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THE IMPACT OF SOWING TIME ON SUGAR CONTENT AND SNOW MOULD DEVELOPMENT IN WINTER WHEAT

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Accumulation of carbohydrates in winter wheat during autumn is closely related to winter hardiness of winter wheat and their resistance against snow mould. The aim of the present investigations was to determine how the sowing time of wheat influences accumulation and utilisation of carbohydrates and incidence of snow mould. Investigations were carried out at the Study and Research farm "Peterlauki" of the Latvia University of Agriculture from 2005 to 2007. Four different dates of wheat sowing were compared. During the years of study, temperatures in autumn and first half of winter were milder in comparison to the average long-term data. The sugar content before winter was the highest (average data) in early sown wheat as they had more time to accumulate carbohydrates. The content of carbohydrates decreased gradually depending on the sowing time – the later the sowing time, the lower the carbohydrate content. However, towards spring, differences in the amount of sugar decreased, and the average sugar content in wheat became similar regardless of the sowing time. Pink snow mould caused by *Microdochium nivale* was observed in all investigation years. The lowest incidence of snow mould was registered in the late sown wheat.

Key words: carbohydrates, *Microdochium nivale*, hardiness, winter resistance, winter wheat

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INTRODUCTION

Winter wheat is one of the most widespread and economically beneficial crops in Latvia; it covers approximately 41% of the total cereal fields. Winter hardiness and survival of plants during winter are important factors that determine the yield of wheat in regions with cold winters and consistent snow cover. These factors include tolerance against different unfavourable conditions such as frost, lack of oxygen, ice coat, etc. Development of snow mould is also related to winter hardiness.

Snow mould is a common disease of winter crops in moderate and cold climate areas. Low temperature and darkness under snow cover interrupt photosynthesis; thus, by respiration plants deplete their reserves and become more susceptible to snow mould (Matsumoto 2009, Serenius et al. 2005). Different fungi have been reported as a causal agent of snow mould; however, in Latvia only *Microdochium nivale* (Fries) [Samuels & Hallett, previous term *Fusarium nivale*, teleomorph *Monographella nivalis* (Schaffnit) E. Müller] and fungi of genus *Typhula* have been identified.

Cold hardening of wheat in autumn is needed in order to improve wheat winter hardiness. Low temperatures induce accumulation of carbohydrates, proteins and other chemical substances in the tissues of wheat (Javadian et al. 2010, Hanslin, Mortensen 2010). Accumulation of soluble carbohydrates in winter wheat during autumn influences winter hardiness of wheat and their resistance against snow mould (Gaudet et al. 1999). A correlation between accumulation of carbohydrates and snow mould resistance has been identified. Varieties that are more resistant to snow mold accumulate higher levels of soluble carbohydrates and metabolise them at a slower rate than susceptible varieties (Gaudet et al. 2001). In comparison with non-infected bluegrass kept under conditions of artificial inoculation, the content of soluble carbohydrates was lower in annual bluegrass infected with *M. nivale*. The amount of carbohydrates is fluctuating among varieties with different levels of resistance against snow mould. It is possible that sugar content is lower in plants that need more resources to defend themselves against pathogens, as well as it might be reduced by a pathogen that uses sugar for nutrition. In general, wheat varieties that are more resistant against *M. nivale* have higher frost resistance (Bertrand et al. 2011).

In tests on timothy and perennial ryegrass, no correlation between carbohydrate content and frost resistance has been identified. However, it has been found that late sown plants are more frost resistant. The different results obtained by different researchers could be explained by diverse strategies used in testing the resistance of different crops and varieties (Østrem et al. 2009).

Snow mould resistance is significantly increased by cold hardening of a plant, and it is necessary to achieve its maximum level. The prolongation of cold-hardening period has gradually decreased the intensity of pink snow mould under conditions of artificial inoculation (Golebiowska, Wedzony 2009). Similar results have been reported by Gaudet et al. who have observed that cold hardening (about 2°C) for a period of 1-6 weeks increased resistance against snow mould caused by *Microdochium nivale* and *Typhula spp*. (Gaudet et al. 2011).

It is known that the sowing time influences plant development in autumn and plant winter hardiness. Late sowing time decreases incidence of snow mould. A significant correlation among varieties, their location, and sowing time has been identified. The number of rye tillers per plant differs depending on the sowing time, and incidence of snow mould has a strong positive correlation with the number of tillers. In addition, the height of seedlings and the number of leaves per plant have influence on cereal damages during winter (Serenius et al. 2005). The size of the wheat plant influences survival rate and ability of plants to recover: large crowns survive and produce more wheat, but small wheat from late seedlings escape infections (Bruehl, Cunfer 1971).

Development of snow mould in winter crops has been observed sporadically in Latvia. Therefore it is not a serious problem, especially for winter wheat sown under an intensive management regime. Escalation of this disease (caused by *M. nivale*) was identified in the 2005 – 2007 investigations in Latvia (Ruza, Bankina 2008).

The aim of the present investigations was to determine how the wheat sowing time influences accumulation and utilisation of carbohydrates and development of snow mould.

MATERIALS AND METHODS

A three-year field study (2005 – 2007) of winter wheat was conducted at the Study and Research farm "Peterlauki" on silt loam brown lessive soil (sod calcareous). Three winter wheat varieties ("Zentos", "Cubus", and "Tarso") were sown in four replications on 4 different dates with a 10-day interval from the end of August till the end of September (30.08±2, 10.09±2, 19.09±2, and 29.09±2). A certified and treated seed material was used. Seeds were sown at the depth of 3 – 4 cm. Fertilisation included application of P_2O_5 (60 kg ha^{-1}) and K_2O (90 kg ha^{-1}). In spring, split nitrogen top dressing was used – 150 kg ha^{-1} of N, of which 90 kg ha^{-1} after the beginning of wheat vegetation and 60 kg ha^{-1} at the beginning of stem elongation stage.

Winter wheat was sampled by cutting off the surface part of plants in autumn (at the end of vegetation season), in the period of wintering (last days of January and first days of February), and in spring (after the beginning of wheat vegetation). Samples were analysed for sugar content. Sampling dates differed among the study years due to different meteorological conditions. Therefore, in the period of 2004/2005 and 2005/2006, autumn samples of winter wheat were taken in the second ten-day period of November, but in the period of 2006/2007 – at the end of the first ten-day period of December. In the latter period, the growing season in spring started extremely early – already on March 12, whereas in other study years the growing season started at the beginning (in 2005) or at the end (in 2006) of the second ten-day period of April. Sugar content was tested at the Analytical Laboratory for Agronomy Research of the Latvia University of Agriculture using the standard Luff-Schoorl method (LVS 252: 2000), according to which reducing sugars are expressed as invert sugar or glucose equivalent. This method is based on iodine titration of excess copper.

Incidence of snow mould was tested at the beginning of wheat vegetation. Incidence of snow mould (% of damaged plants) and causal agent was identified by disease symptoms on the plants and morphological peculiarities of conidia.

Sowing of winter wheat was performed in four terms. The period from sowing (germination) till the end of autumn vegetation was by 10 days shorter for each subsequent portion of sown wheat. Thus, overwintering for winter wheat with different sowing dates started at different stages of plant development. During the study years, meteorological conditions in the autumn-winter period differed considerably (Fig.1). The mean ten-day temperature of September was close to the long-term average, but in October 2005 and particularly in October 2006, the mean air temperature of some ten-day periods was 1.5 to 2 times higher than the long-term average. Also in November and December the temperatures were fluctuating. Only in the year of 2004, temperature in November (with insignificant deviations) was close to the long-term average, and plant vegetation ended later (in the middle of the first ten-day period of November) in comparison with the long-term average (at the end of the last ten-day period of October). However, till the end of the second ten-day period of January, the air temperature was varying between -4.5°C and +3.5°C, and only starting from the end of January a stable wintering period, with the lowest mean temperature of -9.5°C in the first ten-day period

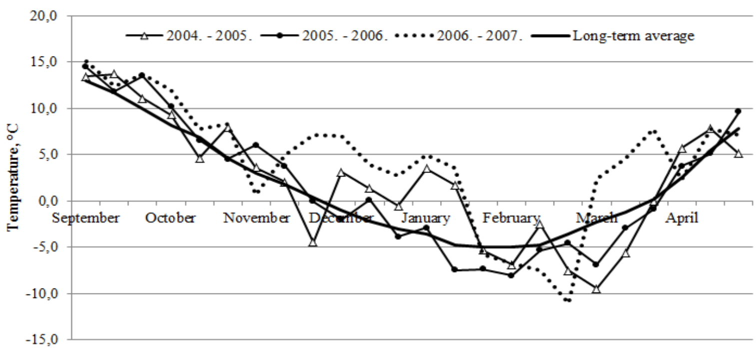


Fig. 1. The average temperature of ten-day periods during overwintering.

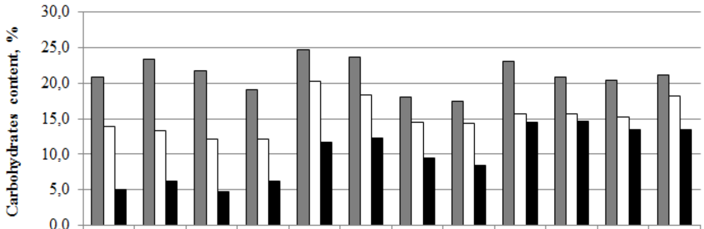
of March, set in. Already from the third ten-day period of March the weather became warmer, and vegetation was renewed on April 8 – 10. In the 2004/2005 wintering period, no serious winter damage for wheat was observed.

The beginning of November 2005 was very warm. In the first ten-day period, the mean air temperature was two times higher (+6°C) than the long-term average. However, later the temperature started to decrease gradually, and already in the middle of the second ten-day period the vegetative growth of plants ended. In the subsequent period of wintering, short periods of thaw were observed and frost reached its lowest temperature, -8.1°C, in the first ten-day period of February. Till the beginning of April, temperature remained below zero. The first ten-day period of April was comparatively cold – the air temperature was close to long-term average. In the year 2006, vegetation of wheat was resumed on April 20 – 21, which was some days later than the long-term average data.

The wintering period of 2006/2007 significantly differed from that in the previous years as well as from the long-term average. The growing season continued till mid-December; however, the temperature remained above zero until the third ten-day period of January and reached its mean value of +5.0 °C in the first ten-day period of January. The long autumn vegetation period, which was comparatively rich in precipitation, had a significant influence on the growth and development of winter wheat resulting in vigorous tillering and strong overgrowth of the plants sown on the first and, though partly, also on the second sowing date, particularly for winter wheat variety "Cubus". Only during the third ten-day period of January, the temperature dropped below zero and later, in the third ten-day period of February, reached -11.1 °C. In March, a comparatively warm weather set in considerably exceeding the long-term average temperature. Vegetation started rather early, on March 25 – 26, which was almost a month earlier than in the previous year.

RESULTS

The lowest sugar content (20.8%) in autumn was detected in wheat sown on the first sowing date of the 2004/2005 investigations (Fig. 2). In plants sown on the second sowing date it reached 23.3%, but in plants sown on each succeeding sowing date the amount of sugar was by almost 2% lower. During that season unstable meteorological conditions prevailed with temperature fluctuations from -4.5 °C to +3.5 °C till the end of the second ten-day period of January, which significantly influenced deviations in the sugar content of plants. Already in mid-winter, sugar content in the plants sown on all sowing dates was by 7% (the first sowing date) to 10% (the second sowing date) lower, but in spring it varied only from 4.8% (the third sowing date) to 6.2% (fourth sowing date). In spring, the amount of sugar in plants sown on the first sowing date was only 24.1% of the initial sugar content registered in autumn (Table). The lowest percentage of sugar



	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
	sowing time 2005				sowing time 2006				sowing time 2007			
autumn	20,8	23,3	21,7	19,1	24,7	23,7	18,1	17,5	23,1	20,9	20,4	21,1
winter	13,8	13,3	12,1	12,1	20,2	18,3	14,5	14,3	15,7	15,7	15,2	18,2
spring	5,0	6,1	4,8	6,2	11,7	12,3	9,4	8,4	14,5	14,6	13,4	13,4

Fig. 2. The content of carbohydrates depending on the year and the sowing time.

Table 1. The content of residual carbohydrates in spring in comparison to the carbohydrate content in autumn, %

Sowing dates	2005	2006	2007
30.08±2	24.1	47.5	62.6
10.09±2	26.3	51.7	70.0
19.09±2	22.1	52.2	65.5
29.09±2	32.5	48.1	63.5

losses was identified among plants sown on the fourth sowing date: 32.5% of the initial sugar content registered in autumn.

In the period of 2005/2006, the warm weather in October and November had a positive effect on sugar accumulation in wheat. As the growing season ended already in the second ten-day period of November (close to long-term average), during this season a correlation between sugar content and sowing date was observed – the highest sugar content (24.7%) was registered in plants sown on the first sowing date. The amount of sugar gradually decreased to 17.5% in plants sown on the fourth sowing date. During that year, vegetation began comparatively late, which, in its turn, essentially influenced the sugar content in plants in spring. This suggests that the greatest reduction in sugar content was registered in the period from mid-winter till the beginning of wheat vegetation, namely, 8.5% in the wheat sown on the first sowing date; however, in plants sown on each subsequent sowing date only a slight reduction was observed – down to 5.1% in the wheat sown on the third sowing date. In comparison to sugar content registered in autumn, the sugar content in spring dropped to 47.5% in the wheat sown on the first sowing date, and to 52.2% in the wheat sown on the third sowing date.

As in the wintering period of 2006/2007 the growing season continued till mid-December, no considerable differences in sugar content among plants sown on different dates were identified, with the exception of plants which were sown on the first sowing date and had a slightly higher sugar content. As the plants sown on the first sowing date were overgrown and had vigorous tillering, the sugar content in them decreased by 7.4% till mid-winter, but in other plants – by 3% – 5%. In mid-winter, the sugar content in all plants, regardless of the date on which they were sown, was almost equal. An early start of the vegetation season delayed utilization of sugars. For all sowing dates, the amount of sugar in wheat ranged between 13.4% and 14.5%, but from mid-winter till spring it reduced by 1% – 2%. Therefore, in spring 2007, sugar content in wheat still varied within 65% – 70% of the sugar registered in autumn.

On average, during all three study years, the highest sugar content (22.9%) in winter wheat before the beginning of wintering was registered in plants sown on the first sowing date, which could be associated with the considerably long vegetation period in autumn (Fig. 3). Similar results were obtained also for wheat sown on the second sowing date, but the amount of sugar in plants sown on the third and fourth sowing date was by 2.5% lower. During wintering, sugar content decreased by 6.3% in plants sown on the first sowing date, but by the beginning of wheat vegetation in spring it decreased by 6.2% more. Thus the total decrease in sugar content in the period from autumn till spring was 12.5%. A similar trend was observed also among plants sown on other sowing dates. For all plants the average decrease in sugar content in the period from autumn till mid-winter was 6.1%, and in the period from mid-winter till spring – 5.3%, which resulted in the total reduction in sugar by 10.4%. However, in the period from wintering till the beginning of wheat vegetation in spring the differences in sugar content among plants sown on different sowing dates levelled out, and in spring the amount of sugar was almost similar in all plants regardless of their sowing date.

Assuming that sugar content in autumn samples was 100%, it was calculated that in mid-winter it had decreased to 70 – 75% (Figure 4). In spring, in comparison with the sugar content in autumn, these values as well as the relative amount of sugar were similar in all plants regardless of their sowing date, i.e., 45 – 49%.

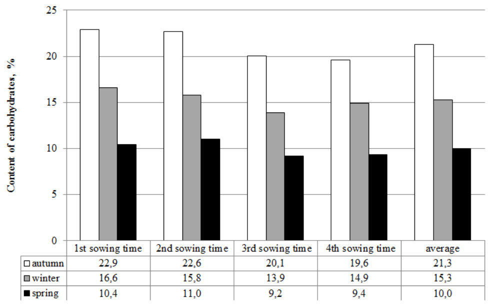


Fig. 3. The content of carbohydrates depending on the sowing time.

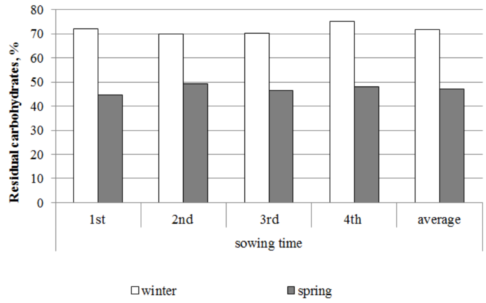


Fig. 4. The average content of residual carbohydrates in comparison with the carbohydratecontent in autumn (2005-2007).

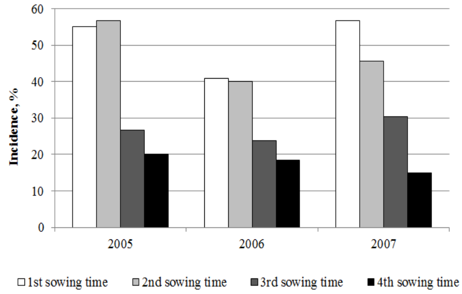


Fig. 5. Incidence of snow mould depending on the year and the sowing date.

The researches suggest that in Latvia snow mould could be caused by several fungi; however, during our investigations only pink snow mould caused by *Microdochium nivale* was identified. Overwintering conditions during the study years significantly influenced the incidence of snow mould, which varied from 15% to 57% depending on the year and time of sowing (Figure 5). The highest incidence of snow mould was observed among early sown wheat (41 – 57%), the lowest – among wheat sown on later dates (only 15 – 20%).

Correlation between the spread of snow mould and the sugar content in plants in different periods of wintering was not identified.

DISCUSSION

It is important for plants to be normally tillered but not overgrown in autumn and to have sufficient plant reserves. Equally, the choice of proper sowing time is closely related to unpredictable meteorological situation. Stupnikova et al. have found a correlation between development of wheat and survival of plants: plants with one or two tillers or at the stage of three leaves survive much better than the plants sown earlier (Stupnikova et al. 2002).

Changes in the content of carbohydrates in plants influence plant winter hardiness. These changes differ among varieties, as well as depend on meteorological conditions and agronomical practices. The same as in our investigations, also other researches have revealed that sugar content in winter wheat sown on different dates levelled out in spring, i.e., if sugar content in November was markedly varying among plants sown on different dates, then till spring it became similar, but differences between varieties remained (Hanslin, Mortensen 2010). As earlier sown plants were more tillered and sometimes even overgrown (2006/2007), in inconsistent wintering conditions under high densities they used considerably more nutrients. The conclusions of Hanslin and Mortensen also suggest that plants having longer stems are less frost hardy in winter (Hanslin, Mortensen 2010).

According to various studies, the sugar content significantly increases winter hardiness of plants; however, there are studies that reveal opposite results. The results of research conducted by Hanslin and Mortensen do not state a significant correlation between sugar content and winterkill of stems. Research findings from their previous studies confirm that increased air temperature in autumn results in lower frost resistance. The authors have found that the height and development stage of wheat during overwintering were more significant than the sugar content because longer plants had a longer period of frost hardening (Hanslin, Mortensen 2010). Similar results were obtained also in our study. Plants rich in the above-ground biomass used considerably more sugar to support their functioning in the period of wintering. In spring, when vegetation began comparatively early, plants had preserved more sugar from the amount accumulated during autumn, in comparison with spring when vegetation began late.

Some authors (Gaudet 1994; Gaudet et al. 2003) have reported an increase in resistance to snow mould due to sugar accumulation in plants in autumn. The spread of snow mould is associated with warm weather conditions in autumn as plants lack frost hardening. Gradual reduction in sugar content in winter and an early start of winter season are favourable for plant infection with snow mould. Excess of sugar in spring might be significant for the survival of winter crops. Results of different studies suggest that snow mould resistance is induced in low temperatures (close to degrees below zero) in autumn and early winter. Non-hardy plants are susceptible to snow mould (Gaudet et al. 2003, Gaudet 2011). However, the results obtained in our study give no evidence that sugar accumulation in autumn might increase the wheat resistance to snow mould. The highest sugar content during all study years was determined for wheat obtained from early sowings, and just these plants had mostly suffered from the snow mould infection. No correlation between the sugar content in plants and the spread of snow mould was identified. According to the results reported by other authors (Hanslin, Mortensen 2010), sugar content in plants is not a determinant factor in the spread of snow mould, but it is mainly the conditions of a plant at the end of wheat vegetation in autumn – developmental stage, length, intensity of tillering (sward density), and conditions of wintering – that determine the spread of snow mould.

The development of pink snow mould may be a result of insufficient hardening (Serenius 2005) due to warmer autumn than average. Pink snow mould caused by *M. nivale* was detected during all study years, and it corresponds to the findings reported by other authors, namely, that snow mould caused by *M. nivale* is characteristic of moderate climate zones where the snow blanket frequently covers the earth for less than 70 days and the soil is usually unfrozen (Gaudet et al. 2011).

CONCLUSIONS

The results of this study indicate that sugar content in autumn before the end of vegetation is the highest for early sown winter wheat, but it slightly decreases with each succeeding date of sowing. Differences in sugar content among plants sown on different dates depend on the length of autumn season and fluctuations in temperature during that period. Sugar content and its changes in the growing season depend mainly on wintering conditions. Although sugar content in plants in spring differs considerably each year, differences in the sugar content in the plants, sown on different dates and within one year, almost completely level out and are slight.

Pink snow mould caused by *Microdochium nivale* (Fries) (Samuels & Hallett, previous term *Fusarium nivale*, teleomorph *Monographella nivalis* (Schaffnit) E. Müller) was identified. Incidence of snow mould fluctuated between 15 – 75%.

Correlation between sugar content in plants and presence of snow mould in different periods of wintering was not identified. The spread of snow mould is directly related to the time of sowing and mainly depends on plant (stem) height, stage of development, and density of sward – vigorously tillered and particularly overgrown plants in swards create favourable conditions for the spread of snow mould.

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REFERENCES

Bertrand A., Castonguay Y., Azaiez A., Hsiang T., Dionne J. 2011. Cold-induced responses in annual bluegrass genotypes with differential resistance to pink snow mold (Microdochium nivale). Plant Science, 180: 111–119.

Bruehl G. W., Cunfer B. 1971. Physiologic and environmental factors that affect the severity of snow mould of wheat. Phytopathology, 61:792-799.

Gaudet D.A., Wang Y., Frick M., Puchalski B., Penniket C., Ouellet T., Robert L., Singh J., Laroche A. 2011. Low temperature induced defence gene expression in winter wheat in relation to resistance to snow moulds and other wheat diseases. Plant Science, 180: 99-110.

Gaudet D.A., Laroche A., Frick M., Huel R., Puchalski B. 2003. Plant development affects the cold-induced expression of plant defence-related transcripts in winter wheat. Physiological and Molecular Plant Pathology, 62: 175-184.

Gaudet D.A., Laroche A., Puchalski B. 2001. Seeding Date Alters Carbohydrate Accumulation in Winter Wheat. Crop Science, 41(3): 728 - 738.

Gaudet D.A., Laroche A., Yoshida M. 1999. Low temperature-wheat-fungal interactions: A carbohydrate connection. Physiologia Plantarum, 106(4): 437-444.

Gaudet D.A. 1994. Progress towards understanding interactions between cold hardiness and snow mould resistance and development of resistant cultivars. Canadian journal of plant pathology, 16:241-246.

Golebiowska G., Wedzony M. 2009. Cold hardening of winter triticale (X Triticosecale Wittm.) results in increased resistance to pink snow mould Microdochium nivale (Fr., Samuels&Hallett) and genotype-dependent chlorophyll fluorescence modulations. Acta Physiology Plant, 31 1219-1227.

Hanslin H.M., Mortensen L.M. 2010. Autumn growth and cold hardening of winter wheat under simulated climate change. Acta Agriculturae Scandinavia Section B – Soil and Plant Science, 60: 437-449.

Javadian N., Karimzadeh G., Mahfoozi S., Ghanati F. 2010. Cold induced changes of enzymes, proline, carbohydrates, and chlorophyll in wheat. Russian Journal of Plant Physiology, 57(4):540-547.

Matsumoto N. 2009. Snow molds: a group of fungi that prevail under snow. Microbes Environments, 24 (1): 14-20.

Østrem L., Rapacz M., Jørgensen M., Hoglind M. 2009. Impact of frost and plant age on compensatory growth in timothy and perennial ryegrass during winter. Grass and Forage Science, 65:15–22.

Ruza A., Bankina B. 2008. Development of snow mould in Latvia. Proceedings of 10th Congress of the European Society for Agronomy. Italian Journal of Agronomy. 3(3):709-710.

Serenius M., Huusela-Veistola E., Avikainen H., Pahkala K. 2005. Effects of sowing time on pink snow mould, leaf rust and winter damage in winter rye varieties in Finland. Agricultural and Food Science, 14: 362-376.

Stupnikova V., Borovskii G. B., Dorofeev N. V., Peshkova A. A., Voinikov V. K. 2002. Accumulation and disappearance of dehydrins and sugars depending freezing tolerance of winter wheat plants at different developmental phases. Journal of Thermal Biology, 27 (1): 55-60.

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