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Winter wheat cultivars 'Kovas DS', 'Zunda DS', 'Vikaras DS', 'Kaskada DS' for high input farming: development and characterization

Žilvinas LIATUKAS[1], Vytautas RUZGAS[1], Kristyna RAZBADAUSKIENĖ[1], Gintaras BRAZAUSKAS[1], Reine KOPPEL[2]

Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry
Instituto 1, Akademija, Kėdainiai distr., Lithuania
E-mail: liatukas@lzi.lt

[2]Jogeva Plant Breeding Institute
Aamisepa 1, Jogeva, Estonia

Abstract

The winter wheat cultivars 'Kovas DS', 'Zunda DS', 'Kaskada DS', and 'Vikaras DS' were developed at the Lithuanian Institute of Agriculture during 2000–2007, employing conventional and biotechnological methods. These cultivars were registered in the European Union Common Catalogue of Varieties of Agricultural Plant Species in 2010 and 2011. The cultivars are characterized by good winter-hardiness and lodging resistance, as well as high grain yield. The average winter-hardiness over the period 2006–2010 estimated in points was 7.9 of 'Kovas DS', 7.0 of 'Zunda DS', 6.8 of 'Kaskada DS', and 8.0 of 'Vikaras DS'. The average stem height was 82, 96, 71 and 85 cm, respectively. The maturity of the cultivars ranged from medium to late. The grain yield of 'Kovas DS' was 7.5, 'Zunda DS' 6.7, 'Kaskada DS' 6.9, 'Vikaras DS' 6.8 t ha^{-1}. The grain yield of the standard cultivar 'Zentos' was 6.6 t ha^{-1}.

All cultivars were medium resistant to powdery mildew, medium susceptible to take-all, except for medium resistant 'Vikaras DS', susceptible to eyespot and common bunt. 'Zunda DS' and 'Vikaras DS' were medium resistant, 'Kovas DS' and 'Kaskada DS' were medium susceptible to *Septoria* leaf blotch. 'Zunda DS' and 'Vikaras DS' were medium susceptible, 'Kovas DS' and 'Kaskada DS' were susceptible to tan spot. 'Kovas DS' and 'Zunda DS' were medium resistant, 'Kaskada DS' and 'Vikaras DS' were medium susceptible to snow mould.

The protein content of 'Kovas DS', 'Zunda DS', 'Kaskada DS' and 'Vikaras DS' was 11.3, 11.9, 11.9, 10.9 %, gluten content 21.6, 22,7, 20.1, 20.6 %, sedimentation value 32.9, 38.3, 22.9, 33.6 ml, falling number index 337, 340, 348, and 372 s, respectively. All tested cultivars are characterized by medium grain quality and low amylase activity, which is important for cultivation in humid climate countries. The investigation of dough properties by a Brabender farinograph showed quality indexes of 'Kovas DS', 'Zunda DS', 'Kaskada DS' and 'Vikaras DS' to be 30.4, 35.0, 19.2, and 27.4 Brabender units, respectively. The bread volume, baked from a 250 g sample was: for 'Kovas DS' 1100, 'Zunda DS' 1180, 'Kaskada DS' 1220 and 'Vikaras DS' 1210 cm^3 and the total baking value was 338, 368, 459 and 440, respectively. This suggests that the new high yielding cultivars are suitable for bread-making and are of good or medium bread-making quality.

Key words: *Triticum aestivum*, cultivars, agronomic characteristics, grain quality.

Introduction

Adequate plant genotypes, able to exploit the technological progress, should be created to suit the rapidly changing and improving agricultural level. Some researchers suggest that a new winter wheat variety can fit the agro technical level for about 15 years (Shewry, 2009). The wheat grain processing and bread-making industry is in the process of continuous development, too. The new processing systems are capable of more precisely exploiting the grain immanence and need raw material of specific characteristics. The uniqueness of wheat is that the kernel contains gluten protein which, along with other quality attributes, provides a wide array of end product uses (Kronstadt, 1996). The wheat growing area is currently on the increase. Although many winter wheat cultivars have been developed and are available on the seed market, it is important that they fit the local growing conditions as much as possible. The genotypes possess the best properties of adaptivity when they have been developed by crossing progressive varieties with local or well adapted foreign germplasm with following selection of segregating populations in local field conditions (Ortiz et al., 2007). It is important that the new varieties concentrate genes which are responsible for resistance to biotic and abiotic stresses and effectiveness of mineral and photosynthetic nutrition. Because of the plant breeders' efforts, the photosynthetic activity and yield potential of winter wheat increased by approximately 25% over the last 30-year period (Crossa et al., 2007). Local winter wheat varieties improve the food security and reduce the import needs, which is critical for each country.

Winter wheat breeding in Lithuania was started in 1922 and has been continued up to now. Several very successful cultivars have been developed during this period. 'Akuotuotieji', 'Dotnuvos 458' and 'Širvinta 1' were intensively grown over two decades. Genetically diverse breeding material was developed after 1990. Ten new cultivars were registered over the 2001–2011 period. Cultivars 'Ada', 'Seda' and 'Tauras' were registered in 2001, 'Milda', 'Lina' and 'Alma' in 2002. The registered cultivars are of excellent bread-making properties, but of medium grain yield and resistance to diseases, rather tall. To prevent lodging in the years with high precipitation level, the crops need growth regulators, which are strictly controlled in the export production. The progress in bread-making industry, new equipment and methods enable production of quality baking products using wheat grain of medium quality.

The industry and public demands have prompted development of new type of cultivars combining high grain yield, disease and pest resistance, tolerance of lodging and severe winter conditions, intended for different end uses. Fodder production industry prefers very high yielding varieties. Starch industry requires wheat grain with improved starch quality and high protein content. To respond to the up-to-date requirements a complex of conventional and biotechnological methods has been employed in the development of the novel cultivars 'Kovas DS' and 'Zunda DS' registered in 2010, 'Vikaras DS' and 'Kaskada DS' registered in 2011 and presented in this article.

Materials and methods

Winter wheat breeding nurseries were located in a nine-course crop rotation of Cereal Breeding Department of the Lithuanian Institute of Agriculture. The soil of the experimental site is *Endocalcari-Epihypogleyic Cambisol* (*CMg-p-w-can*), light loam. It contained 1.5–2.0% humus, available phosphorus (P_2O_5) ranging from 190 to 240 mg kg^{-1}, available potassium (K_2O) from 180 to 260 mg kg^{-1} and pH 6.5 to 7.0. Black fallow preceded the experiment. Fertilizer NPK rates (in pure elements) before sowing were 30–60–90 kg ha^{-1}. Nitrogen N_{90} kg ha^{-1} was applied after resumption of vegetation. Weeds were controlled by herbicides in the autumn. No other pesticides were applied during the plant growing season. The seeds were pesticide-treated only for the Advanced Cultivars Nursery (ACN). The crop was planted at a rate of 4.5 million seeds ha^{-1} with a plot drill "Hege 80" (Austria) in the Control and Advanced Cultivars Nurseries. Lines in the doubled haploid (DH) nursery were sown by a single row drill "Hege 90".

The early homogeneous material of the cultivars, presented in this study, was developed by the DH technology using maize as haplo-producer from single cross of two parent varieties (Brazauskas et al., 2005). Hybridization was done under greenhouse and field conditions, lines candidates were investigated in the field nursery. The data on the development of the new cultivars are provided in Table 1.

Table 1. The history of development and registration of the new winter wheat cultivars

Development stage	Cultivars			
	'Kovas DS'	'Zunda DS'	'Kaskada DS'	'Vikaras DS'
Pedigree	'Flair'/'Lut.9329'	'Pegassos'/'Biscay'	'Dirigent'/'Cortez'	'Olivin'/'Cubus'
Number in a catalogue	5060-47	5185-36	5422-6	5374-42
Crossing time	2000	2001	2002	2002
Number of DH population	21	11	14	14
Number of DH lines	624	349	238	238
Years of testing in breeding nurseries:				
selection of doubled haploid lines,	2003	2004	2005	2005
plots, one replication,	2004	2005	2006	2006
replicated testing block,	2005–2010	2006–2010	2007–2010	2007–2010
additional testing for common bunt resistance,	2006–2010	2006–2010	2007–2010	2007–2010
additional testing in wheat monoculture block,	2006–2010	2006–2010	2007–2010	2007–2010
state variety testing for registration	2007–2009	2007–2009	2008–2010	2008–2010
Year of registration	2010	2010	2011	2011

Doubled haploids were screened by a short breeding scheme. The DH seeds were sown in a nursery of DH lines, 1 line in 1 m row with 30 cm distance between rows. The lines were evaluated for winter-hardiness, lodging, powdery mildew (causal agent *Blumeria graminis*) and *Septoria* leaf blotch (causal agent *Mycosphaerella graminicola*) resistance, stem density in a row, spike parameters and yield potential. The selected lines were hand harvested and threshed with a stationary single spike threshing machine.

The DH lines with acceptable agronomic properties and grain number were sown in the control nursery (CN) in 8.5 m^2 (5 × 1.7 m) plots without replication for one year testing. The nursery contained 300–500 lines per year. The standard cultivar 'Zentos' was sown every 30th plot. The lines selected in this nursery were later tested in the ACN in 18.7 m^2 (11 × 1.7 m) plots in four replications. The nursery contained 50–100 lines per year. The standard cultivar 'Zentos' was sown every 20th plot. One replication was treated with chopped wheat straw after application of autumn herbicides. This replication was subjected for tan spot (causal agent *Pyrenophora tritici-repentis*) and snow mould (causal agent *Monographella nivalis*) resistance screening. These nurseries were evaluated for autumn and spring growth peculiarities, winter-hardiness, leaf diseases and lodging resistance in scores, heading time (days from 1st January to heading), plant height in cm, yield in t ha^{-1}, 1000 grain weight (TGW) and test weight (HW) in g, grain end-use quality elements (Tables 2–4) (LST 1498:1997, LST 1522:2004, LST

1523:1998, LST 1696:2001, LST ISO 3093:1982). Grain yield was harvested at full ripening with plot combines "Hege 125C" and "Wintersteiger Classic" (Austria).

All lines in the ACN were additionally evaluated in the wheat mono-crop nursery for take-all and snow mould resistance, grain yield, 1000 grain and test weight. The fertilizing, sowing rate and time were the same as in the conventional nursery. The nursery was ploughed two weeks and seed bed was prepared one day before sowing. The seeds were sown with a sowing machine "Hege 90" in 3.0 m^2 (1.35 × 2.2 m) plots in four replications. Application of fertilizers and pesticides was the same as in the main breeding nursery. The take-all (causal agent *Gaeumannomyces graminis* var. *tritici*) severity was assessed as ears discoloration symptoms from early to late milk stages in scores, using the scale 1 to 9, where 1 is the highest resistance. Snow mould was evaluated in spring after resumption of winter wheat vegetation.

Also, the lines were evaluated for common bunt (causal agent *Tilletia caries*) resistance in percent at dough stage (Szunics, 1990), resistance to grain sprouting in ears was screened in the laboratory (Mares, 1993), coleoptile length in cm (Bai et al., 2004), and spot blotch (*Cochliobolus sativus*) resistance at 1st leaf stage in scores in the laboratory (Liatukas, Ruzgas, 2011) (Tables 2–3). Resistance to diseases and grain sprouting in ears were evaluated on a score scale 1–9, where 1 means the highest resistance. Resistance to leaf diseases was evaluated from stem elongation to dough stage. Resistance to common bunt was evaluated in percent. Winter-hardiness and lodging were evaluated on a scale 1–9, where 1 indicated the lowest resistance. The autumn growth rate was evaluated at the end of active vegetation and spring growth was evaluated two weeks after resumption of vegetation on a scale 1–5, where 1 indicated the lowest growth rate. End-use quality evaluations were conducted by the Chemical Research Laboratory of the Lithuanian Institute of Agriculture, on the samples obtained from the 2006–2010 testing period. High molecular weight glutenins were evaluated by the methods described in Paplauskienė et al. (2009).

Investigation of bread-making properties. In the experiment, dough was prepared using Brabender farinograph from the sample of 250 g flour. After mixing, the dough was kept for 45 min in a temperature of 28–30°C. This was followed by rolling out the dough twice with resting periods. After this, the dough was put into the fermentation chamber for 90 min. The bread was baked for 20 min. The next day the volume of bread was measured using rapeseed and the following sensory evaluations were done: appearance of the entire product: A good – D bad. Crumb: A good – C satisfactory. Colour, crumb and taste: A good – C satisfactory. Elasticity of bread was measured from a piece of loaf (5 × 5 × 5 cm) by depressing the loaf texture 3.0 cm with a lead cube during 5 s. After the lead cube was released (after 5 s) the reversion of loaf texture was measured in centimetres. The reversion was determined using a scoring system 0–10 (poor to good). Structure value of crumb texture was determined by the pore size using a scoring system of 1–8 (small to large).

The research data were statistically processed by employing LSD_{05} (95% probability level) using the statistical package *ANOVA* (Tarakanovas, Raudonius, 2003).

Meteorological conditions. The testing period included years with very diverse weather conditions, which can be characterized as follows: 2005–2006 – warm autumn, cold winter with medium snow cover, dry spring and dry hot summer; 2006–2007 – warm autumn and winter with short cold period, medium spring and summer; 2007–2008 – normal autumn, very warm winter, rather dry spring and first part of summer; 2008–2009 – normal autumn, warm winter, normal spring, wet summer; 2009–2010 – normal autumn, very hard winter, normal spring, wet and hot summer (data from the Dotnuva Weather Station).

The seasons 2005–2006, 2009–2010 were favourable for evaluation of overwintering resistance, 2006–2007, 2008–2009, 2009–2010 were favourable for evaluation of disease resistance, 2006–2007, 2007–2008, 2008–2009 were favourable for evaluation of yield potential. Only the season 2005–2006 was favourable for evaluation of high grain quality, the conditions of the rest of the seasons determined low grain quality.

Results and discussion

The four new cultivars are awnless, white-glumed soft red winter wheat. By autumn growth type the cultivars are characterized as follows: 'Zunda DS' is fast growing (4.1 score), 'Kovas DS' and 'Kaskada DS' are of medium growth rate (2.4 and 2.1 scores) and 'Vikaras DS' is of slow growth rate (1.5 scores) (Table2). Therefore 'Kaskada DS' and 'Vikaras DS' can be sown from the beginning of September. Also, autumn weed control is recommended for these cultivars due to poor coverage of soil in the autumn. The recommended sowing time for 'Kovas DS' is medium and 'Zunda DS' should be sown later. The average winter hardiness score of 'Kovas DS' and 'Vikaras DS' was 8, the same as of the standard 'Zentos', which possesses high winter hardiness level. 'Zunda DS' and 'Kaskada DS' had a lower winter hardiness score 7. Winter hardiness scores for 'Zentos', 'Kovas DS', 'Zunda DS', 'Kaskada DS', 'Vikaras DS' ranged from 6 to 9, 6.8 to 9, 3 to 9, 2 to 9 and 6 to 9, respectively. The standard 'Zentos' exhibited the lowest overwintering in 2006, which resulted from low resistance to snow mould. The rest of the cultivars showed the lowest overwintering in 2010 when a combination of thin snow cover and severe cold resulted in about 25% loss of winter wheat crops in Lithuania. These cultivars possessed lower cold resistance.

The climate change makes development of new winter wheat cultivars more complicated due to unpredictable temperature fluctuations during autumn and winter. Meteorological data of the last decade shows that the majority of autumns were warmer than usual, whereas lower temperatures were not characteristic. The tendency of temperature changes shows the necessity to select winter wheat genotypes with slow to medium autumn growth type which helps to prevent overgrowth and reduction of cold resistance. Selection of winter wheat cultivars by autumn growth type is a new standard for the development of competitive cultivars. However, prostrate growth type has also been found to be associated with freezing tolerance, but it does not supply high resistance without other complex factors (Roberts, 1990).

The recent severe winters in 2006 and 2009–2011 showed that winter-hardiness is one of the vital traits for winter wheat cultivars in Lithuania. During the testing period, the winter of 2005–2006 was suitable for elimination of cold and snow mould susceptible genotypes. The winter of 2009–2010 was favourable for the evaluation of winter-hardiness complex due to low temperatures, thin snow cover and very wet soils. Stress factors involved in the winterkill are very complex and consist of traits such as extreme air or soil temperatures below critical for the respective wheat cultivar (winter of 2009–2010), inadequate hardening (winter 2006–2007), long period of cold-induced desiccation (Gusta et al., 1997), prolonged temperatures of low sub-zero temperatures. In particular, temperatures below −15ºC during mid-winter result in rapid loss of winter-hardiness (winter of 2009–2010). Alternate freezing and thawing, which results in increased injury from ice crystal growth with each freeze (Braun, Saulescu, 2002) occurs constantly, but at different rate during Lithuanian winters and beginning of spring. High winter-hardiness is associated with a lower yield potential. Therefore, breeding for winter-hardiness is complicated as recovering the maximal level of hardiness in higher yielding genotypes is only possible by applying very high selection pressure in larger segregating populations.

Table 2. Agronomic traits of the new winter wheat cultivars, 2006–2010

Trait	Cultivars					LSD_{05}
	'Zentos'	'Kovas DS'	'Zunda DS'	'Kaskada DS'	'Vikaras DS'	
Autumn growth, scores	1.9	2.4	4.1	2.1	1.5	0.42
Winter-hardiness, scores	8.0	7.9	7.0	6.8	8.0	0.86
Spring regrowth, scores	2.9	3.3	4.4	3.5	1.5	0.51
Days from 01 01 to heading	157	156	157	157	159	2.00
Plant height, cm	111	82	96	71	85	6.45
Lodging, scores	8.3	8.9	8.7	9.0	8.9	n.s.
Coleoptile length, cm	6.6	4.5	7.1	4.0	4.1	0.59
Grain sprouting in ears, scores	6.5	6.9	7.6	7.0	8.8	1.05
Grain yield, t ha^{-1}	6.6	7.5	6.7	6.9	6.8	0.58
Grain yield, t ha^{-1}*	4.8	5.5	6.3	5.2	5.9	0.92
1000 grain weight, g	45.3	45.5	45.0	38.2	36.4	5.33
1000 grain weight, g*	44.1	42.9	47.3	38.2	39.8	4.84
Test weight, g l^{-1}	825	751	806	760	766	62.1
Test weight, g l^{-1}*	735	691	750	670	736	80.4

* – wheat monoculture nursery

Rapid spring regrowth is a highly desirable trait during a dry spring as it allows faster soil cover and higher water use efficiency. However, resumption of vegetation should be slightly delayed to avoid frost damage in early spring (Braun, Saulescu, 2002). Spring regrowth rate of 'Vikaras DS' was slow (1.5 score), of 'Kovas DS' and 'Kaskada DS' it was medium (scores 3.3 and 3.5) and of 'Zunda DS' it was fast (score 4.4). All cultivars, except for 'Vikaras DS', showed medium or higher rate of spring regrowth. 'Vikaras DS' had advantage in wet spring when it could develop a high number of shoots and later develop a very dense canopy. The rest of the cultivars had some advantages during a dry spring due to faster soil cover and higher water use capacity.

'Zunda DS' and 'Kaskada DS' had the same medium-late maturity as the standard 'Zentos', 157 days to heading from 1st January. 'Kovas DS' was 1 day earlier than 'Zentos', whereas 'Vikaras DS' had late maturity as its heading time was 2 days later than that of 'Zentos'. The new cultivars belong to the groups of medium and late maturity and are characterized by a higher yield potential than the shorter maturity ones.

'Kaskada DS' was medium short (71 cm), 'Kovas DS' and 'Vikaras DS' were of medium height (82 and 85 cm), 'Zunda DS' was medium-high (96 cm). Lodging resistance of all cultivars was high due to short or medium straw length. At recent stages of the domestic wheat breeding effort, the consensus remained that the optimal plant height for the conditions of many countries of Europe is 80–90 cm (Anonymous, 2011). Use of growth regulators is not essential for 'Kaskada DS'. The cultivars 'Kovas DS' and 'Vikaras DS' should only be treated for a target yield of 8 t ha^{-1}, and 'Zunda DS' for over 6 t ha^{-1}. Later maturity of these genotypes in combination with acceptable plant height and disease resistance allows formation of high grain yield.

'Kovas DS', 'Kaskada DS' and 'Vikaras DS' possessed short coleoptiles (4.5, 4.0 and 4.1 cm, respectively), 'Zunda DS' had coleoptiles of medium length (7.0 cm). At present, cultivars possessing long coleoptiles have no distinct advantage for European countries over a wide area. However, such cultivars can perform better in some situations. Longer coleoptiles improve stand establishment where stubble retention is practiced (Rebetzke et al., 2005). Longer coleoptiles provide greater seedling early vigour, competitive power, crop establishment, more efficient soil water use, and better penetration through soil crust (Spielmeyer et al., 2007). Among the new cultivars only 'Zunda DS' can be sown deeper than the recommended 3–5 cm depth.

The winter wheat harvesting period in Lithuania lasts for 3–4 weeks and in some years longer. Long-term observations indicate that during the harvesting period rains occur every third day. Incessant rain lasting for a week or longer is also very likely. This means that the problem of pre-harvest sprouting is highly relevant. The new cultivars were medium susceptible to grain sprouting (6.7–7.5 scores), except for 'Vikaras DS' which was very susceptible (8.8 scores). Pre-maturity alpha-amylase activity as an indicator of pre-harvest sprouting occurrence is shown by the falling number (FN) index analyses. Sprouted wheat has low FN and lower values of other quality elements. Prediction of sprouting resistance by alpha-amylase activity is possible only in some cases (Lan et al., 2005). This trait can be comprehensively determined only by a separate screening. Harvesting of the new cultivars should not be delayed, especially for 'Vikaras DS', which is late maturing.

Grain yield of 'Kovas DS' was statistically higher (7.5 t ha^{-1}) than that of the rest of the cultivars (6.6–6.9). Grain yield of all cultivars was lower in the monoculture nursery. It ranged from 4.8 t ha^{-1} ('Zentos') to 6.3 t ha^{-1} ('Zunda DS'). 'Zunda DS' and 'Vikaras DS' (6.3–5.9 t ha^{-1}) yielded statistically significantly higher than the rest of the cultivars. 'Kovas DS' and 'Zunda DS' had medium sized grains (TGW 45.5, 45 and 42.9, 47.3 g, respectively) and 'Vikaras DS' and 'Kaskada DS' had small grains (TGW 36.4, 38.2 and 39.8, 38.2 g, respectively) under conventional and mono-wheat growing conditions.

Test weight (HW) was low, but still acceptable for 'Kovas DS', 'Vikaras DS' and 'Kaskada DS' (751, 766 and 761 g l^{-1}, respectively). Under conventional crop rotation, 'Zunda DS' had HW similar to that of high quality 'Zentos' (806 and 825 g l^{-1}). Under monoculture conditions, HW was considerably lower. Only 'Zunda DS' had acceptable HW (750 g l^{-1}).

Higher yields may be obtained by increasing total dry matter production, harvest index, or both. The theoretical upper limit for the harvest index was established by Austin et al. (1980) and later validated by Reynolds et al. (2009) at 62% under non-stressed conditions. The harvest index of modern cultivars in many recent experiments was close to 50% (Mladenov et al., 2011), which increased from 20–30% of old cultivars up to 50% for modern ones. So, it seems that this trait has a potential to be further increased. However, TGW was not improved and even decreased due to higher grain number per ear and higher stand density. HW did not show any significant improvement, either. In most cases HW increase was associated with higher stress resistance.

Under Lithuanian conditions, winter wheat has a potential of high yield formation in some part of soil area. However, due to relatively harsh climate new cultivars must possess very complex resistance traits.

The cultivars are high yielding. The mean grain yield of 'Kovas DS' was 7.5, Zunda DS' 6.7, 'Kaskada DS' 6.9, 'Vikaras DS' 6.8 t ha^{-1}.The mean grain yield of the standard cultivar 'Zentos' was 6.6 t ha^{-1}. 'Kovas DS' exceeded the mean grain yield of the standard cultivar by 0.9 t ha^{-1}. The average grain yield of the new cultivars 'Zunda DS', 'Kaskada DS' and 'Vikaras DS' statistically was at the same level as the standard 'Zentos'. Although the yield of the new cultivars was higher by up to 2 t ha^{-1} in some years, this demonstrates that high yield potential does not guarantee a stable yield without a complex of traits. Under our conditions, wheat breeding should focus on those traits that ensure plant survival, i.e. winter-hardiness, resistance to plant diseases and precipitation fluctuation, etc.

All cultivars were medium resistant to powdery mildew (scores 2.3–3.5), but 'Kovas DS' and 'Kaskada DS' possessed slightly higher resistance (scores 2.7 and 2.3) (Table 3). Powdery mildew resistance of European winter wheat cultivars ranged from resistant to medium susceptible, although most cultivars were medium resistant (Anonymous, 2011). This resistance type depended on quantitative resistance which provides stable resistance over decades, but it is slightly affected by environment (Miedaner, Flath, 2007). At present, breeding for powdery mildew resistance involves permanent development and selection of genotypes with acceptable resistance from European winter wheat pool saturated with numerous genes for quantitative resistance.

'Kaskada DS' was susceptible to *Septoria tritici* blotch (STB) (6.6 score), but possessed higher resistance than the standard 'Zentos' (7.7 score). 'Kovas DS' was medium susceptible (6.1 score), 'Zunda' DS and 'Vikaras DS' were medium resistant (5.0 and 5.1 scores). 'Zentos' and 'Kaskada DS' were very susceptible to tan spot (scores 8.8 and 8.0), 'Kovas DS' was susceptible (score 7.1), 'Vikaras DS' and 'Zunda DS' were medium susceptible (scores 6.2 and 5.5). The STB is one of the most important leaf diseases in wheat worldwide. Due to high yield losses fungicide application was common. Since the early 2000s, European isolates have become increasingly resistant to strobilurins (Torriani et al., 2009) and a shift towards higher tolerance to azoles has occurred (Cools, Fraaije, 2008). Hence, the use of resistant cultivars is progressively seen as an attractive method of control. Also, resistance breeding over the last decade has been effective and resistant cultivars have been made available for cultivation (Anonymous, 2011). Resistant cultivars are diseased up to 20%, whereas susceptible ones are diseased up to 80%. Recent investigation of winter wheat cultivars in Europe showed high stability of adult-plant resistance to STB (Schilly et al., 2011). Highly effective resistance to *S. tritici* is based on monogenic isolate-specific *Stb* genes (Chartrain et al., 2009) and quantitative, non-isolate-specific resistance (Eriksen et al., 2003). This is a challenge for resistance selection, because quantitative resistances can only be detected in the cultivars lacking effective isolate-specific genes.

Tan spot is also an important leaf disease in wheat worldwide, but it dominates in wheat monoculture or second wheat. Reactions of resistant and susceptible cultivars are similar to those exhibited to STB. Resistance breeding was successful in 'hot spots' of the disease (Singh et al., 2010), but European wheat resistance is lower compared to STB. However, some resistant cultivars are available to growers, too (Anonymous, 2011).

Table 3. Disease resistance of the new winter wheat cultivars, 2006–2010

Disease*	Cultivars					LSD_{05}
	'Zentos'	'Kovas DS'	'Zunda DS'	'Kaskada DS'	'Vikaras DS'	
Powdery mildew	3.4	2.7	3.4	2.3	3.5	0.32
Septoria leaf blotch	7.7	6.1	5.0	6.6	5.1	0.68
Tan spot	8.8	7.1	5.5	8.0	6.2	0.89
Eyespot	6.1	6.0	5.9	6.4	6.0	n.s.
Take-all	5.9	5.8	6.0	5.9	5.0	0.46
Snow mould	6.3	4.9	4.7	6.0	6.3	0.64
Common bunt	79.0	32.1	90.3	63.3	32.4	21.5
Spot blotch	8.0	6.5	6.0	7.1	8.8	1.18

* – all diseases assessed in scores, common bunt – in percent

According to average eyespot level, the cultivars were medium susceptible, but maximal disease value (data not shown) showed that all cultivars were susceptible. The progress of eyespot resistance breeding is slow due to the lack of new resistance genes in agronomically acceptable background and relatively small area where this disease causes essential yield losses. At present, only *Pch1* is widely used for breeding. *Pch2* supports lower resistance level and is found only is some cultivars. QTL's supports some resistance, but research on quantitative resistance is limited (Wei et al., 2011). Among cultivars, registered in Germany in 2011, about 10% possess considerable resistance level (Anonymous, 2011), which makes fungicide treatments not economical.

All cultivars were medium susceptible to take-all (scores 5.8–6.0), except for 'Vikaras DS' which possessed medium resistance (score 5.0). At least, medium resistance level of all new cultivars shows that indirect selection occurs even under long crop rotation of breeding nurseries. Visual symptoms of take-all are seen only from time to time in long rotation nurseries, whereas in take-all nursery symptoms were very severe. These relationships show that take-all does considerable damage even when visual symptoms on ears are absent. Up to now, wheat resistance to take-all has been considered low with no significant differences among cultivars. However, the recent study in the United Kingdom has shown a clear differentiation of cultivars (McMillan et al., 2011).

'Kaskada DS' and 'Vikaras DS' were medium susceptible (scores 6.0 and 6.3, respectively) to snow mould like the standard 'Zentos' (score 6.3). 'Kovas DS' and 'Zunda DS' were medium resistant (scores 4.9 and 4.7, respectively). Snow mould is one of the reasons of poor over wintering when steady snow cover occurs for a longer time. The disease can be controlled by cultivar resistance, seed treatment and crop rotation. Under conditions highly favourable for the disease only the combination of all mentioned factors can support excellent control, whereas resistant cultivars alone can support high control level under lower disease pressure (Eken et al., 2011). Cultivar screening is complicated due to irregular occurrence of the disease. Fairly good screening can be achieved only under artificial conditions, if snow cover occurs. Laboratory screening is very narrow and laborious (Browne et al., 2006).

'Kovas DS' and 'Vikaras DS' were medium susceptible to common bunt (32.1% and 32.4%), 'Zunda DS' and 'Kaskada DS' were susceptible (90.3% and 63.3%). World wheat pool contains many highly common bunt resistant genotypes; however, very seldom a genotype possesses acceptable agronomic background (Bonman et al., 2006). Resistant cultivars are required for organic production in Europe and worldwide. However, our new cultivars are not suitable for organic growing due to low common bunt resistance. Common bunt does not exert any negative impact on intensively grown wheat due to chemical seed treatment. The resistance of wheat to common bunt is closely related to dwarf bunt (causal agent *T. controversa*) resistance. The last disease is controlled by a very limited number of seed treatment pesticides. The dwarf bunt resistance screening is much more complicated than that of common bunt (Bonman et al., 2006). Therefore, wheat screening for common bunt resistance is a convenient method to select promising genotypes for dwarf bunt resistance.

'Kovas DS', 'Zunda DS', 'Kaskada DS' were medium susceptible (score 6.0–7.1) to spot blotch (causal agent *Bipolaris sorokiniana*) causing leaf spotting. 'Vikaras DS' was very susceptible (score 8.8) like the standard 'Zentos'. Under European conditions, this pathogen causes yield losses mostly due to root rot and seed black point. Significant negative effects on winter wheat foliage have not been reported, and only limited research is available about this fungus on wheat (Csösz et al., 2008). This pathogen is occurring all over the world and has a potential to become a new winter wheat disease in Europe. Our recent study showed that some European winter wheat accessions possess a fairly good resistance level (Liatukas, Ruzgas, 2011). As a result, resistance breeding is possible using European winter wheat pool.

The grain quality and baking properties of the new cultivars were compared to the standard 'Zentos' possessing excellent milling and baking traits (Table 4). The average grain protein concentration of all cultivars, except for 'Vikaras DS' (10.9%) was statistically comparable although somewhat lower than that of 'Zentos' (12.4%). Gluten concentration of 'Zunda DS' (22.7%) was the same as that of 'Zentos, and 'Kovas DS' had slightly lower but statistically similar concentration of gluten (21.6%). 'Vikaras DS' and 'Kaskada DS' had lower value of the trait (20.6% and 20.1%). The highest sedimentation value was found in 'Zentos' and 'Zunda DS' (44.1 and 38.3 ml), a little lower in 'Kovas DS' and 'Vikaras DS' (32.9 and 33.6 ml). The inferior sedimentation value was detected in 'Kaskada DS'. This cultivar is intended for biscuit-making or starch separation industry. All cultivars were characterized by an excellent FN index (337–372). Starch percent statistically did not differ between the cultivars. Lower ash percent was a desirable trait in previous years. However, recent studies showed higher ash content to be more favourable for health (Fardet, 2010). Of course, higher ash content does not guarantee higher content of the most desirable mineral element at a specific time. Comprehensive chemical analyses should be done in order to select the most desirable wheat genotype. 'Zunda DS' had the lowest ash concentration (1.6%), statistically significantly higher percent of ash was characteristic of 'Kaskada DS' (1.9%) and 'Vikaras DS' (1.8%). All cultivars were similar in flour output; however, Vikaras DS' possessed slightly higher flour output (70.0%).

Dough quality is one of the most important features enabling one to predict the final bread making value of a winter wheat cultivar. Dough elasticity was measured by Brabender's farinograph, whose operations are based on physical methods. The diagram (farinogram) showed direct indexes: water absorption, dough developing time, stability and other traits.

'Kovas DS' and 'Zunda DS' had slightly lower dough mixing time (1.6 min) compared to 'Zentos' (1.9 min), whereas 'Vikaras DS' and 'Kaskada DS' had considerably lower dough mixing time 1.4 and 1.2 min, respectively. Water absorption was statistically similar for all cultivars. By dough stability 'Kovas DS', 'Zunda DS' and 'Vikaras DS' were superior to the standard 'Zentos', whereas 'Kaskada DS' possessed the level statistically similar to the standard cultivar.

Table 4. Grain and end-use quality of the new winter wheat cultivars, 2006–2010

Trait	Cultivars					LSD_{05}
	‘Zentos’	‘Kovas DS’	‘Zunda DS’	‘Kaskada DS’	‘Vikaras DS’	
Protein, %	12.4	11.3	11.9	11.9	10.9	1.32
Gluten, %	22.6	21.6	22.7	20.1	20.6	1.85
Sedimentation, ml	44.1	32.9	38.3	22.9	33.6	5.27
Falling number index, s	318	337	340	348	372	27.3
Starch, %	68.2	67.8	69.3	68.1	70.0	n.s.
Ash, %	1.7	1.7	1.6	1.9	1.8	0.14
Flour, %	69.1	69.4	69.0	67.1	70.0	n.s.
Dough developing time, min	1.9	1.6	1.6	1.2	1.4	0.21
Water absorption, %	59.5	59.1	57.1	55.3	58.7	n.s.
Dough stability, min	3.4	3.9	4.5	3.2	4.1	0.39
Degree of softening after 10 min, BU	76.2	88.8	84.8	86.0	90.6	7.38
Degree of softening after 12 min, BU	98	105	107	100	112	9.48
Quality index	37.8	30.4	35.0	19.2	27.4	4.59
High molecular weight glutenin composition:						
Glu A1	0	1	1	2*	0	
Glu B1	7 + 9	6 + 8	7 + 9	6 + 8	7 + 9	
Glu D1	5 + 10	5 + 10	5 + 10	5 + 10	5 + 10	
Scores	7	8	8	8	7	

n.s. – non-significant

The mixing tolerance showed dough elasticity. “Strong” and “weak” flours produce dough with very different mixing properties. The difference mainly results from the quantity and quality of protein. Different food stuffs prepared from wheat require very different flour strength for their manufacture. The new Lithuanian winter wheat varieties have different elasticities of dough.

Dough softening after 10 min was statistically higher for all cultivars (84.8–90.6) compared to the standard ‘Zentos’ (76.2). However, the least dough softening was observed for ‘Zunda DS’ (84.7) and ‘Kaskada DS’ (86.0). Only ‘Vikaras DS’ had significantly higher (112) dough softening after 12 min compared to the standard ‘Zentos’.

It is possible to consolidate all traits in the calculated Brabender’s quality index. Quality index of ‘Zunda DS’ (35) was statistically similar to the standard ‘Zentos’ (37.8). ‘Kovas DS’ and ‘Vikaras DS’ had statistically significantly lower values (30.4 and 27.4, respectively). ‘Kaskada DS’ possessed the least quality index 19.2.

The prediction of a bread-making quality of winter wheat varieties by the analysis of high molecular weight (HMW) glutenin subunits is an important point in the breeding programs. On the other hand, the electrophoretic HMW glutenin tests are a proper method to test the genetic make-up of the new varieties, to verify if the variety is homogeneous or not. Quality score of HMW subunits was 7 (scoring scale 4–10 is used, where 10 is the highest quality level) for the standard ‘Zentos’ and ‘Vikaras DS’, the rest of the cultivars had quality score 8. The standard ‘Zentos’ possessed score 7, but it was characterized as possessing the highest values of quality traits in many cases compared to the rest of the cultivars. Therefore, HMW subunits are suitable only for rough evaluation of quality, and marking of genotypes with superior or very low grain quality.

The evaluation of bread-making properties of the new winter wheat varieties by direct baking test was done at Estonian Jogeva Plant Breeding Institute using grain harvested in Lithuania in 2009. The Lithuanian winter wheat ‘Ada’, widely grown in Estonia, was chosen as the standard for baking test. The growing conditions in 2009 were not conducive to the development of high quality winter wheat grain. Nevertheless, the volume of bread, baked from a 250 g flour sample was from 1100 cm^3 (‘Kovas DS’) to 1220 cm^3 (‘Kaskada DS’). Baking losses were 9.0–10.3%. General appearance of bread was good, crumb was intermediate, and taste was good of all cultivars. Pore size of bread was medium for ‘Kovas DS’ and ‘Zunda DS’, larger for ‘Kaskada DS’ and ‘Vikaras DS’. The best elasticity index was detected in the bread of ‘Vikaras DS’ (Table 5).

Table 5. The baking properties of the new winter wheat cultivars, 2009

Traits	Cultivars				
	‘Kovas DS’	‘Zunda DS’	‘Kaskada DS’	‘Vikaras DS’	‘Ada’
Volume of bread, cm^3	1100	1180	1220	1210	1400
Appearance	BC	BC	B	B	B
Colour	AB	B	BC	B	A
Crumb	B	B	B	B	AB
Taste	A	A	A	A	A
Structure	5–6	5–6	7	6	6
Structure value	75	75	90	80	80
Elasticity	3.3	4.0	3.9	4.1	3.9
Elasticity index	4.5	6.5	6.5	7.0	6.5
Baking losses, %	10.3	9.7	9.0	9.9	10.2
Total baking value	338	368	459	440	480

The total baking value of the investigated cultivars 'Kovas DS', 'Zunda DS', 'Kaskada DS', and 'Vikaras DS' was 338, 368, 459 and 440, respectively. For 'Ada', characterized by excellent bread-making properties, it was 480. This implies that the new high yielding cultivars are suitable for bread-making and are of good and medium bread-making quality. It is common that high yielding winter wheat cultivars exhibit intermediate quality properties. At the same time, baking tests showed good results even from grains harvested in the year unfavourable for the formation of high quality grain. Therefore, a decision on wheat cultivars' suitability for bread-making should be based on the baking tests but not solely on grain quality results, which are highly environment-depended.

Conclusions

1. The winter wheat cultivars 'Kovas DS', 'Zunda DS', 'Kaskada DS', and 'Vikaras DS' were developed at the Lithuanian Institute of Agriculture during 2000–2007, combining conventional and biotechnological methods.

2. The cultivars are characterized by good winter-hardiness and lodging resistance, as well as high grain yield. The average winter-hardiness over the period 2006–2010 estimated in points was 7.9 of 'Kovas DS', 7.0 of 'Zunda DS', 6.8 of 'Kaskada DS', and 8.0 of 'Vikaras DS'. The average stem height was 82, 96, 71 and 85 cm, respectively.

3. The cultivars are high yielding. The mean grain yield of 'Kovas DS' was 7.5, 'Zunda DS' 6.7, 'Kaskada DS' 6.9, 'Vikaras DS' 6.8 t ha^{-1}. The mean grain yield of the standard 'Zentos' was 6.6 t ha^{-1}.

4. All cultivars were medium resistant to powdery mildew and susceptible to eyespot and common bunt. 'Zunda DS' and 'Vikaras DS' were medium resistant to Septoria leaf blotch and 'Kovas DS' and 'Kaskada DS' were medium susceptible. 'Zunda DS' and 'Vikaras DS' were medium susceptible to tan spot and 'Kovas DS' and 'Kaskada DS' were susceptible. The cultivars were medium susceptible to take-all, except for 'Vikaras DS', which was medium resistant. 'Kovas DS' and 'Zunda DS' were medium resistant to snow mould, whereas 'Kaskada DS' and 'Vikaras DS' were medium susceptible.

5. The protein content of 'Kovas DS', 'Zunda DS', 'Kaskada DS' and 'Vikaras DS' was 11.3, 11.9, 11.9, 10.9 %, sedimentation value 32.9, 38.3, 22.9, 33.6 ml, gluten content 21.6, 22,7, 20.1, 20.6 %, falling number index 337, 340, 348, and 372 s, respectively. All cultivars are characterized by medium grain quality and low amylase activity, which is important for cultivation in humid climate countries.

6. The investigation of dough properties by a Brabender farinograph showed that dough stability of 'Kovas DS', 'Zunda DS', 'Kaskada DS' and 'Vikaras DS' was 3.9, 4.5, 3.2 and 4.1 min, general quality index 30.4, 35.0, 19.2 and 27.4 Brabender units, respectively.

7. The volume of bread, baked from a 250 g flour sample was for 'Kovas DS' 1100 cm^3, 'Zunda DS' 1180 cm^3, 'Kaskada DS' 1220 cm^3 and 'Vikaras DS' 1210 cm^3. General appearance was good, crumb was intermediate. Pore size of bread was intermediate for 'Kovas DS' and 'Zunda DS', larger for 'Kaskada DS' and 'Vikaras DS'. The best elasticity index was detected in the bread of 'Vikaras DS'. The total baking value of the investigated cultivars 'Kovas DS', 'Zunda DS', 'Kaskada DS', and 'Vikaras DS' was 338, 368, 459 and 440, respectively. This implies that the new high yielding varieties are suitable for bread-making and are of good or medium bread-making quality.

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Žieminio kviečio veislės 'Kovas DS', 'Zunda DS', 'Vikaras DS' ir 'Kaskada DS' intensyviam auginimui: kūrimas ir savybės

Ž. Liatukas[1], V. Ruzgas[1], K. Razbadauskienė[1], G. Brazauskas[1], R. Koppel[2]

[1]Lietuvos agrarinių ir miškų mokslų centro Žemdirbystės institutas
[2]Jogevos augalų selekcijos institutas, Estija

Santrauka

Lietuvos žemdirbystės institute 2000–2007 m., taikant tradicinius ir biotechnologinius selekcijos metodus, sukurtos naujos žieminio kviečio (*Triticum aestivum* L.) veislės 'Kovas DS', 'Zunda DS', 'Kaskada DS' ir 'Vikaras DS'. Šios veislės 2010 ir 2011 m. buvo įrašytos į Europos Sąjungos žemės augalų rūšių veislių bendrąjį katalogą. Šių veislių kviečiai pasižymi geru žiemkentiškumu ir atsparumu išgulimui. 2006–2010 m. laikotarpiu jų vidutininis atsparumas nepalankioms žiemos sąlygoms įvertintas: veislės 'Kovas DS' – 7,9, 'Zunda DS' – 7,0, 'Kaskada DS' – 6,8, 'Vikaras DS' – 8,0 balais. Augalų stiebai neaukšti, siekia vidutiniškai atitinkamai 82, 96, 71 ir 85 cm. Šių veislių kviečiai pasižymi vidutine bei vėlyva branda ir dideliu grūdų derliumi. Patręšus N_{120}, grūdų vidutinis derlius veislės 'Kovas DS' gautas 7,5, 'Zunda DS' – 6,7, 'Kaskada DS' – 6,9, 'Vikaras DS' – 6,8 t ha^{-1}. Per tyrimų metus standartinės veislės 'Zentos' kviečiai užderėjo vidutiniškai 6,6 t ha^{-1}. Visų veislių kviečiai buvo vidutiniškai atsparūs miltligei, vidutiniškai jautrūs javaklupei, išskyrus vidutiniškai atsparius veislės 'Vikaras DS' kviečius, jautrūs stiebalūžei ir kietosioms kūlėms. Veislių 'Zunda DS' ir 'Vikaras DS' kviečiai buvo vidutiniškai atsparūs, 'Kovas DS' ir 'Kaskada DS' – vidutiniškai jautrūs lapų septoriozei. Veislių 'Zunda DS' ir 'Vikaras DS' augalai buvo vidutiniškai jautrūs, 'Kovas DS' ir 'Kaskada DS' – jautrūs dryžligei. Veislių 'Kovas DS' ir 'Zunda DS' kviečiai buvo vidutiniškai atsparūs, 'Kaskada DS' ir 'Vikaras DS' – vidutiniškai jautrūs pavasariniam pelėsiui. Baltymų kiekis veislių 'Kovas DS', 'Zunda DS', 'Kaskada DS' ir 'Vikaras DS' kviečių grūduose buvo atitinkamai 11,3, 11,9, 11,9, 10,9 %, glitimo kiekis – 21,6, 22,7, 20,1, 20,6 %, sedimentacija – 32,9, 38,3, 22,9, 33,6 ml, kritimo skaičius – 337, 340, 348, 372 s. Visų veislių kviečių grūdai pasižymėjo vidutine kokybe ir mažu amilazių aktyvumu, o tai labai svarbu juos auginant drėgno klimato šalyse. Miltų tešlos tyrimai Brabenderio faringrafu parodė, kad veislių 'Kovas DS', 'Zunda DS', 'Kaskada DS' ir 'Vikaras DS' kviečių grūdų tešlos kokybė vertinama atitinkamai 30,4, 35,0, 19,2 ir 27,4 Brabenderio vienetų. Duonos, iškeptos iš 250 g miltų, išeiga veislės 'Kovas DS' kviečių grūdų gauta 1100, 'Zunda DS'– 1180, 'Kaskada DS' – 1220, 'Vikaras DS' – 1210 cm^3, o bendras kepinio įvertinimas buvo atitinkamai 338, 368, 459 ir 440 balų. Tai reiškia, kad naujų didelio derlingumo veislių kviečių grūdai tinkami duonai kepti ir pasižymi vidutinėmis ar geromis kepimo savybėmis.

Reikšminiai žodžiai: *Triticum aestivum*, veislės, agronominiai požymiai, grūdų kokybė.