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Cultivar and plant density influence on weediness in spring barely crops

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Summary

The influence of plant density on weed suppression was investigated in the crops of spring barley cultivars ‘Aura DS’, ‘Barke’ and ‘Gustav’ in the field trials conducted at the Lithuanian Institute of Agriculture in 2008 and 2009 in Central Lithuania (55º23′50″N and 23º51′40″E). The soil of the experimental site is *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*), neutrally acid light loam, rich in phosphorus and potassium. Seed rates were adjusted for seed weights and germination rate to give a population density of 200, 400 or 600 plants per m^2. Strong and significant effects of crop density on weed growth were established. Weed biomass decreased with an increasing sowing density of spring barley. Crop density was a more reliable factor compared with cultivar selection for enhanced crop competitiveness against weeds. Spring barley plant height was a relevant indicator defining competitive ability against weeds.

The augmentation of spring barley seed rate from 2 to 4 million viable seeds per hectar was found to be adequate for satisfactory suppression of broad-leaved weed infestations for tall spring barley cultivars ‘Aura’ and ‘Barke’. For short cultivars (‘Gustav’) the seed rate could be higher.

Key words: spring barley, cultivar, seed rate, weed biomass.

Introduction

Weeds are an important constraint in agricultural production system (Qerke, 2006), because uncontrolled weeds will sooner or later lead to considerable reductions in crop yield. Chemical weed control, most notably characterised by tremendous increase in labour productivity, rapidly evolved into standard approach, making other management options for regulating weed population size less important (Bastiaans et al., 2008). The heavy reliance on chemical weed control is nowadays considered objectionable (Liebmann et al., 2001). Public concern about the effects of herbicide use on the environment and human health has increased the interest in reducing the use of herbicides in agriculture and in developing alternative methods for weed control. Efficient and timely weed control is one of the major tasks of competitive contemporary agriculture (Liebman et al., 2001; Sarrantonio, Gallandt, 2003). One way to control weeds in cereals is to improve the ability of the crop itself to suppress weeds (Jordan, 1993; Lemerle et al., 2001; Mohler, 2001). The seeding rate of the crop is an important factor in determining the biomass production of weeds and most studies show a decreasing weed biomass at higher crop densities (Blackshaw, 1993; Tollenaar et al., 1994; Doll, 1997; Petraitis, 2001; Auškalnis, Auškalnienė, 2007). At relatively low crop densities, crop cover early in the growing season is low, leaving a larger amount of resources available for the weeds, thus enabling them to establish and grow quickly (Medd et al., 1985; Murphy et al., 1996; Hakansson, 1997; Lemerle et al., 2001).

Crop shading ability may improve weed control without extra costs and negative environmental impacts (Satorre, Snaydon, 1992; Lemerle et al., 1996). Effects of cultivar morphology on weed growth were shown in different crops, but mainly in cereals. Cereal varieties differ in competitiveness against weeds (Christensen, 1995; Lemerle et al., 1996) therefore choice of variety enters the suite of preventive weed control methods (Hansen et al., 2008).

In several investigations competitive wheat stands reduced weed dry matter by more than 60% compared with stands with low competitiveness (Lemerle et al., 1996) and a significant reduction of weed reproductive structures at higher crop densities for different winter wheat cultivars has been observed (Korres, Froud-Williams, 2002), while in other studies this effect was not confirmed (Rasmussen, 2004). Weed biomass decreased with increasing sowing density of spring wheat: however, the seed rate did not have any significant influence on the spring wheat grain yield (Auškalnienė, Auškalnis, 2008). When weeds were controlled with herbicide, no effects of crop density or spatial uniformity on crop biomass or yield were observed (Kristensen et al., 2008).

The results also suggest that the relative size of the crop and weed plants when crop-weed competition becomes intense is critical in determining the effects of crop density and pattern on weed biomass. When the crop has an initial size advantage, increasing crop density and spatial uniformity can help the crop maintain its advantage and suppress the weeds (Olsen et al., 2006).

The aim of our research was to investigate the influence of different height cultivars and seed rates on weed biomass in spring barley stand.

Material and methods

Field experiments were conducted in 2008 and 2009 at the Lithuanian Institute of Agriculture (LIA) in Central Lithuania (55º23′50″N and 23º51′40″E). The soil of the experimental site is *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*), neutrally acid light loam, rich in phosphorus and potassium: P_2O_5 content – 164 to 213 mg kg^{-1}, K_2O – 156 to 221 mg kg^{-1}, soil humus – 1.9–2.2%, pH – 7.3. Preceding crop of spring barley was spring wheat. Pre-sowing fertilizer complex $N_{63}P_{42}K_{70}$ a.i. ha was applied. Spring barley was sown with a seed drill with 12.5 cm row spacing on 22 April in 2008 and on 21 April in 2009. The seed rates were adjusted for seed weights and germination rate to give a population of 200, 400 and 600 plants m^{-2}. Spring barley cultivars 'Aura', 'Barke' and 'Gustav' were grown.

'Aura DS' – tall plants, wide leaves.

'Barke' – medium high plants, medium wide leaves.

'Gustav' – short plants, narrow leaves.

A split-plot design with four replicates was used, with the cultivar of spring barley being the main-plot and crop density the subplot. The total trial field area was 20.4 m^2 (12 x 1.7 m), accounting plot area – 17 m^2 (10 x 1.7). The spring barley was treated with fungicides Archer 1.0 L ha^{-1} in 2008 and Falkon 0.6 l ha^{-1} 2009. Percentage of crop establishment was calculated in four places of each trial plot after spring barley germination. For the assessment of spring barley mass increment, plant samples were taken five times during the growing period: at BBCH 21–26, BBCH 31, BBCH 39, BBCH 71–72, BBCH 75–85. The weed number and green mass were established in 4 places of 0.25 m^{-2}, in each plot of spring barley when weed biomass was at its maximum BBCH 71–73 (end of June–beginning of July), and grain was harvested in August.

The weather conditions during the May–July period in 2008 were dry – only 21% of perennial mean of rainfall precipitated in May, respectively 67% in June, and 64% in July. The air temperature in May was equal to perennial mean, in June 0.5ºC and in July 0.6ºC above the perennial mean. In 2009, there was a shortage of moisture in May – precipitated 52% of perennial mean. While in June and July the total amount of rainfall amounted to 270% and 123% of perennial mean of precipitation, respectively. The mean air temperature was above perennial mean in May and July by 0.5ºC and by 1.0ºC below perennial mean in June. The meteorological conditions of 2008 and 2009 are shown in Figure 1.

All data were analyzed using „R" program, two-way *Anova*, *Split Plot*, and correlation-regression analyses (Tarakanovas, Raudonius, 2003, Crawley, 2007, Ritz, 2009). To achieve homogeneity of variance, the weed biomass data were Sqr (x + 1) transformed.

Results and discussion

Target densities were underachieved under dry weather conditions in spring. The percentage of crop establishment ranged from 60 to 80%. Means across years gave crop densities of 120–150, 250 and 330–380 m^{-2} (Figure 2).

Natural weed abundance was relatively low in both years, with weed numbers ranging between 40–70 m^{-2} in 2008 and 10–20 m^{-2} in 2009. The dominant weed species in the trials were *Chenopodium album* L., *Lamium purpureum* L., *Viola arvensis* Murray, *Stellaria media* (L.) Vill. Annual dicotyledonous accounted for more than 98% of the total weed number (Table 1).

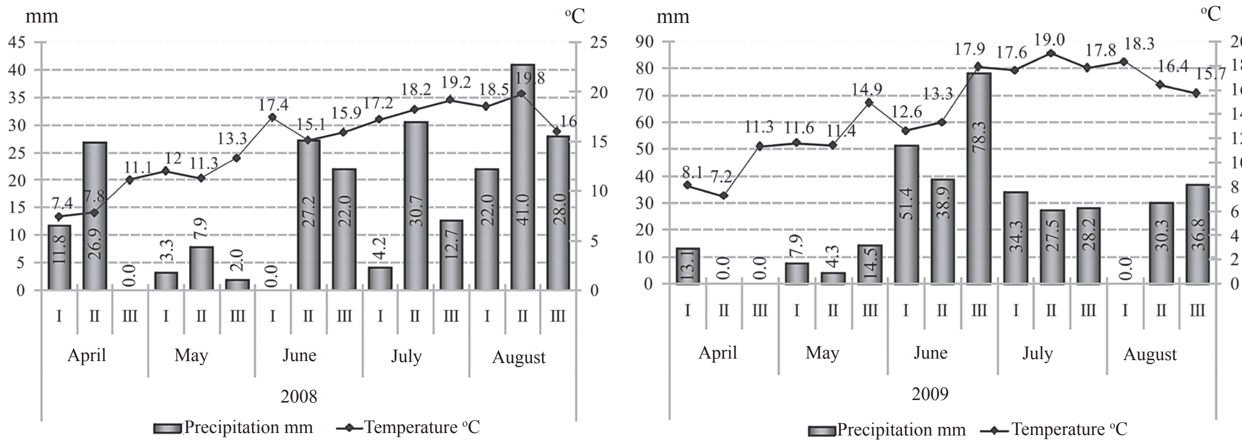


Figure 1. Meteorological conditions of 2008–2009

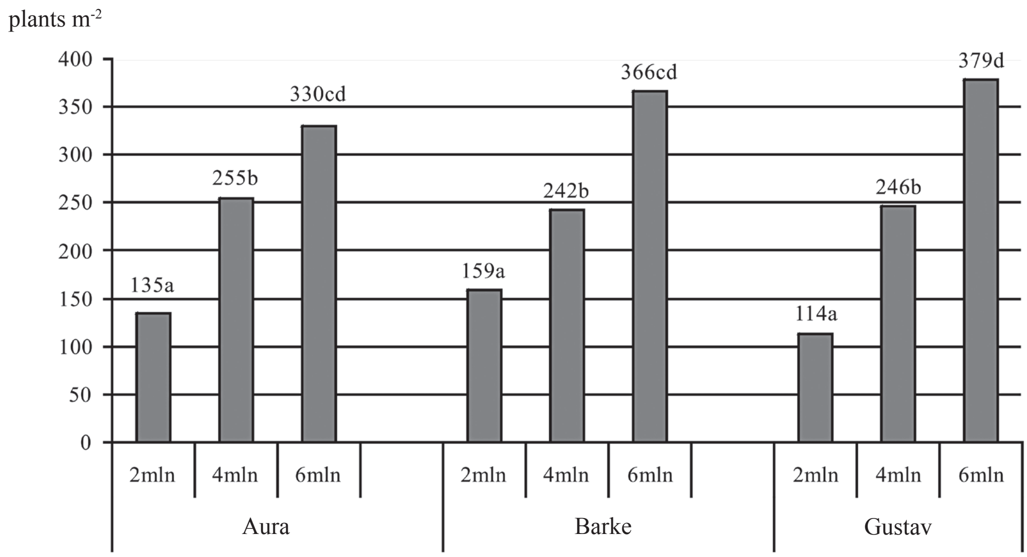


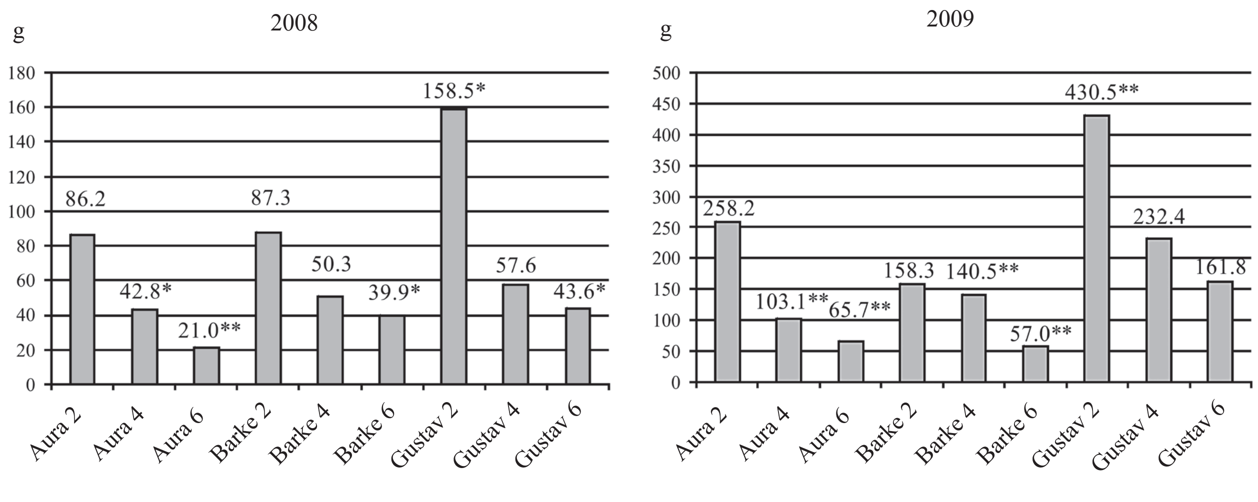
Figure 2. The number of seedlings m^{-2} of spring barley

Table 1. Weed species composition and mean density in spring barley stands
Dotnuva, 2008–2009

Weed species	Mean density of weeds			
	2008		2009	
	Weeds m^{-2}	%	Weeds m^{-2}	%
Chenopodium album L.	14.7	24.3	2.2	15.6
Galium aparine L.	0.4	0.7	1.6	11.3
Viola arvensis Murray	20.2	33.3	0.6	4.2
Lamium purpureum L.	10.5	17.3	2.2	15.6
Veronica hederifolia L.	2.1	3.5	1.6	11.3
Euphorbia helioscopia L.	2.1	3.5	0.1	0.7
Fumaria officinalis L.	0.1	0.2	0.1	0.7
Stellaria media (L.) Vill.	3.4	5.6	5.3	37.5
Sonchus arvensis L.	0.6	1.0	0.3	2.1
Other	6.5	10.7	0.1	0.7
Total	60.6	100.0	14.1	100.0

There were obtained some differences in weed species composition between years. In 2008, *Viola arvensis* prevailed in spring barley fields – it accounted for more than 30% of the total weed number, while *Stellaria media* dominated in spring barley crops in 2009 – it accounted for 36.3% of the total weed number. A higher weed number was found in the plots with the lowest seed rate of spring barley.

Ability to suppress weeds can be measured by the biomass of weeds growing in mixture with the crop. It is possible that the characteristic leading to ability to tolerate competition may differ from those conferring ability to suppress weeds (Lemerle et al., 1996). However, within the collected data we established significant (at $P < 0.05$ and 0.01) differences in weed mass between years and cultivars of spring barley. There were identified significant differences in weed suppression among the cultivars of spring barley, especially in the plots with low densities. The tall spring barley cultivar 'Aura' in most cases was a better competitor with weed compared to the short cultivar 'Gustav' (Figure 3).



Note. *, ** – significant at $P < 0.05$, $P < 0.01$; 2, 4, 6 – million viable seeds per ha.

Figure 3. Weed mass g m^{-2} in different stand densities of spring barley

Weed mass in 2009 was more than twice as high as that in 2008 because of the meteorological conditions during the summer. Quite high amount of precipitation occurred in June and July with the total amount of rainfall reaching 270% and 123% of perennial mean of precipitation, respectively.

In both years, the highest amount of weed mass was determined in the the spring barley stands of cv. 'Gustav', in the plots with a seed rate of 200 viable seeds per m^2. Significantly lower amount of weed biomass was identified in the spring barley 'Aura' and 'Barke' plots with a seed rate of 600 viable seeds per m^2. Some studies agree with our findings that the seeding rate of the crop is an important factor in determining the biomass production of weeds (Doll, 1997; Olsen et al., 2006).

The analysis of regression showed, that in all cultivars of spring barley with increasing crop density, weed mass decreased. The relationship between crop density and weed green mass showed to be significant at $P < 0.01$ and $P < 0.05$ (Table 2).

Our research evidence is in agreement with the data of Olsen et al. (2006), who found strong and significant effects regarding the crop density on the weed biomass in two years of investigation. The weed biomass decreased with increased wheat crop density in 29 out of 30 cases.

To understand the relationship between crop densities and weed suppression, it is important to investigate the effects on different types of weeds. Studies with winter wheat, and different weed species varied in their biomass and effects on crop biomass and yield, but the relative effect of crop density on weed suppression was consistent across the species (Olsen et al., 2005).

The data of biomass of *Chenopodium album*, *Lamium purpureum*, *Stellaria media* and *Viola arvensis* showed, that the changes in weed biomass were higher due to the changing plant density compared to the cultivar influence (Table 3).

Plant density was more important than selection of cultivars for reduction of biomass of

Chenopodium album and *Stellaria media* suppression. Similar findings were obtained by other authors, who observed higher importance of sowing density vs cultivar selection for improved weed suppression (Korres, Froud-Williams, 2002). However, for *Lamium purpureum* and *Viola arvensis* both factors were important. Cv. 'Aura' had higher suppression ability compared to 'Barke' and 'Gustav'. It could be concluded that suppression ability of the cultivars depended on weed species composition.

Table 2. The relationship between crop density (x) and weed green mass (y) in different varieties of spring barley

Data of 2008–2009 years

Cultivar	Equation	DF	*r*	F_{actual}
		2008		
'Aura'	y = 116.5 − 0.16x	10	−0.78**	16.05
'Barke'	y = 108.9 − 0.12x	10	−0.65*	7.50
'Gustav'	y = 209.3 − 0.30x	10	−0.74**	12.05
Average of 3 cultivars	y = 546.2 − 2.10x	34	−0.65**	24.28
		2009		
'Aura'	y = 314.3 − 0.39x	10	−0.71**	10.04
'Barke'	y = 221.0 − 0.27x	10	−0.79**	16.55
'Gustav'	y = 485.4 − 0.48x	10	−0.62*	6.47
Average of 3 cultivars	y = 340.2 − 0.38x	34	−0.51**	2.07
		Average of 2008–2009		
'Aura'	y = 215.4 − 0.27x	22	−0.52**	8.16
'Barke'	y = 164.96 − 0.19x	22	−0.62**	13.85
'Gustav'	y = 347.3 − 0.39x	22	−0.45*	5.55
Average of 3 cultivars	y = 242.6 − 0.28x	70	−0.42**	15.46

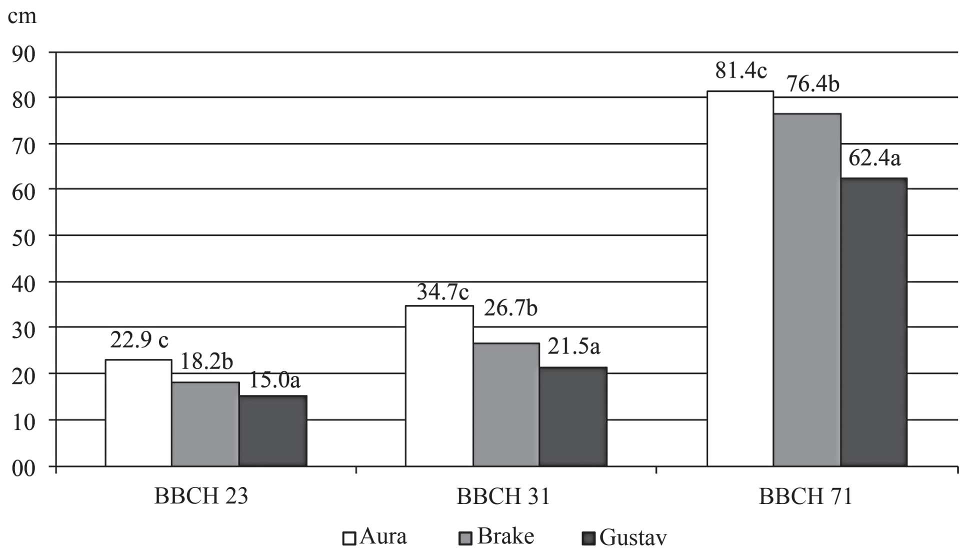
Note. DF – degrees of freedom, *, ** – indicate significance at $P < 0.05$, $P < 0.01$.

Table 3. Effect of cultivar and plant density on the mass g m^{-2} of different weeds 2008–2009

Weeds	Cultivar (factor A)			Seed rate (million per ha^{-1}) (factor B)		
	'Aura'	'Barke'	'Gustav'	2	4	6
Chenopodium album L.	22.6 ns	21.9 ns	35.7 ns	42.3 c	22.2 b	15.8 a
Lamium purpureum L.	4.7 a	9.8 b	9.3 b	4.7 a	9.8 b	9.3 b
Stellaria media L.Vill.	4.5 ns	6.5 ns	8.4 ns	11.9 c	4.7 b	2.8 a
Viola arvensis Muray	9.1 a	12.1 b	17.4 c	23.2 c	9.6 a	5.7 a

Note. Different letters within one factor indicate significant differences, Fisher's test ($P < 0.05$).

In some studies, plant height was shown to be the most important factor for suppression of certain weed species (Cousens et al., 2003). Larger individuals have a disproportionate advantage in competition with smaller individuals and suppress their growth, a phenomenon called 'size-asymmetric competition' (Schwinning, Weiner, 1998). Size asymmetry appears to be caused by competition for light, which is 'one-sided', in that larger plants shade smaller plants, whereas smaller plants have almost no effect on the light available to their larger neighbours. However, plants have evolved sensory mechanisms (Smith, 2000) and morphological plasticity to avoid being suppressed by their neighbours (Ballare, 1999). In our case, spring barley cultivars differed in plant height (Figure 4).



Note. Different letters within one factor indicate significant differences, Fisher's test ($P < 0.05$).

Figure 4. Height of spring barley plants (cm) at different growth stages
Average of 2008–2009

During all tested growing periods plants of the spring barley cv. 'Aura' were significantly (at $P < 0.01$) the highest compared to 'Barke' and 'Gustav'.

Our data confirm the proposition of Eisele (1992) who indicated that tall cereal cultivars were shown to increase weed suppression more efficiently than shorter types. The ranking of cultivars in descending order at high density was consistent with that at low density: 'Aura', 'Barke', 'Gustav'.

Our results support the proposition that increased crop density increases weed suppression and can play a role in weed management in cereals.

Weed management strategy based on increased sowing density can be used in conventional agriculture as a way to reduce herbicide application levels. In addition to reduced herbicide application, this weed management strategy may have other positive environmental effects, including fuel consumption and carbon dioxide (CO_2) production.

Conclusions

1. We established strong and significant effect of crop density on weed growth. Weed biomass decreased with increasing sowing density of spring barley. Crop density was a more reliable factor compared with cultivar selection for enhanced crop competitiveness against weeds.

2. The height of spring barley plants was a relevant indicator to define competitive ability against weeds.

3. The augmentation of spring barley seed rate from 2 to 4 million viable seeds per hectare was found to be adequate for satisfactory suppression of broad – leaved weed infestations for the tall cultivars of spring barley – 'Aura' and 'Barke'. For the short type cultivars ('Gustav') the seed rate could be higher.

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Veislių ir augalų tankumo įtaka vasarinių miežių piktžolėtumui

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Santrauka

Lietuvos žemdirbystės institute 2008 ir 2009 m. lauko bandymų metu tirta vasarinių miežių trijų veislių – ʽAura DS', ʽBarke' bei ʽGustav' – pasėlio tankumo įtaka piktžolėtumui. Dirvožemis – giliau karbonatingas giliau glėjiškas rudžemis (RDg4-k2), *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*), neutralaus rūgštumo lengvas priemolis, fosforingas ir kalingas. Miežių sėklos norma buvo apskaičiuota pagal sėklų masę siektinam pasėlio tankumui 200, 400 ir 600 augalų 1 m^{-2}. Pasėlio tankumas turėjo esminę įtaką piktžolių augimui – tankėjant miežių pasėliui, piktžolių masė mažėjo. Pasėlio tankumui esant 400 daigių sėklų 1 m^{-2}, piktžolių masė sumažėjo abiem tyrimų metais visų veislių vasariniuose miežiuose.
Miežių augalų aukštis buvo tinkamas požymis nustatant jų konkurencinę gebą piktžolėms. Miežių sėklos normą padidinus nuo 2 iki 4 milijonų daigių sėklų 1 ha^{-1}, pasėlio stelbiamoji geba trumpaamžėms dviskiltėms piktžolėms abiem tyrimų metais padidėjo iš esmės. Dar didesnis sėklos normos padidinimas buvo efektyvus tik žemaūgei ʽGustav' veislei.

Reikšminiai žodžiai: vasariniai miežiai, veislės, sėklos norma, piktžolių biomasė.