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ВЛИЯНИЕ УСЛОВИЙ ОСЕННЕЙ ВЕГЕТАЦИИ НА ПЕРЕЗИМОВКУ ОЗИМОЙ РЖИ И ПШЕНИЦЫ ПРИ РАЗНЫХ СРОКАХ ПОСЕВА

(✉) **Ермошкина Н.Н., Артёмова Г.В., Стёпочкин П.И., Сурначев А.С., Мусинов К.К.**
Сибирский научно-исследовательский институт растениеводства и селекции – филиал Федерального исследовательского центра Института цитологии и генетики Сибирского отделения Российской академии наук
Новосибирская область, р.п. Краснообск, Россия
(✉) e-mail: natali.erm@bk.ru

Изучено влияние условий осенней вегетации на рост, развитие и перезимовку растений озимой пшеницы и ржи при разных сроках посева. Работа выполнена в 2016–2019 гг. в условиях лесостепи Приобья. Материалом исследований служили сорта тетраплоидной озимой ржи Влада и Тетра короткая и сорта озимой пшеницы Новосибирская 40 и Новосибирская 3. Посев проведен в три срока: 1-й – 23 августа, 2-й –31 августа и 3-й – 7 сентября по чистому пару. Выбор оптимального срока посева создает благоприятные условия для роста и развития озимых культур и подготовки их для дальнейшей перезимовки. Согласно проведенным исследованиям отмечено, что интенсивность осеннего побегообразования и роста растений в большей степени зависит от продолжительности периода осенней вегетации. Снижение темпов роста и образования побегов кущения от 1-го срока посева к 3-му связано со снижением суммы эффективных температур. При посеве в поздние сроки сумма эффективных температур по годам варьировала в диапазоне 90–197°. При этом перезимовка озимой ржи сохранялась на уровне 94–100%, в то время как у озимой пшеницы она снизилась до 40%. Лучшим вариантом, обеспечивающим стабильность зимней устойчивости, является 2-й срок посева (31 августа) при сумме эффективных температур 250–300°, растения формируют 3–4 побега кущения, высота растений достигает 18–25 см. Озимая рожь опережает озимую пшеницу как по темпам осеннего роста и побегообразования, так и по развитию конуса нарастания.

Ключевые слова: озимая рожь, озимая мягкая пшеница, сроки посева, продолжительность осенней вегетации, сумма эффективных температур, перезимовка

EFFECT OF AUTUMN VEGETATION CONDITIONS ON OVERWINTERING OF WINTER RYE AND WHEAT WITH DIFFERENT SOWING DATES

(✉) **Ermoshkina N.N., Artyomova G.V., Stepochkin P.I., Surnachev A.S., Musinov K.K.**
Siberian Research Institute of Plant Growing and Breeding – Branch of the «Federal Research Center the Institute of Cytology and Genetics» of the Siberian Branch of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk region, Russian
(✉) e-mail: natali.erm@bk.ru

The research was carried out in order to study the effect of autumn vegetation conditions on the growth, development and overwintering of winter wheat and rye depending on different sowing dates. The work was performed in 2016–2019 in the conditions of the forest-steppe of the Ob region. The research material included the varieties of tetraploid winter rye Vlada and Tetra short and winter wheat varieties Novosibirskaya 40 and Novosibirskaya 3. Sowing was carried out on three dates: 1st – 23 August, 2nd – 31 August and 3rd – 7 September under bare fallow. The choice of the optimal sowing time creates favorable conditions for the growth and development of winter crops and their preparation for further overwintering. According to the studies, it was noted that the intensity of autumn shoot formation and plant growth to a greater extent depends on the duration of the autumn growing season. A decrease in the plant growth rate and formation of tillering shoots from the first sowing date to the third date was associated with a decrease in the sum of effective temperatures. When sowing on a later date, the sum of effective temperatures varied in the range of 90–197° over the years. Under these conditions, overwintering rate of winter rye remained at the level of

94–100%, while in winter wheat it decreased to 40%. The best option, which ensured the stability of winter resistance, was the second sowing date (August 31) with a sum of effective temperatures of 250-300°, whereby the plants formed 3–4 tillering shoots and the plant height reached 18–25 cm. Winter rye outperforms winter wheat in autumn growth rate, shoot formation and in the vegetation cone development.

Keywords: winter rye, soft winter wheat, sowing time, duration of autumn vegetation, sum of effective temperatures, overwintering

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INTRODUCTION

The formation of a trait of winter hardiness of winter crops is greatly influenced by the conditions of autumn vegetation [1, 2]. The period of the initial stages of organogenesis includes the phases of plant development associated with the formation of generative organs, structural and functional rearrangements, changes in the water and carbon balance, which determines the adaptability of plants to overwintering conditions [3].

For a favorable overwintering of winter grain crops, the correct choice of sowing time is necessary, which must correspond to the biological requirements of the crop, take into account the soil and climatic conditions of the autumn vegetation. Against the background of increasing climate instability, expressed in deviations of the temperature regime and the regime of precipitation and in the duration of the autumn growing season from the average long-term values, the variation in the optimal sowing time increases. It is important to study the influence of the duration and temperature conditions of autumn vegetation on the development of plants, which ensure the formation of resistance to the limiting factors of overwintering of winter crops in specific regions of cultivation [4–6].

The limiting factor for the growth processes of winter crops is the temperature regime of the autumn period. A decrease in average daily temperatures at later sowing dates leads to a lag in plant development. Theoretical calculations of the optimal sowing time are related to the sum of positive temperatures in the autumn period from sowing to the end of the growing season. Moreover, the temperature values vary depending on the climatic zone of cultivation [7–11].

Differences in the level of overwintering of varieties and forms of winter crops, along with the temperature conditions of the winter period, are largely due to the intensity of autumn plant growth, the formation of tillering shoots, and the peculiarities of the passage of the stages of organogenesis. For guaranteed overwintering before wintering, winter rye and wheat plants should form, on average, up to 3-4 tillering shoots reaching 2-3 stages of organogenesis

[12].

The connection between the autumn growth processes of plants and their winter hardiness has been repeatedly noted in the works of A.I. Nosatovsky, I.I. Tumanova, F.M. Kuperman, V.A. Moiseichik, Z.A. Morozova and other authors [13–17]. According to A.I. Zadontsev, winter grain plants with optimal sowing times, the height of which is 14–16 cm, are characterized by the maximum frost resistance. Overgrown plants have a height of 23–25 cm and more, the winter hardiness of such plants is reduced[1] [18].

Biological control according to the stages of organogenesis makes it possible, much earlier than with phenological observations, to recognize the unfavorable effect of weather conditions and agrotechnical factors on plants.

Varieties with a high level of winter resistance are needed for sustainable cultivation of winter grain crops in Siberia. Promising varieties of winter wheat and rye have been created through the efforts of Siberian breeders which have high adaptive qualities. The main advantage of Siberian breeding varieties lies in their higher level of ecological stability, since the successful selection of specifically resistant genotypes in the breeding process is possible only under conditions similar to those in which the variety will be cultivated. At the Siberian Research Institute of Plant Growing and Breeding, a branch of the Federal Research Center of the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences the greatest efficiency in the creation of winter wheat varieties with high adaptability and plasticity potential was obtained by the method of recombination selection using interspecific hybridization [19]. Varietal rye populations cultivated in the Siberian region are mainly represented by tetraploid forms, created on the basis of varieties of the Siberian ecotype, combining a high level of winter hardiness with grain size.

The aim of the research is to study the effect of autumn vegetation conditions on the growth, development and overwintering of winter wheat and rye plants at different sowing dates.

MATERIALS AND METHODS

The studies were carried out in the forest-steppe conditions of the Ob region in 2016–2019. The research material was the varieties of tetraploid winter rye Vlada and Tetra short and winter wheat varieties Novosibirskaya 40 and Novosibirskaya 3[2]. Sowing was carried out in three terms: 1st - August 23rd, 2nd - August 31st and 3rd - September 7th for pure fallow in the usual row method with a SSFK-7 seeder with a seeding rate of 5 million seeds / ha for winter rye and 6 million seeds / ha for winter wheat. Plot area 10 m^2, replication five times with a randomized placement of plots.

To conduct counts and observations, we used the methodology of the State Variety Testing of Agricultural Crops[3]. The main mathematical parameters were calculated according to the method of B.A. Dospekhova[4]. During the period of termination of the growing season before the establishment of snow cover, plant samples were taken for laboratory analysis. The linear dimensions of the leaves (the height of the main shoot from the base of the tillering node to the tip of the upper leaf) and the coefficient of tillering (the average number of shoots) were determined. When studying the formation of the growing cone of winter crops, the stages of organogenesis were determined according to F.M. Kuperman[5] using an MBS-9 microscope.

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We selected 10 plants from two repetitions at the end of the autumn growing season. In field conditions, the degree of overwintering of plants was determined as the percentage of the number of overwintered plants (on fixed 6 or 8 plots of 0.25 m^2) to the number of plants that passed away in winter. Meteorological data were obtained by the hydrometeorological station of the village Ogurtsovo (Novosibirsk region).

The weather conditions of the autumn-winter period during the years of scientific research varied significantly. According to long-term data, the end of the autumn growing season in the forest-steppe conditions of the Ob region begins on October 5, when the average daily temperature passes through the 5°C mark towards a decrease. The least favorable conditions for the autumn development of plants developed in 2017, when the end of the growing season was already marked on September 23. The average daily air temperature was 9.2 °C, which is lower than long-term values; the amount of precipitation was close to normal (105%). In 2016, the end of the growing season was marked on September 30, a feature of this year was a significant excess of the average daily September temperatures up to 15-16 °C, relative to the long-term average (10-12 °C) with a total precipitation of 40% of the norm. Autumn 2018 is characterized by a long growing season (until October 14) with an average temperature background (10.8 ° C) and precipitation of 113% to the norm.

In winter, the height of the snow cover varied from 40 to 70 cm from year to year. The maximum height of the snow cover in 2016 was set at 60–65 cm, in 2017 - 65–70 cm, which is 2 times more than the average annual data (30–35 cm). Snow cover in 2018 was 40–50 cm. The minimum temperature at the depth of the tillering node did not drop below minus 5 °C.

Contrasting conditions in 2016–2019 made it possible to evaluate the effect of autumn vegetation on overwintering of plants at different sowing dates in the studied crops.

RESULTS AND DISCUSSION

Over the years of research, the duration of the germination period - the end of the autumn growing season was significantly influenced by two factors: the conditions of the year and the timing of sowing. With the 1st sowing period, carried out at the beginning of the 2nd decade of August, the growth and development of plants continued from 33 days in 2017 to 54 - in 2018.The sum of effective temperatures, respectively, varied in these years from 263 to 351°. In 2016, with a short growth period (up to 38 days), the sum of effective temperatures was 346°, which is explained by high average daily temperatures up to 28 °C during September. The vegetation of plants of the 3rd sowing term lasted from 19 to 36 days, while the sum of effective temperatures varied from 90 to 197 ° over the years (see Table 1).

During the research period, more intensive growth and formation of tillering shoots were noted in winter rye and wheat plants of the 1st sowing period. A decrease in the growing season when sowing in the 2nd and 3rd periods leads to a decrease in the linear growth of plants and a decrease in the number of tillering shoots. These patterns depend on the hydrothermal conditions of the year. In the years with a short growing season (2016, 2017), the height of plants of the 3rd sowing period was recorded 1.5 times less than that of plants sown on August 23 (see Table 2). With an increase in the duration of the autumn growth period, the difference between the plant heights of different sowing dates decreases. In 2018, winter wheat plants of the 1st sowing date had a height of 26.4 cm at the end of the growing season, plants of the 3rd term - 21.6 cm.

The intensity of the process of plant shoot formation in the autumn period is also associated with the duration of the growing season. The largest number of tillering shoots (5.0 and 6.3) was observed in both wheat and rye in 2018 when sown on 23 August, when the growing season was 54 days. When sowing on September 7, 2018, with a reduction in the duration of the growing season associated with the timing of sowing, the number of tillering shoots in rye decreased to 3.9, in wheat - to 3.1. In 2017, plants of the 3rd sowing date in 19

Табл. 1. Сумма эффективных температур и продолжительность вегетационного периода по годам при разных сроках посева озимых культур

Table 1. The sum of effective temperatures and the duration of the growing season by years for different sowing dates of winter crops

Year	Element	Sowing time		
		1-st (23.08)	2-nd (31.08)	3-rd (07.09)
2018	The sum of effective temperatures, degr.	351	250	197
	Number of growing days	54	45	36
2017	The sum of effective temperatures, degr.	263	146	90
	Number of growing days	33	24	19
2016	The sum of effective temperatures, degr.	346	296	167
	Number of growing days	38	31	21

Табл. 2. Высота растений и число побегов кущения в разные сроки посева озимой ржи и пшеницы (2016–2018 гг.)

Table 2. Plant height and number of tillering shoots on different sowing dates for winter rye and wheat (2016–2018)

Sample	Sowing time					
	1-st (23.08)		2-nd (31.08)		3-rd (07.09)	
	Plant height, cm	Shoots number, pcs.	Plant height, cm	Shoots number, pcs.	Plant height, cm	Shoots number, pcs.
			2018			
Rye	29,6 ± 0,9	6,3 ± 0,6	27,1 ± 0,7	5,4 ± 0,4	22,9 ± 0,8	3,9 ± 0,3
Wheat	26,4 ± 1,1	5,0 ± 0,5	21,6 ± 0,6	4,0 ± 0,3	21,6 ± 0,5	3,1 ± 0,2
			2017			
Rye	26,1 ± 0,8	4,9 ± 0,4	18,5 ± 0,5	2,9 ± 0,1	14,8 ± 0,3	1,4 ± 0,2
Wheat	22,3 ± 1,3	4,7 ± 0,6	17,0 ± 0,4	2,7 ± 0,2	13,8 ± 0,3	1,2 ± 0,1
			2016			
Rye	27,5 ± 1,2	5,5 ± 0,5	24,2 ± 1,0	3,7 ± 0,3	18,0 ± 0,5	2,3 ± 0,2
Wheat	33,0 ± 1,3	3,1 ± 0,3	29,6 ± 0,8	2,6 ± 0,2	24,0 ± 0,6	1,3 ± 0,1

days formed an average of 1.4 tillering shoots in rye and 1.2 tillering shoots in wheat.

The processes of linear growth and shoot formation of winter rye and wheat differ in their intensity. Winter rye plants form a more powerful above-ground mass in autumn. So, in 2018, when sowing on 23 August for 54 days of growing season, the height of rye plants was 29.6 cm, in wheat - 26.4 cm, while rye formed 6.3 shoots, and wheat - 5.0. In the third sowing period under low temperature conditions, growth processes and shoot formation slow down significantly both in winter wheat and rye, but the differences between the growth rates of the two crops remain. For 36 days of growing season with a sum of active temperatures of 197°, the linear growth of rye was 22.9 cm, wheat - 21.6 cm, and the number of shoots decreased accordingly (3-4).

In 2017, under conditions of low temperatures

and a short growing season with minimal values of linear growth and shoot formation at all sowing periods, the differences between crops are insignificant. In both rye and wheat, up to 4–5 shoots of tillering were formed during 33 days of growing season in the 1st sowing period, when sowing in the 3rd period, only the beginning of the tillering process was noted.

Under the conditions of an increased temperature background (+3.1 ° C to normal) in 2016, winter wheat in terms of linear growth was significantly ahead of rye. The height of wheat plants at the 1st sowing period averaged 33.0 cm, which is 5.5 cm higher than that of rye. However, the number of tillering shoots in wheat was recorded significantly less and averaged 3.1, while in rye up to 5–6 shoots were formed. The same trend persisted in crops at later dates.

The number of tillering shoots in winter crops is primarily affected by the duration of the autumn growing season. With the sum of effective temperatures of 197 °, an average of 3-4 tillering shoots were formed in 36 days, and only 1-2 shoots were formed during 21 days of vegetation, although the sum of effective temperatures was slightly lower and amounted to 167 °. The processes of linear growth of plants are influenced by the temperature conditions of autumn.

For a more complete study of the development of winter crops in the autumn period, comparative observations of the growth and development of the growing cone were carried out. According to a number of authors, the degree of growth cone development correlates with the level of winter hardiness. The best overwintering was noted in plants where the growing cone reaches the 2nd phase of organogenesis, which coincides with the period of autumn tillering.

A comparative study of two winter crops of wheat and rye revealed significant differences in the rates of autumn development of growing cones. By the end of the autumn growing season, rye was observed to elongate the upper part of the cone and differentiate the base of the cone into segments and leaf ridges, which corresponds to the third stage of organogenesis (see Table 3). The duration of this stage in these studies ranged from 24 (sowing on August 31, 2017) to 54 days (sowing on August 23, 2018) before the end of the growing season. Depending on the temperature conditions of the year, the sizes of the growth cone change, the greatest length (up to 1.11 mm) and enhanced segmentation of the growth cone were noted in

Табл. 3. Размеры конуса нарастания и этапы органогенеза озимой ржи и озимой пшеницы в осенний период вегетации при разных сроках сева (2016–2018 гг.)

Table 3. The sizes of the vegetation cone and the stages of organogenesis of winter rye and winter wheat in the autumn growing season on different sowing dates (2016–2018)

Sample	Sowing time					
	1-st (23.08)		2-nd (31.08)		3-rd (07.09)	
	The vegetation cone size, mm	Organogenesis stage	The vegetation cone size, mm	Organogenesis stage	The vegetation cone size, mm	Organogenesis stage
			2018			
Rye	0,70 ± 0,06	3-rd	0,64 ± 0,04	3-rd	0,46 ± 0,05	3-rd or 2-nd
Wheat	0,31 ± 0,02	2-nd	0,28 ± 0,03	2-nd	0,21 ± 0,01	1-st
			2017			
Rye	0,92 ± 0,12	3-rd	0,68 ± 0,05	3-rd	0,48 ± 0,04	2-nd
Wheat	0,35 ± 0,03	2-nd	0,20 ± 0,02	1-st	0,15 ± 0,02	1-st
			2016			
Rye	1,11 ± 0,15	3-rd	0,86 ± 0,07	3-rd	0,77 ± 0,07	2-nd
Wheat	0,34 ± 0,05	2-nd	0,25 ± 0,02	2-nd	0,22 ± 0,02-й	1-st

2016 at maximum daytime temperatures up to 20 °C. However, the transition to the 4th phase of organogenesis with short daylight hours does not occur until the end of the light stage.

The assessment of winter hardiness of winter rye and wheat plants was carried out in experiments with different sowing dates (see the figure). Overwintering conditions during the years of research were noted to be quite favorable (the soil temperature at the depth of the tillering node did not fall below minus 5 ° C). Thus, the level of winter resistance, along with the hardening conditions, was largely determined by the intensity of autumn growth and development of plants. A great safety of both rye and wheat at all sowing dates was noted in the spring of 2017, when the plants were formed in a short autumn period, but at the same time the sum of effective temperatures reached 167 ° for crops of the 3rd term and 346 ° for crops of the 1st term. The number of tillering shoots varied depending on the sowing time from 2.3 to 5.5 for rye and from 1.3 to 3.1 for winter wheat.

The decrease in the level of overwintering in 2018 can be explained by the less favorable conditions of the winter period and the insufficient duration of the autumn growing season in 2017 (from 19 to 33 days when sowing at different times). In this case, low positive temperatures negatively affected the autumn development of plants, while the number of surviving plants in winter wheat decreased by almost 2 times (to 18%) compared to the previous year. Moreover, late sowing, carried out in the first decade of September, showed greater resistance to overwintering than sowing in early periods. Such results are explained by the higher rates of sugar accumulation in the tillering node of young plants, which allows them to survive more successfully in winter.

The level of overwintering of plants in 2019 was noted to be quite high - up to 83–100% of preserved plants in winter rye and 66–68% in winter wheat. The long period of autumn vegetation (54–45–36 days in terms of sowing) and the sum of effective temperatures (above 197 °) in autumn 2018 contributed to the good development of plants. They formed more than 5 tillering shoots at an early sowing date and 3-4 shoots at sowing on September 7. In rye in crops of the 1st term, the plant height was 29–30 cm, the number of tillering shoots reached 6–7, which led to partial damping off and a decrease in the level of overwintering in comparison with crops of the 2nd and 3rd terms. In all variants of the experiment, the winter hardiness of winter wheat was noted lower than in winter rye by 13-15% in 2017 and by 74-80% in 2018.

CONCLUSIONS

As a result of a comparative study of the initial stages of growth and development of winter crops, it was revealed that the intensity

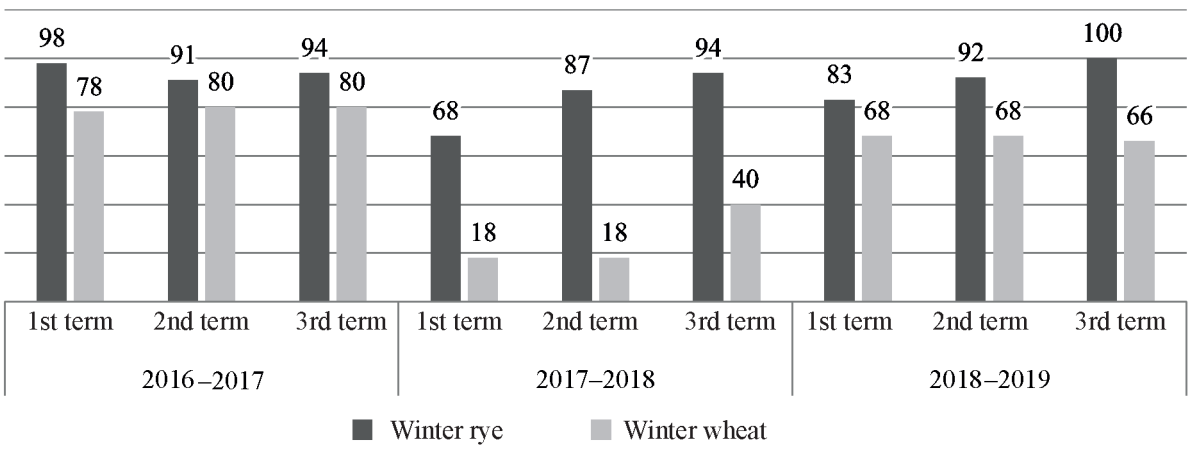

Диаграмма перезимовки озимой ржи и пшеницы при трех сроках посева (2016–2019 гг.), %
Diagram of overwintering of winter rye and wheat on three sowing dates (2016–2019), %

of autumn shoot formation to a greater extent depends on the duration of the growing season. Plants of the 3rd sowing date within 19–21 days of vegetation (2016, 2017) formed only 1–2 shoots of tillering, while during 36 days of vegetation in 2018, 3–4 shoots were formed. The increased temperatures in the autumn of 2016 led to the overgrowth of winter wheat plants by 30–40%, while the process of shoot formation was noted below or at the level compared to 2017.

The sum of effective temperatures in a wide range from 167 to 351 ° C in the autumn of 2016 and 2018 proved to be sufficient for the development of plants of all sowing terms, which ensured a high safety of plants during overwintering in 2017 and 2019. The short period of the autumn growing season from 19 to 33 days (depending on the sowing time) and low temperatures in autumn 2017, along with less favorable winter conditions, led to a significant decrease in the level of overwintering in winter wheat.

No significant differences in the influence of the sowing time on the level of winter rye and wheat overwintering were revealed over the years of research. The conditions of the year had a great influence on overwintering. The best option that ensures the stability of winter resistance is the 2nd sowing date (August 31), when the plants form 3-4 tillering shoots, and their height reaches 18-25 cm.

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Информация об авторах

(✉) **Ермошкина Н.Н.,** аспирант, научный сотрудник; **адрес для переписки:** Россия, 630501, Новосибирская область, р.п. Краснообск, ул. С-100, зд. 21, а/я 375; e-mail: natali.erm@bk.ru

Артёмова Г.В., кандидат биологических наук, заместитель руководителя по научной работе

Стёпочкин П.И., доктор сельскохозяйственных наук, ведущий научный сотрудник

Сурначев А.С., аспирант, младший научный сотрудник

Мусинов К.К., аспирант, младший научный сотрудник

Author information

(✉) **Natalia N. Ermoshkina,** Postgraduate Student, Researcher**; address:** 21, S-100 St., PO Box 375, Krasnoobsk, Novosibirsk region, 630501, Russia; e-mail: natali.erm@bk.ru

Galina V. Artyomova, Candidate of Science in Biology, Deputy Head for Research

Petr I. Stepochkin, Candidate of Science in Agriculture, Lead Researcher

Alexey S. Surnachev, Postgraduate Student, Junior Researcher

Kenzhebek K. Musinov, Postgraduate Student, Junior Researcher

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