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On the Quality of Bare-Grained Oats and Influence of its Cultivation Technology Elements on the Yield

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ABSTRACT
The research was carried out with the aim to establish the formation regularity of both yield and its elements, as well as to formulate technological and quality indicators of bare-grained oats under the influence of different sowing periods. The studies were carried out in the conditions of the northern forest-steppe zone of the Kemerovo region (Russia) on the territory belonging to the Kemerovo Research Institute of Agriculture, a branch of the SFNCA RAS in 2018-2019. The soil of the site is leached chernozem, heavy loamy in granulometric composition, of medium thickness. The object of research was the mid-season variety of bare-grained oats Bare-grained. The predecessor is pure steam. Sowing was carried out in three periods: early – on May 4 (when the soil was physically ripe, subsequent ones with an interval of 8-10 days, depending on the prevailing weather conditions), medium - on May 12 and 14, late - on May 20 and 24. Against the background of each sowing period, the seeding rates of 4.0 were studied; 4.5; 5.0; 5.5; 6.0 million crops/ha. It has been established that the optimal sowing time for obtaining high quantitative indicators (yield, number of grains, grain size) of bare-grained oats in the northern forest-steppe of the Kemerovo region is an early period (first decade of May); while a later period (third decade of May) is more promising for such high-quality indicators as protein content, fat in grain, essential and nonessential amino acids, etc. The optimal seeding rate for bare-grained oats at early sowing period is 4.0-4.5 million/ha. At a later period, it is advisable to increase the seeding rate to 5.0-5.5 million/ha.

KEY WORDS: OATS, SEEDING RATES, SOWING TIME, QUALITY YIELD.

INTRODUCTION

Oats are a ubiquitous crop in global agriculture. Consumption of oats in the Russian Federation over the past decade has increased by 10%, amounting to 350-370 thousand tons, or 2.4-2.6 kg per capita (Abashev et al. 2018). In Russia, the sown area of oats slightly exceeds 3.3 million hectares, second only to wheat, barley and corn. In the Kemerovo region in 2020, oat sowing occupied 85.5 thousand hectares, the average yield was 17.6 c/ha, the maximum areas under the crop are occupied by the varieties Phobos, Creole, Altai large-grain. In recent years, because of the more valuable nutritional and feed benefits, producers have taken an increasing interest in bare-grained oats. The region is actively engaged in selection for bare-grain varieties, the potential yield of which is much higher, up to 60 kg/ha. Bare-grained oats have a clear advantage over varieties of hulled oats, its protein contains a higher content of essential amino acids, a complex of vitamins (B1, B2, E, F), minerals, various biologically active substances with antioxidant properties, which determines its dietary and therapeutic and prophylactic properties. , and also determines its functional, special properties and possibilities of its application (Nikitenko et al. 2015; Sterna et al. 2016; Lyubimova and Eremin 2018; Batalova et al. 2019).

At the same time, bare-grained spring oats make higher demands on growth conditions than hulled oats because of their morphological structure and biological characteristics. One of the reasons for the decline in the yield of oats with modern genetic potential is the insufficient level of production technology (Kononchuk et al. 2017; Polonskiy et al. 2019). Seeding rates, together with optimal sowing times, play an important role in the relationship between agrotechnical measures, which in turn contribute to

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obtaining high as well as sustainable yields for oats (Chen et al. 2021).

Research of Bobrovsky and Kosyanenko (2013) was carried out in the conditions of the Krasnoyarsk Territory, and showed that the protein content of bare-grained oats is higher than that of hulled oats and depends on the seeding rate. Thus, at a seeding rate of 5.5 million seedlings / ha, its content was 16%, and at 3.5 million seedlings/ha it increased to 17.4% (Bobrovsky and Kosyanenko 2013). Rendov et al. (2018) noted that for the conditions of the southern forest-steppe of the Omsk region, the best terms for sowing bare-grained oats are the second decade of May and the first decade of June with a seeding rate of 4.5 million seed crops/ha. The highest yield of bare-grained oats was obtained during sowing in the first decade of June (2.07 t/ha) (Rendov et al. 2018). Under the conditions of the northern forest-steppe of the Kemerovo region, bare-grained oats produce a higher yield when sown in the second and third decades of May with a seeding rate of 6.0 million seedlings/ha (Isachkova et al. 2018). Batalova et al. (2019) showed the feasibility of increasing the seeding rate from 4.5 to 5 million crops seed crops/ha in the southern part of the Central Non-Black Earth Region, which increases the yield of bare-grained oats up to 4.0 t/ha.

Scherer and Pirozhkov (2018) noted that when sowing bare-grained oats with a seeding rate of 5 and 6 million seedlings/ha, higher quality indicators are formed, so the protein and fat content in grain at these rates is 14.11-15.22% and 4.94-5.30%, respectively, however, at the same time, a decrease in the mass of 1000 grains was revealed. The optimal sowing time in the forest-steppe zone, according to Sartakova, Chumanova and Soldatova (2006) is the second decade of May, however, the best indicators were observed when sowing at an early period with a seeding rate of 5-6 million germinable grains per hectare (Sartakova, Chumanova and Soldatova 2006; Scherer and Pirozhkov 2018; Batalova et al. 2019; McCabe and Burke 2021).

Technologies for the cultivation of spring oats have been developed in many regions of the country; however, in relation to bare-grained varieties, the technologies have not yet been sufficiently developed to realize the potential of cultivated varieties. The purpose of the research is to establish the patterns of the formation of yield and its elements, technological and quality indicators of bare-grained oats under the influence of different sowing periods and seeding rates.

MATERIAL AND METHODS

The studies were carried out in the conditions of the northern forest-steppe of the Kemerovo region in the fields of the Kemerovo Research Institute of Agriculture, a branch of the SFNCA RAS in 2018-2019. The soil of the site was leached chernozem, heavy loamy in granulometric composition, of medium thickness. The humus content was 7.8%, the reaction of the soil solution was close to neutral, and pH was 6.0. The object of research was the mid-early variety of bare-grained oats Gavroche, included in the State Register of Breeding Achievements approved for use in the 10th region in 2014. The duration of the growing season was 65-83 days. Grains were of medium size. The mass of 1000 grains were in between 25-32 g.

The average yield in the West Siberian region was 3.24 t/ha, the maximum yield was 4.57 t/ha and was valued for quality. Protein content were 17.5-20.0%, oil - 7.0-8.0%, sugar - 4.0-5.0%, starch - 62.0-69.0%. The nature of the grain was 540-660 g/l. Splitting of filmy grains was at the level of 0.7%. It was resistant to lodging, germination of grains on the vine, and dusty smut. The predecessor was pure steam. Sowing was carried out in three periods: early on May 4 (when the soil was physically ripe, subsequent ones with an interval of 8-10 days, depending on the prevailing weather conditions), medium - on May 12 and 14, late - on May 20 and 24. Against the background of each sowing period, the seeding rates of 4.0 were studied; 4.5; 5.0; 5.5; 6.0 million crops/ha. Sowing was carried out with a seeder SN-10 Ts, plot area 10 m2 in six replicates. The location of the plots was randomized. The harvesting of the experimental plots was carried out with a combine Sampo-130.

During the research, the following methods were used: methodology for state variety testing of agricultural crops; determination of natural weight according to GOST 10840-64; determination of the content of crude fat in grain in accordance with GOST 13496.15-97; determination of nitrogen and crude protein content in grain in accordance with GOST 13496.4-93; determination of raw ash in grain according to GOST 26226-95; determination of calcium in grain according to GOST 26570-95; determination of phosphorus content in grain according to GOST 26657-97; determination of dry matter content in grain according to GOST 31640-2012; statistical processing of experimental data was carried out according to the method of field experiment using the SNEDEKOR software package.

RESULTS AND DISCUSSION

The weather conditions of the crop growing season in (2018) with an early sowing period were unfavorable for the growth and development of the culture in the initial phases of development, which proceeded against the background of low air temperatures (-2.70C to average annual indicators) and a large amount of precipitation (+32 mm), which influenced the decrease in field germination of plants. The period of sprouting and sprouting was marked by increased air temperatures against a background of high humidity (hydrothermal index = 2.0). Grain filling and ripening took place with sufficient moisture supply and elevated air temperatures (hydrothermal index = 1.4) (table 1) (Polonskiy et al 2019; McCabe and Burke 2021).

The prevailing meteorological conditions of the middle and late periods were relatively favorable, the main subperiods of the growing season (seedlings, flowering, ripening) were marked by high air temperatures and a large amount of precipitation (hydrothermal index = 1.4-2.0). The weather conditions of the growing season for plants of the early sowing period in 2019 were characterized by sufficient moisture supply. Elevated air temperatures (+ 0.6 °C to the long-term average) contributed to the early emergence of seedlings (on average on the 8-10th day). The vegetative phase of the growing season took place at an air temperature and precipitation close to the mean annual values (hydrothermal index = 1.1).

Table 1. Meteorological conditions during different growing seasons of bare-grained oats (2018-2019).

Sowing time	Period	Sowing – seedling			Seedling – ear formation			Ear formation - ripening		
		temperature, ºC	precipitation, mm	hydrothermal index	temperature, ºC	precipitation, mm	hydrothermal index	temperature, ºC	precipitation, mm	hydrothermal index
Early	Many-year	8,2	28	-	14,9	111	1,2	17,3	102	1,2
	2018	5,5	60	-	19,0	154	2,0	17,0	116	1,4
	2019	8,8	10	-	14,7	100	1,1	18,6	103	1,1
Middle	Many-year	11,0	11	0,5	15,2	96	1,3	17,3	102	1,2
	2018	8,1	49	-	19,0	154	2,0	17,0	116	1,4
	2019	10,3	34	1,7	16,0	95	1,2	18,6	103	1,1
Late	Many-year	13,9	33	1,2	17,2	103	1,2	17,6	107	1,2
	2018	13,6	34	1,3	19,8	145	1,8	15,3	143	1,9
	2019	13,4	48	1,8	18,1	118	1,3	18,2	121	1,3

Grain filling and ripening took place under favorable conditions (hydrothermal index = 1.1), which contributed to the formation of a high yield. The water and temperature regimes during sowing of the middle and late period were characterized by low air temperatures against the background of a large amount of precipitation (hydrothermal index = 1.7 and 1.8, respectively), which led to an increase in the sprouting phase. The vegetative and generative sub-periods were relatively favorable for the growth and development of bare-grained oat plants (hydrothermal index = 1.2-1.3). In 2018, on average in terms of sowing, the best results were obtained at an early period (3.11 t/ha), which exceeds the values of other periods by 0.64-0.66 t/ha. Higher yields were noted at higher seeding rates (table 2) (Batalova et al. 2019).

In (2019), a significant influence of the sowing time on the formation of the yield of bare-grained oat varieties was noted (69.4%). In the Gavrosh variety, the average yield at the early sowing period was 4.19 t/ha, with the average - 2.52 t/ha, with the late sowing - 1.97 t/ha. At the same time, with an early and medium sowing period, the best results were obtained at low seeding rates (4 million seedlings per hectare), with a later period - at a rate of 5 million seedlings per 1 hectare. On average, over the years of research, the best yield indicators were obtained with an early sowing period - 3.65 t/ha, which is 1.15 and 1.44 t/ha higher than the average and late terms, respectively.

At the same time, a higher yield at an early period was formed at seeding rates from 4.0 to 5.0 million/ha, and at a later one - at seeding rates of 5.0-5.5 million/ha. The formation of yield in the Gavrosh variety was influenced by such indicators as: productive stalk ($r = 0.8240$ at $R = 0.5140$), grain weight per panicle ($r = 0.5731$ at $R = 0.5140$) and grain size ($r = 0.9474$ with $R = 0.5140$). A significant influence of soil moisture content on the yield of bare-grained oat varieties was revealed. In the Gavrosh variety, high indicators of productive moisture in a meter layer of soil during all phases of growth contributed to a decrease in yield (sowing: $r = -0.7111$; tillering - stem elongation: $r = -0.9449$; ripening: $r = -0.9696$ at $R = 0.5140$) (Batalova et al. 2019).

The sowing time influenced the plant survival rate, i.e., the ratio of the number of preserved plants to harvesting to the number of sown seeds, which characterizes the ability to germinate and plant resistance to unfavorable environmental factors during the growing season. In the Gavrosh variety, the best survival rates in different years of study were noted at early sowing period of 53.7 -56.8%, at middle and late periods, there was a decrease in the indicator - 42.8-44.6% and 41.4-42.9% respectively. At the same time, better survival was observed at lower seeding rates. The high resistance of bare-grained oat plants of early sowing terms to the effects of the prevailing weather conditions determined an increase in the productive stalk of bare-grained oats ($r = 0.5651$ at $R = 0.5140$) in these variants of the experiment. Thus, the number of productive stems on average for two years at early sowing periods was 409 pieces/m2 due to better productive tillering, an average term - 403 pieces/m2, a late one - 380 pieces/m2 (Polonskiy et al 2019).

Table 2. Yield of bare-grained oats (2018-2019).

Seeding rate, mln./ha	2018			2019			2018-2019 (average)		
	early term	middle term	late term	early term	middle term	late term	early term	middle term	late term
4,0	3,22	2,61	2,45	4,27	2,60	1,87	3,75	2,61	2,16
4,5	3,20	2,45	2,16	4,20	2,44	1,94	3,70	2,45	2,05
5,0	3,07	2,58	2,65	4,27	2,49	2,03	3,67	2,54	2,34
5,5	3,28	2,44	2,66	4,09	2,54	2,00	3,69	2,49	2,33
6,0	2,80	2,26	2,34	4,14	2,52	2,00	3,47	2,39	2,17
comparing the terms	3,11	2,47	2,45	4,19	2,52	1,97	3,65	2,50	2,21
HCP_{05} factor A (term)	0,14			0,11			0,13		
factor B (norm)	0,20			0,14			0,17		

The sowing time influenced the morphological parameters of bare-grained oat plants. In the Gavroche variety, taller plants were noted at an early sowing period (83.8 cm), with an average period, the plant height averaged 74.3 cm, and at a later period - 83.6 cm. Due to the existing relationship between plant height and panicle structure (r = 0.5436 ... 0.5976 at R = 0.5140), the best panicle morphological parameters were observed in tall genotypes formed in the Gavrosh variety at an early sowing date. At the same time, with early sowing, loose panicles were formed with the number of flowers in one spikelet 3.0 pcs. At a later period, panicles formed more compact with a large number of whorls (4.7 pcs.), But their shorter length than at the early and middle terms of sowing, and with a higher density (1.26 pcs.) Due to a greater number of spikelets (table 3) (Polonskiy et al 2019).

Table 3. Morphological parameters of bare-grained oat panicles, on average for the sowing period (2018-2019).

Year	Sowing period	Panicle length, cm	Number of whorls, pcs.	Average length of a whorl, cm	Number of spikelets in a panicle, pcs.	Number of flowers in a panicle, pcs.	Panicle density, pcs/cm	Number of flowers in a spikelet, pcs.	Number of grains in a spikelet, pcs.	Winnowing chaff from grain,%	Number of grains in a panicle, pcs.
2018	Early	15,2	4,2	3,6	20,2	50,6	1,33	2,5	1,6	8,6	32,3
	Middle	15,8	4,2	3,8	20,7	51,2	1,31	2,5	1,6	6,0	32,6
	Late	15,8	4,6	3,4	19,8	56,0	1,25	2,8	1,6	3,9	30,8
2019	Early	16,7	4,3	3,9	19,5	66,8	1,17	3,4	2,5	1,9	47,9
	Middle	15,9	4,1	3,9	18,2	55,6	1,14	3,3	2,6	0,9	41,1
	Late	16,0	4,7	3,4	20,3	64,2	1,27	3,2	2,2	0,8	44,7
2018-2019 (average)	Early	16,0	4,3	3,8	19,9	58,7	1,25	3,0	2,1	4,8	40,1
	Middle	15,9	4,2	3,9	19,5	53,4	1,23	2,9	2,1	4,0	38,7
	Late	15,9	4,7	3,4	20,1	60,1	1,26	3,0	1,9	2,4	35,5

These indicators determined the best grain content in the panicle at an early sowing period: 40.1 pcs., While at the middle and late periods the indicator was 38.7 and 35.5 pcs. When analyzing various seeding rates, the best indicators of the panicle structure in the Gavrosh variety were noted on more rarefied crops (4.0 and 4.5 million seedlings/ha) at all periods. The breakdown of hulled grains is an important indicator for bare-grained oats (McCabe and Burke 2021).

It was revealed that the trait is more pronounced under the condition of low average daily air temperatures and sufficient moisture in the initial phases of plant growth and development (r = 0.9954 at R = 0.9500). In this regard, there was a decrease in this indicator from early to late sowing periods. The mass of 1000 grains in bare-grained oats are one of the most important indicators that determine the seed and food value of the variety. The grain size of bare-grained oats varies greatly, both inside the spikelet and inside the panicle, which is largely influenced by the weather conditions of growing. On average, according to the experiment, the mass of 1000 grains were 22.5 g. The Gavrosh variety showed a significant decrease in the mass of 1000 grains from the early to the late sowing period: 22.5, 21.7 and 21.3 g with HCP05 = 0.6, which determined the level of productivity of the variety under different cultivation conditions (r = 0.9474 with R = 0.5140) (table 4) (McCabe and Burke 2021).

Table 4. Technological indicators of bare-grained oat grain (2018-2019).

Seeding rate, mln./ha	2018			2019			2018-2019 (average)		
	early term	middle term	late term	early term	middle term	late term	early term	middle term	late term
Weight of 1000 grains, g									
4,0	20,2	19,0	20,5	24,9	23,2	21,5	22,6	21,1	21,0
4,5	20,3	21,7	20,4	24,3	23,0	22,7	22,3	22,4	21,6
5,0	20,4	20,7	20,9	24,9	23,0	21,8	22,7	21,9	21,4
5,5	20,5	20,7	20,7	25,0	22,6	21,9	22,8	21,7	21,3
6,0	20,1	19,8	20,6	24,5	23,2	21,4	22,3	21,5	21,0
comparing the terms	20,3	20,4	20,6	24,7	23,0	21,9	22,5	21,7	21,3
HCP_{05} Factor A (term)	0,9			0,6			0,8		
Factor B (norm)	0,7			0,8			1,0		
Factor C (grade)	0,6			0,4			0,6		
Natural weight of grain, g/l									
4,0	588	561	552	625	634	621	607	598	587
4,5	591	572	550	628	632	626	610	602	588
5,0	588	569	563	629	630	626	609	600	595
5,5	594	568	549	635	637	621	615	603	585
6,0	589	564	537	629	631	624	609	598	581
comparing the terms	590	567	550	629	633	624	610	600	587
HCP_{05} Factor A (term)	4,9			4,6			4,8		
Factor B (norm)	6,2			5,9			6,1		
Factor C (grade)	4,0			3,7			4,0		

Table 5. Biochemical parameters of bare-grained oat grain at different sowing dates, 2018-2019

Seeding rate, mln./ha	2018			2019			2018-2019 (average)		
	early term	middle term	late term	early term	middle term	late term	early term	middle term	late term
Moisture content, %	7,53	6,86	7,63	7,10	7,51	7,65	7,32	7,19	7,64
Mass fraction of crude protein,%	13,88	14,22	15,37	15,22	15,36	15,63	14,55	14,79	15,50
Mass fraction	7,28	7,69	7,64	7,67	7,72	7,93	7,48	7,71	7,79
crude fat,%	3,88	2,39	2,32	2,03	1,97	2,06	2,96	2,18	2,19
Mass fraction	0,13	0,15	0,10	0,11	0,12	0,12	0,12	0,14	0,11
Crude ash,%	0,48	0,48	0,49	0,44	0,49	0,58	0,46	0,49	0,54

The grain size of the Bare-grained variety was influenced by the conditions of moisture supply during the tillering period - going into the tube, with a greater value noted on the crops of the middle term (r = -0.9317 at R = 0.5140).

Different variants of the experiment also influenced the completeness and density of the grain of bare-grained oats, which are characterized by the full-scale weight of the grain. In the Gavroche variety, the indicator was 600 g/l on average over the experience. There was a tendency to decrease the natural weight from the early to the late sowing period, which is explained by the reduced moisture supply of late crops during the tillering-tube emergence period (r = 0.9456 ... 0.9605 at R = 0.5140). The processed technological elements also influenced the quality indicators of grain. Thus, there was a significant excess of the content of crude protein (15.50%) and crude fat (7.79%) in grain at a late sowing period over early and middle periods (Table 5) (Polonskiy et al 2019).

The main advantage of bare-grained oat varieties over hulled oats is the increased content of essential (valine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, phenylalanine) and non-essential (arginine, asparagine, glutamine, glutamic acid, glycine, carnitine, amino acids) ornithine in protein, the total content of which was 3.713 and 9.467% at the early sowing period, with the average - 3.695 and 9.067%, at the late sowing - 3.814 and 9.751%, respectively (Polonskiy et al 2019; McCabe and Burke 2021).

CONCLUSION

The findings of the present study showed that the optimal sowing time for bare-grained oats in the northern forest-steppe of the Kemerovo region to obtain high quantitative indicators is an early period (first decade of May), and a later period (third decade of May) is also promising. At early sowing terms, there are increased indicators of the density of the productive stalk and grain size, which determine the level of yield of the variety. Late sowing periods contribute to a better formation of the morpho-biological parameters of the panicle (length, density, number of spikelets, number of flowers, and number of grains).

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