. The selected genotypes differed in flower and seeds color. The flower color of the collection accession DM-15 is light blue and that of seed is sandy. The variety 'VB Ugniai' is characterized by a dark blue color of flowers and dark sand color of seeds. According to the test data, yield of green mass ranges from 56 to 70 t ha^{-1}, of seeds – 2.4 ± 0.07 t ha^{-1} depending on the agro-meteorological conditions. This variety is of a short growing season (82 days), of seed type, characterized by accelerated growth rates in all stages of growth, resistance to fungal diseases.

During the period 2008–2012 one species of lupine were investigated in field trials: 5 early maturing breeding lines of narrow - leafed forage lupine developed by an individual selection method and characterised by high resistance to anthracnose and high yield. Sufficient amount of infection and lupine variety 'VB Vilniai' and breeding lines N1575, N1579 growth stage – end of flowering. The disease severity was 9.5 - 13.8 % (*Fig. 2*).

Fungal diseases spread on lupine plants every year. Disease spread depends on variety genetics, meteorological conditions, previous crops, and weediness of the field. Lupine anthracnose is one of the most harmful diseases which affect all lupine species at any plant growing stage (Maknickiene, 2004). Lupine grain yield depends on the plant growth stage at which anthracnose affects the plants. The selected narrow-leaved lupine lines showed a high resistance to this fungal disease. Conditionally resistant to anthracnose are hybrid lines (N1670, N1675 and N1702) in

which affected plants were less than 1.5 %. In the world lupine gene bank, there are no varieties fully resistant to fungal and viral diseases. But lupine varieties that are partially resistant at a low disease epitophe undergo less infection in the vegetation period. The tested selected lines produced a high seed yield (N1670 2.40 ± 0.31 t ha^{-1}, N1675 2.52 ± 0.41 t ha^{-1} and N1702 2.53 ± 0.56 t ha^{-1}).

Research results of buckwheat (*Fagopyrum esculentum* Moench). Buckwheat variety 'VB Vokiai' has passed DUS (distinctness, uniformity and stability) tests in Poland as well as quality tests at varieties research stations of Lithuanian Variety Testing Centre. Variety 'VB Vokiai' was included into Lithuanian variety list in 2006 year. Five years of research show that the yield of variety 'VB Vokiai' was by 6.7-11.2 % higher than of foreign varieties (Table 3). According to our studies, stem height of plants this variety was 102 cm. Grain of 'VB Vokiai' variety was particularly big size - 35.5 ± 0.84 g. Depending on the growth conditions (availability of nutrients, meteorological factors) 1000 grain weight varied, but the variation was very slight. Regarding the size of big grain fraction, the big grain (sieve hole diameter 4.5 mm) comprised 89.7 % of all grain of buckwheat 'VB Vokiai' variety. Grain husk content is an indicator indirectly showing the groats output.

The output of buckwheat groats suitable for processing should be not less than 71 – 73 %. Grain husk content of 'VB Vokiai' was 26.7 %. Among the foreign variety 'Volma' was similar husk content (26.3 %), higher husk content was 'Smuglianka' (27.6 %) and 'Anita Bieloruskaja' (27.4 %), but all tested varieties were characterized by the medium husk content.

Buckwheat is short vegetation period plants. Growing period cover June, July and August months. Buckwheat flowering period and grain formation physiologically proceed at the same time – from the end of June till the mid of September, but the most intensive period is July. Buckwheat grain ripe about one month from the beginning of flowering period, so for the yield formation very important are July and August months. Therefore, meteorological conditions in July and August was important for the yield formation. The relationship between hydrothermal coefficient (HTC) of July and buckwheat grain yield was strong r = 0.83** ($p < 0.01$) ((Fig. 3).

Discussion

The success of the breeding work depends on the abundance and value of the initial material.

Seed quality is one of the most important indicators for forage and low alkaloid content narrow-leaved lupine. Regarding biological and nutritional value lupines are ascribed to particularly protein-rich plants (Holodov and Vorontsov 1983; Kurlovich, 2002); their proteins are of good digestibility and, in accordance with international standards, are comparable to casein and soy proteins (Kurlovich, 2002). A rapid mutation of pathogen's populations, its ability to continuously form a large amount of races differing in virulence and aggressiveness are the chief obstacles in the development of resistant lupine varieties (Semaskiene *et al*., 2008). When limited amount of genetic resources is used in breeding work lupine anthracnose can occur in the varieties differing in genetic potential. From the presented data we can see that the development of the infection is influenced by human factors and pathogen's characteristics, genotype, as well as the weather conditions. The world lupine genefund does not contain any varieties completely resistant to fungal or viral diseases. It is likely that the varieties characterised by a partial resistance do not lose this character for a longer period and in the years of weak epiphytoty such varieties either do not catch the infection or are insignificantly affected.

Buckwheat varieties 'Volma', 'Smuglianka' and 'Anita Bieloruskaya' from Belarus were included in the Lithuanian Variety List till 2003. These varieties were high-yielding, however, they were not well adapted to Lithuanian agroclimatic conditions and their grain yield were unstable in the conditions of Lithuania. It was very important to develop Lithuanian buckwheat varieties, distinguished for a stable high grain yield and good adaptability to the local agroclimatic conditions. During the 15 research years a new buckwheat variety 'VB Vokiai' was selected.

The Lithuanian variety 'VB Vokiai' is of low height, the average stem height is 87 cm and even in the wet seasons plants are not high (Almantas, 2002; Romanovskaja, Ražukas, 2006). Grain size which has by 1000 grain weight is one of the most important buckwheat variety features. But it can vary depending on growing conditions. For example, the trial data of 2000-2001 gave 1000 grain mass – 32.2 g of the variety VB Vokiai (Almantas, 2002).

But during the 2001-2004 period the conditions for plant growing were extreme, so 1000 grain weight was lower – 31.0 g (Romanovskaja, Ražukas, 2006). 1000 grain weight is one of the defining characteristics of the variety. It has been proved that 1000 grain weight is inheritable according to intermediate type. That shows prevalence of polymorphysm of the above mentioned character in the hybrid population, where one of the components is variety of local breeding (Alexeeva and Pausheva, 1988; Anokhina, 1990; Anokhina *et al*., 1990).

Data of our former researches showed that big size grain inherited 47.6 % of selection new numbers of a buckwheat (Romanovskaja, Razukas, 2008). Meteorological conditions of the vegetation period had a significant impact on plant height and productivity of buckwheat. Summer seasons were very wet during almost all years of the study (except for 2008 and 2012). Under such meteorological conditions the plants grew taller.

The main research object of the Lithuanian narrow-leaved lupine and buckwheat breeding program was and still remains the selection of high yielding varieties of early maturity, resistant to fungal diseases. Due to high resistance to diseases and pests, all Lithuanian narrow-leaved lupine and buckwheat varieties are perfect for growing in ecological farms.

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Figure and Tables

Table 1. Meteorological data of 2008-2012 long term average of 1961-1990

Month	Meteorological conditions					Long term average
	2008	2009	2010	2011	2012	
			Air temperature, °C			
May	11.4	12.4	14.0	12.9	13.8	12.5
June	15.8	14.9	16.7	18.3	14.8	15.7
July	17.8	18.0	21.8	19.6	19.5	16.9
August	17.6	16.4	19.8	17.3	15.2	16.3
September	11.9	13.6	11.5	13.3	12.9	11.6
			Precipitation, mm			
May	104	46	113	79	38	60
June	69	129	142	41	99	77
July	58	107	208	155	81	78
August	55	68	117	101	83	68
September	31	60	80	63	45	65

Table 2. Seed yield and infection by fungal diseases (%) in narrow-leaved lupine (Voke branch, 2008-2012)

Variety	Seed yield, t ha^{-1}	Infected plant anthracnose, %	Infected plant fusarium, %	Vegetation period in days
'VB Vilniai'	1.8±0.05	9.5±0.26	7.1±0.19	98
'VB Antaniai'	2.1*±0.07	7.2*±0.21	3.8±0.14	90
'VB Derliai'	3.2±0.08	3.4±0.12	2.0*±0.06	88
'VB Ugniai'	2.4*±0.07	6.0*±0.18	2.1*±0.02	82
$LSD_{0.05}$	*0.053*	*0.342*	*0.147*	-

Table 3. Grain yield and agronomic characteristics of buckwheat varieties in the competitive varieties trials 2008-2012

Variety	Grain yield, t ha^{-1}	1000 grain weight, g	Plant height, cm	Husk content, %	Amount of large grain, %	Vegetation period in days
'VB Vokiai'	3.12±0.33	35.5±0.84	102±5.20	26.6±1.00	89.7±5.20	86
'Volma'	2.91±0.67	31.8*±0.87	110±9.05	26.2±0.81	81.7*±6.05	96
'Smuglianka'	2.77±0.57	32.0*±1.03	94±7.62	27.5±1.74	77.4*±4.71	94
'Anita Belaruskaya'	2.83±0.37	30.7*±0.67	95±8.29	27.4±0.93	80.4*±3.76	96
$LSD_{0.05}$	*1.018*	*2.621*	*10.184*	*2.420*	*7.795*	-

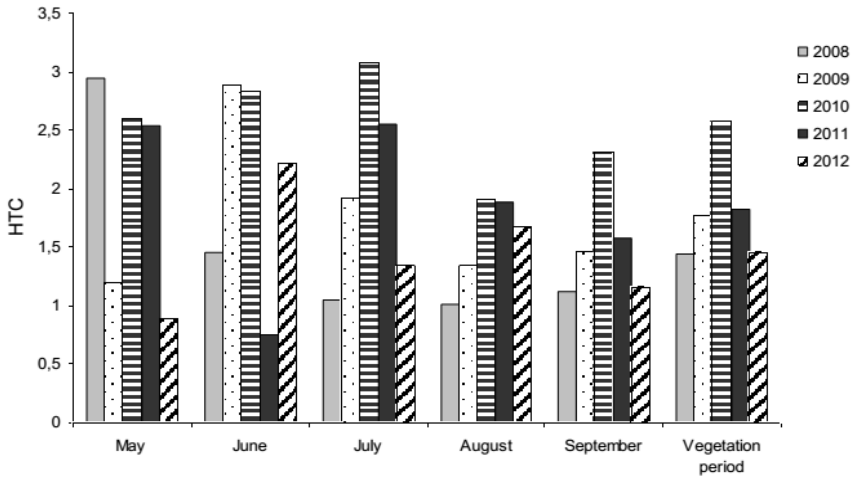

Fig. 1. Hydrothermal coefficients (HTC) during vegetation period 2008 - 2012.

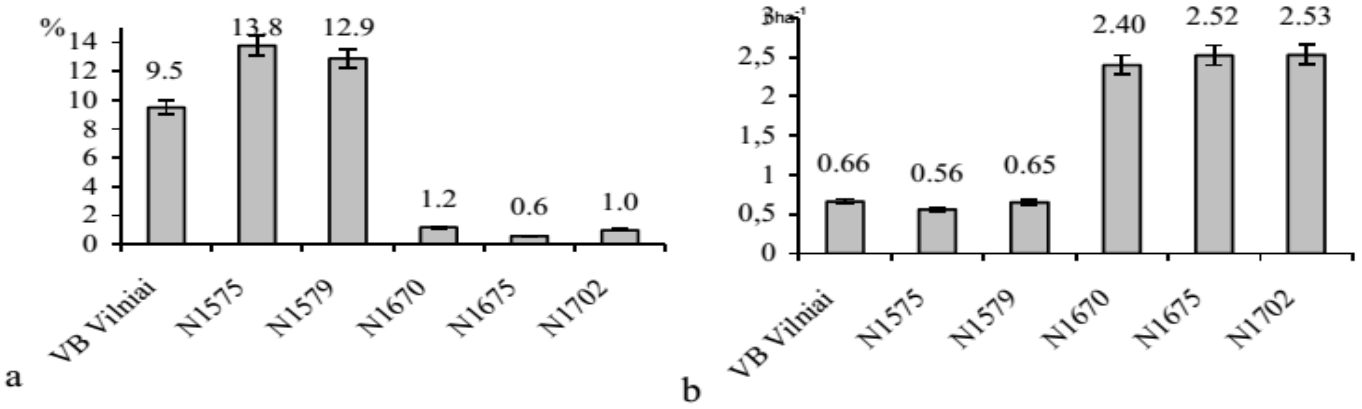

Fig. 2. Anthracnose affected of vegetation period (a) and seed yield (b) narrow-leaved breeding lines 2008-2012 (Voke branch), $LSD_{0.05(a)}$ – 0.846; $LSD_{0.05(b)}$ – 0.078

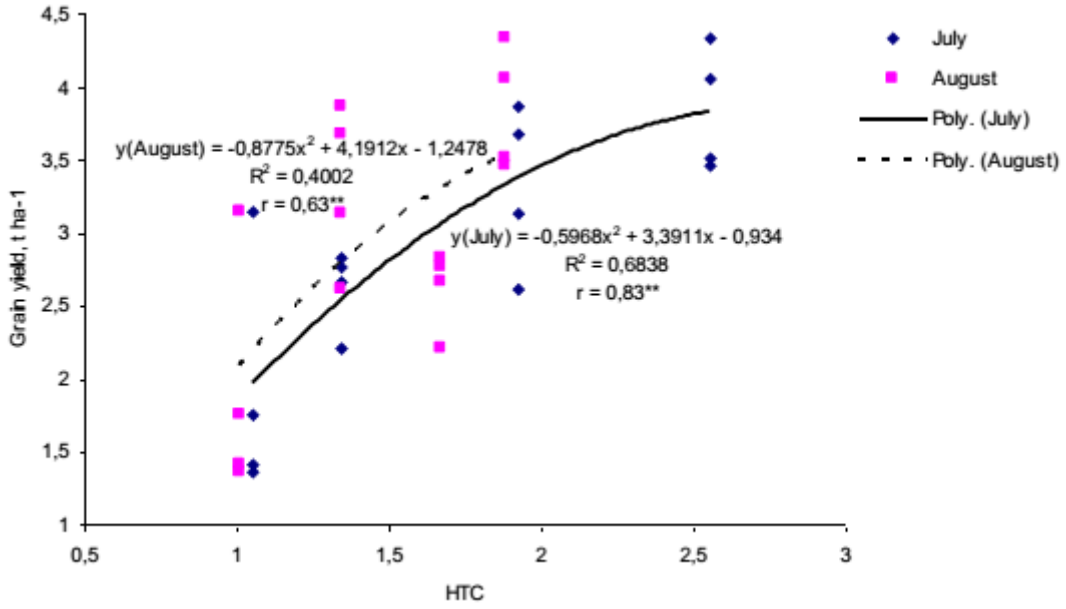

Fig. 3. Relationship between hydrothermal coefficients of July and August and grain yield of buckwheat in 2008-2012.