The effect of planting date on winter rye and triticale overwinter survival and yield in Eastern Siberia

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Abstract. A field experiment was conducted at an agro-ecological station (53 ° 33’58.75" N and 102 ° 35’23.90" E) of the Siberian Institute of Plant Physiology and Biochemistry on gray forest medium loam soil. Winter rye (family 6) and winter triticale (No. 430-6002) were sown in 4 terms with a 10-day interval (10, 20, 30 August and 10 September) in three replications. The results of the two-year studies show that the winter crops included in the experiment had a higher (higher than 5 t/ha) and more stable yield between the years with the planting dates held on August 20, 30 and September 10 for rye and August 30 and September 10 for triticale. Earlier sowing time contributed to intensive tillering, strong growth, which led to the plant death and lower yields.

Plant survival in winter, which is due to resistance to various adverse conditions, such as low temperatures, lack of oxygen, ice cover, the freeze-thaw cycle, is an important factor determining the yield of winter crops, especially in regions with harsh winters. Winter rye (Secale cereale L.) and winter triticale (×Triticeosecale Wittmack) are among the most winter tolerance crops grown for the production of food and feed grains in Eastern Siberia. The yield of crops depends on the parameters of agrotechnical measures intended for a specific agro-climatic region. The planting date plays an important role in the complex of processing methods to get in autumn developed plants capable to survive in harsh winter conditions. Optimal dates for autumn sowing of winter cereal crops provide plants capable of achieving maximum cold resistance, full vernalization, and optimal energy reserves [3, 5].

Problems associated with winter crops yield can be caused by insufficient winter tolerance of plants under the influence of adverse meteorological conditions of the autumn and winter periods. Climate changes significantly affect the growth and development of winter crops [8, 7]. Changes in climatic patterns (temperature and precipitation) leads to a change in growth and development of winter crops in autumn. For example, in the warm and moist long autumn, plants grow and become unstable to pathogens and adverse environmental factors of the winter period, which reduces the level of overwintering [4, 9]. A short period of autumn growth leads to less developed plants, while reducing winter tolerance and yield. For each agro-climatic region, specific timeframes for planting winter crops are optimal. For example, in many climatic regions of the United States and Canada, a decrease in grain yield was observed when non-compliance with the recommended planting dates [2, 6]. To obtain high grain yields, the sowing of winter cereals in the southern regions of Canada should be from August 15 to September 1 [3], and in the northern regions from August 12 to September 7 [1].
The purpose of the current research was to determine the level of overwintering and yields of winter rye and triticale in conditions of Eastern Siberia at different planting dates.

The field experiment was conducted during 2016/17 and 2017/18 at the Zalarinsky agro-ecological station of the Siberian Institute of Plant Physiology and Biochemistry (53 ° 33'58.75 "N and 102 ° 35'23.90" E). Winter rye (fam. 6) and triticale (No. 430-6002) were planted in four sowing dates (August 10, August 20, August 30 and September 10), with a seeding rate of 7 mio of grains per hectare for rye and triticale. The depth of sowing of seeds is 5-6 cm. The soil is gray forest medium loam: Сtot = 2.6-3.3 %%, Ntot = 0.22–0.32%, pH = 5.8–6.0, total exchangeable bases is 23.2–28.4 mg-eq/100g. Experiments were carried out in three replications.

In the autumn period, meteorological conditions for growth and development of winter crops (rye and triticale) by the years of sowing did not significantly differ in the number of days before the temperature passes 10°C. On the contrary, the periods of temperature changes ranging from 5°C to 0°C and minus 5°C differed significantly (table 1). When the average daily temperature passes 5°C, the process of winter crops adaptation to low temperature begins. The autumn period with a range of average daily temperatures from 5°C to 0°C is considered the first phase of hardening and from 0°C to minus 5°C is the second phase of hardening.

**Table 1.** The characterization of the autumn period for winter crops growth and development.

| Characteristics                                                                 | Years 2016 | Years 2017 |
|--------------------------------------------------------------------------------|------------|------------|
| The number of days from sowing average daily total active air temperatures passing >10 °C | 43         | 41         |
| The number of days from sowing to average daily air temperature ranging from 5°C to 0°C | 9          | 19         |
| The number of days from sowing to average daily air temperature ranging from 0°C to minus 5°C | 19         | 31         |

To determine the statistical significance of the differences between the mean values of the variants (at P ≤ 0.05), Kruskal Wallis test was used, followed by a Student-Newman-Keuls multiple test method using SigmaPlot 12.5.

One of the main reasons for the reduction in winter crops yields is their death during the winter period. To achieve maximum tolerance, it is important that the seeds are sown at a certain time; this determines their development level before winter comes with the optimal number of tillers, which varies greatly from 2 to 5, depending on the crop, variety and other factors [11, 12]. So Stupnikova I V [10] found a correlation between the development of winter wheat and its overwintering under conditions of Eastern Siberia: plants with one - two shoots or at the three-leaf stage survive much better than more developed plants that were sown earlier. In our experiment in the autumn period, the winter crops of early sowing dates (August 10) reached the tillering stage - 3-4 shoots, the second term (August 20) - 2 less often 1 shoots, the third term - three leaves and the fourth term - two leaves.

The number of survived plants varied to a large extent from the species of the crop and slightly during the years of observation. In 2017, the maximum survival of winter rye when sown on August 20-30 and September 10 was higher than 90%. With earlier sowing on August 10, winter hardiness decreased to 70% (figure 1).
Figure 1. The effect of planting dates on the survival of winter rye (A, B) and triticale (C, D). A - C - 2016/17, B - D - 2017/18. Data is presented as a median, bars indicate 75% and 25% percentiles. Different letters indicate statistically significant differences at $P \leq 0.05$. Identical letters indicate variants between which no statistically significant differences were found.

In 2018, the survival of winter rye in planting dates (August 30 and September 10) reached 90%, and in earlier periods (August 10 and 20), this parameter was 80% or less. For all planting dates, the winter resistance of winter rye was significantly higher compared to triticale. Triticale showed a high level of winter tolerance during the late sowing on August 30 and September 10, 80 and 98%, respectively (figure 1). When sowing on August 10 and 20, the survival of triticale plants was significantly lower ($P<0.05$) than during the late sowing, both in 2017 and in 2018.

High grain yield was obtained at the later sowing of winter rye (September 20, 30 and 10), due to the high number of surviving plants (figure 2).
### Figure 2.
The effect of planting dates on the winter rye (A, B) and triticale (C, D) yield. A - C - 2016/17, B - D - 2017/18. Data is presented as a median, bars indicate 75% and 25% percentiles. Different letters indicate statistically significant differences at $P \leq 0.05$. Identical letters indicate variants between which no statistically significant differences were found.

In 2017, the maximum yield of winter rye was obtained with the planting dates of August 20, 30 and September 10. Triticale had the highest grain yield at the planting dates on August 30 and September 10. In 2018, the yield reached 5.8 t/ha for winter rye during late sowing (September 10), although there were no significant differences between the planting dates of September 10 and August 30. For winter triticale, the yield was higher than 5 t/ha when sowing on August 30. However, no significant differences were found between the 3rd and 4th sowing dates. With early sowing (August 10), the winter rye yield decreases to 4 t/ha and lower; for triticale, when sowing on August 10 and 20, it was 0.8 and 3.6 t/ha, respectively.

On average, over two years of research, the data obtained showed that winter rye had the high level of winter tolerance and grain yield when sown on August 20, 30 and September 10, and when sown on August 10, these indicators were lower. For triticale, the high number of surviving plants and the large yield were observed at later sowing dates (August 30 and September 10). Although the weather conditions for the autumn periods differed from one year to another, the response of plants in different years to the planting dates was the same.

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