Yield and quality of spring cereals depending on cultivation conditions

Yu Yu Parshutkin¹, P N Nikolaev², O A Yusova³ and V S Yusov⁴

¹Seed Farming Laboratory, Omsk Agrarian Scientific Center, 26, Koroleva ave., Omsk, 644012, Russia
²Fodder Grain Selection Laboratory, Omsk Agrarian Scientific Center, 26, Koroleva ave., Omsk, 644012, Russia
³Laboratory of Plant Biochemistry and Physiology, Omsk Agrarian Scientific Center, 26, Koroleva ave., Omsk, 644012, Russia
⁴Laboratory of Spring Durum Wheat Selection, Omsk Agrarian Scientific Center, 26, Koroleva ave., Omsk, 644012, Russia

E-mail: 55asc@bk.ru

Abstract. The purpose of the study is to identify the optimal sowing time and the predecessor to obtain high-quality grain of spring durum wheat and spring barley in the conditions of the southern forest-steppe of Western Siberia. Object of study: varieties of spring durum wheat – Jemchujina Sibiri and Omskij corund; varieties of spring barley – Omskij 90 and Beatrice. The sowing was held on May 7, 14, 21, 28 and June 4. The biochemical assessment of grain quality indicators included the content of raw gluten, protein, starch, crude fat, grain hardness, grain unit. The fallow sowing of spring durum wheat on May 7 increased the values of the thousand grain weight, grain hardness, gluten, protein, color of dry pasta; when sowing from May 14 to 28 – yields, grain unit, color of dry pasta for cereals. For spring barley, an increase in yield and protein content was observed during sowing on May 14; during sowing on June 4 – protein and oil content. Fallow sowing made it possible to increase yield and grain quality both in varieties of spring durum wheat and spring barley.

1. Introduction
At present, the issue of observed and forthcoming climate change, both globally [1, 2] and in relation to agronomy [3], is considered to be one of the most relevant and disputable topics. Therefore, the problem of creation and use of varieties with improved adaptability in agricultural production is particularly relevant [4, 5]. An important aspect of adaptability is the identification of optimal planting and crop timing [6], which is determined experimentally for each cultivation zone, along with the precursor.

The purpose of the study is to identify the optimal sowing time and predecessor for obtaining high-quality grain of spring durum wheat and spring barley in the conditions of the southern forest-steppe of Western Siberia.
2. Research objects and methods
The research was carried out in 2013-2016 in the experimental fields of the seed production department of Omsk Agrarian Scientific Center located in the southern forest-steppe of Western Siberia.

Object of study: varieties of spring durum wheat – Jemchujina Sibiri and Omskij corund; varieties of spring barley – Omskij 90 and Beatrice.

The sowing was carried out on May 7, 14, 21, 28 and June 4 with a sowing rate of 4.5 million germinating seeds per 1 hectare for two predecessors – pure black fallow and cereals (second crop after fallow). Soil treatment technology and crop tending are generally accepted in the southern forest-steppe of Western Siberia. The accounting plot area is 15 m². Placement – systematic, repetition – fourfold. The grain yield was recorded according to the method of state crop variety testing (5, 6). The biochemical assessment of the grain quality of the studied crops was carried out: content of raw gluten (GOST R 54478-2011), protein (GOST 10846-91), starch (GOST 10845-98), crude fat (GOST 13496.15-85), grain hardness (GOST 10987-76), grain unit (GOST 10840-64). Mathematical processing of data was also carried out (7).

3. Research results

3.1. Spring durum wheat

Yield is the main indicator of the crop cultivation technology [7-9]. On average, in varieties the yields increased from May 14 to 28 from 2.0 to 2.5 t/ha for fallow and from 1.0 to 1.3 t/ha for cereals. When sown on June 4, its sharp decrease was observed (2.0 and 1.1 t/ha, respectively). According to the predecessor, pure fallow in the studied varieties formed the highest yield on May 14 (2.81 and 2.46 t/ha in the varieties Jemchujina Sibiri and Omskij corund, respectively) (Table 1). According to the grain precursor, an increased yield was obtained during sowing from May 14 to 28 (2.40...2.50 t/ha – Jemchujina Sibiri; 2.13...2.16 – Omskij corund). The Jemchujina Sibiri was the most productive (0.35 t/ha for fallow and 0.26...0.34 t/ha for cereals regarding Omskij corund).

The thousand grain weight decreased from earlier sowing dates (37.3 g on May 7 for fallow; 36.6 g on May 7 and 14 for cereals) with sowing on June 4, the thousand grain weight was 34.1 and 30.1 g, on average in varieties. According to the fallow precursor, the increased grain size was observed with sowing on May 7 (36.5 and 38.1 g in the Jemchujina Sibiri and Omskij corund varieties); for cereals – May 7 and 14 (36.0...37.3 g). Omskij corund variety was characterized by larger grain (+1.7 g for fallow on May 7 and 14; +0.8…+1.5 g for cereals from May 7 to 28) compared to the Jemchujina Sibiri.

Grain hardness is a mirror image of the grain filling conditions, its ripening, harvesting and storage. To a greater extent, researchers associate grain hardness with nitrogen content in plants during ripening and prevailing weather conditions (9). On average, in the variety the grain hardness decreased with the sowing dates from May 7 to June 4 (for fallow – from 67.4 to 61.3%; for cereals – from 66.3 to 62.6%). The maximum values of this feature for varieties are characteristic of the Jemchujina Sibiri when sown on May 7 for fallow and for cereals (68.3%); of Omskij corund – on May 7 and 14 for fallow (66.5 and 67.0%) and May 14, 21 for cereals (65.3%). The Jemchujina Sibiri exceeded Omskij
corund variety in terms of grain hardness when sown on May 7, 21 and 28 (+1.8...+3.7% for fallow; +1.2...+4.5% for cereals).

Table 1. Productivity and quality of spring durum wheat grains, on average over 2013-2016.

| Sowing time | Productivity | Grain quality | Color of dry pasta, points |
|-------------|--------------|---------------|-----------------------------|
|              | yield, t/ha  | thousand grain weight, g | hardness, % | gluten, % | protein, % |              |
| precursors – fallow |              |               | 747.8 / 735.8 | 68.3 / 66.5 | 29.4 / 29.9 | 14.75 / 15.12 | 4.5 / 3.8 |
| May 7        | 2.41 / 1.91 | 36.5 / 38.1   | 745.0 / 739.3 | 65.3 / 67.0 | 29.0 / 28.8 | 14.68 / 14.31 | 4.3 / 3.9 |
| May 14       | 2.81 / 2.46 | 35.4 / 37.1   | 748.0 / 747.3 | 66.5 / 64.0 | 28.1 / 27.9 | 14.15 / 13.90 | 3.9 / 4.3 |
| May 21       | 2.69 / 2.38 | 35.3 / 35.4   | 746.0 / 749.8 | 67.5 / 63.8 | 27.8 / 28.0 | 14.22 / 13.77 | 3.9 / 4.3 |
| May 28       | 2.59 / 2.35 | 35.7 / 35.4   | 710.5 / 695.8 | 61.5 / 61.0 | 26.1 / 24.7 | 13.62 / 12.98 | 3.8 / 4.0 |
| June 4       | 2.27 / 1.96 | 34.1 / 34.0   | 750.8 / 743.5 | 68.3 / 64.3 | 27.8 / 28.6 | 14.02 / 14.32 | 4.0 / 4.0 |
| precursors – cereals |              |               | 750.5 / 758.5 | 67.3 / 65.3 | 28.7 / 28.0 | 14.34 / 14.02 | 4.1 / 4.1 |
| May 7        | 2.07 / 1.66 | 36.0 / 37.1   | 749.5 / 751.5 | 65.8 / 65.3 | 27.3 / 26.8 | 13.58 / 13.92 | 3.9 / 4.3 |
| May 21       | 2.45 / 2.13 | 34.8 / 36.3   | 751.0 / 754.0 | 63.3 / 63.0 | 27.4 / 26.7 | 13.97 / 13.42 | 3.8 / 4.2 |
| May 28       | 2.50 / 2.16 | 34.1 / 34.9   | 709.5 / 702.0 | 62.8 / 62.3 | 26.7 / 24.6 | 13.58 / 12.97 | 3.8 / 4.1 |
| June 4       | 2.10 / 1.64 | 31.2 / 28.9   |              | 0.12 / 1.56 | 10.3 / 0.6 | 0.7 / 0.24 | 0.18 / 0.01 |

Note: the numerator contains data on the Jemchujina Sibiri, the denominator contains data on Omskij corund.

Wheat has a unique property – to form gluten thus affecting the viscous-elastic properties of dough. The gluten content on average in varieties in the fallow precursor decreased from 14.7% with sowing on May 7 to 13.1% with sowing on June 4. The studied varieties were characterized by the maximum gluten content (29.4 and 29.9%) according to the fallow precursor on May 7. According to the cereals predecessor, the increased value of this feature in the Jemchujina Sibiri was noted on May 14 (28.7%). In Omskij corund – on May 7 (28.7%). The Jemchujina Sibiri reliably exceeded Omskij corund in terms of gluten content at late sowing (+1.4% for fallow on June 4; +0.7 and +2.1% for cereals on May 28 and June 4). The protein content is genetically controlled, however, its increased content is achieved by high level of agricultural equipment. The peculiarity of the durum wheat protein is that it does not dissolve in water. It was found that with the increase in protein content and the improvement in its quality, the cooking properties of pasta products are increased. High percentage of protein was obtained at sowing on May 7 and 14, both for fallow (15.0%) and in non-fallow precursor (14.2%), on average in varieties. The maximum protein content for fallow was noted with sowing on May 7 (14.75 and 15.12% for the Jemchujina Sibiri and Omskij corund, respectively); according to non-fallow predecessor – May 7 for Omskij corund and May 14 for the Jemchujina Sibiri (14.32 and 14.34%).
The Jemchujina Sibiri exceeded Omskij corund in terms of grain hardness sown on May 14 and 28, June 4 (+0.37...+0.64% for fallow; +0.32...+0.61% for cereals).

According to the color of dry pasta, also caused by the content of carotenoid pigments, a higher score was obtained during fallow sowing on May 7 (4.2 points), during non-fallow sowing – on May 14 and 21 (4.1 points), on average in varieties. The maximum value of this indicator in the Jemchujina Sibiri was observed at an early date (May 7 for fallow – 4.5 points; May 7 and 14 for cereals – 4.0 and 4.1 points); in Omskij corund – at later dates (May 21 and 28 for fallow and May 21 for cereals – 4.3 points). The Jemchujina Sibiri had a more pronounced color of dry pasta with sowing dates of May 7 and 14 for fallow (+0.7 and 0.4 points); Omskij corund variety had increased values of this indicator at the sowing dates from May 21 to June 4 for cereals (+0.3 and 0.4 points).

During the seedling-earing period, a positive reliable relation was noted between yield and rainfall (r = 0.528), Table 2. A weak correlation coefficient is typical for a pair of signs yield – average daily temperature (r = 0.289) and yield – effective heat sum (r = 0.294). The obtained correlation values confirm that the high air temperature during this period is not favorable for spring durum wheat.

During the period of earing and ripening, rainfall and heat are urgently needed to obtain high and good-quality crop. A fairly close relationship was identified between yield and the effective heat sum (r = 0.569), yield and the sum of rainfall (r = 0.612).

### Table 2. Correlation between spring durum wheat yields and meteorological factors in a particular interfacial period

| Indicator                               | Seedling – earing | Earing – yellowing |
|-----------------------------------------|-------------------|--------------------|
| Sum of rainfall                         | 0.528 ± 0.161**   | 0.612 ± 0.157**    |
| Effective heat sum above 10°C           | 0.294 ± 0.157     | 0.569 ± 0.154      |
| Mean daily air temperature              | 0.289 ± 0.148     | 0.105 ± 0.161      |
| Relative humidity                       | 0.323 ± 0.187*    | 0.314 ± 0.158*     |
|                                         |                   |                    |

* – reliable at p ≤ 0.01, ** – reliable at p ≤ 0.001

#### 3.1. Spring barley

Increased yields of barley on average in varieties were observed at sowing on May 14 (4.11 t/ha for fallow and 3.35 t/ha for cereals, Table 3), as confirmed by literature data [11]. At an early date (May 7) and from May 21 to June 4 the yield decreased (3.51... 3.98 t/ha for fallow and 2.73...3.08 t/ha for non-fallow precursors). The maximum yield of varieties was also observed with sowing on May 14 (4.28 and 3.32 t/ha for Omskij 90; 3.64 and 3.38 t/ha for Beatrice for fallow and cereals, respectively). Omskij 90 had an increase in relation to Beatrice (+0.12...+0.53 t/ha at sowing from May 14 to 28 for fallow; +0.37 t/ha at sowing on May 7 and 28 according to cereals precursor).

The maximum protein content was typical at sowing on May 14 and June 4 (respectively 13.71 and 13.51% for fallow; 12.33 and 12.87% for cereals), on average in varieties. The analysis of varietal specificity showed that according to the fallow precursor, the increased protein content in Omskij 90 was noted with sowing on June 4 (14.66 t/ha), in Beatrice variety – on May 28 (14.07 t/ha). When sowing according to cereals precursor, the increased protein content corresponds to the sowing dates of May 14 and June 4 (12.41 and 12.72% in Omskij 90; 12.24 and 13.01% in Beatrice variety). Omskij 90 was characterized by an increased protein content during fallow sowing on May 7 and from May 21 to June 4 (+0.23...+1.57 %); for cereals – from May 7 to 28 (+0.17...+1.01%) in relation to Beatrice variety.

The starch content when sown for fallow decreased from May 7 (58.36%) to June 4 (57.49%), on average in varieties. With cereals sowing, on the contrary, it increased from 59.46% on May 7 to 60.12% on May 21 and June 4. The studied varieties were characterized by an increased starch content: for fallow – Omskij 90 with sowing on May 21 (58.47%), Beatrice – May 7 (58.96%); when sowing for cereals on May 21 and June 4 (60.01...60.22%). According to this indicator, the Beatrice
exceeded Omskij 90 for fallow with seeding dates on May 14 and 28 (+0.33 and +0.44%); for cereals – May 7 (+0.66%).

Table 3. Yield and grain quality of barley varieties, on average for 2015-2017

| Sowing time | Yield, t/ha | Grain quality | Precursor – fallow | Precursor – cereals |
|-------------|-------------|---------------|---------------------|---------------------|
|             | protein, %  | starch, %     | crude fat, %        |                     |
| May 7       | 4.08 / 3.78 | 13.80 / 13.28 | 58.03 / 58.69       | 1.96 / 2.29         |
| May 14      | 4.28 / 3.94 | 13.59 / 13.82 | 58.03 / 58.36       | 2.43 / 3.04         |
| May 21      | 4.04 / 3.92 | 14.29 / 12.98 | 58.47 / 58.04       | 1.39 / 2.13         |
| May 28      | 3.77 / 3.24 | 14.30 / 14.07 | 57.60 / 58.04       | 2.32 / 2.51         |
| June 4      | 3.72 / 3.78 | 14.66 / 13.09 | 57.49 / 57.49       | 3.08 / 4.25         |
| s           | 0.09        | 0.18          | 0.13                | 0.25                |

Note: the numerator contains data on Omskij 90, the denominator contains data on Beatrice variety.

Increased oil content was formed during sowing on June 4, both for fallow and cereals (3.67 and 2.62%), on average in varieties. The varieties were characterized by an increased content of crude fat at a given sowing time for fallow (3.08 and 4.25%). According to cereals precursor, increased oil content was noted in Omskij 90 with sowing on May 28 (2.99%); Beatrice – June 4 (3.16%). The Beatrice variety was characterized by increased oil content at all sowing periods according to the fallow precursor (+0.33...+1.17 %); for non-fallow – with a sowing period of June 4 (+0.81%) in relation to Omskij 90.

The weather conditions during growth and development undoubtedly had a significant influence on quality and productivity of spring barley (Table 4). Considering the inverse correlation of grain starch content with both the sum of temperatures (r = -0.971) and the sum of rainfall (r = -0.350), it can be concluded that in order to generate these indicators of quality and productivity, an optimal ratio of hydrothermal indicators is necessary. A similar relationship with the main climatic factors is observed in terms of grain yield: r = 0.606 with the sum of temperatures and r = -0.869 with the sum of rainfall. Excessively high temperatures and rainfall have contributed to the decline in quality and productivity. Barley oil content was in strong positive dependence on the sum of temperatures (r = 0.956) and in weak negative dependence – with the sum of rainfall (r = -0.149).

Table 4. Yield and grain quality of barley varieties, on average for 2015-2017

| Indicator | Mean daily air temperature | Total rainfall |
|-----------|----------------------------|---------------|
| Protein   | 0.968 ± 0.110**           | -0.495 ± 0.060* |
| Starch    | -0.971 ± 0.122**          | -0.350 ± 0.025* |
| Crude fat | 0.956 ± 0.900**           | -0.149 ± 0.016* |
| Yield     | -0.606 ± 0.030*           | -0.869 ± 0.071* |

* – reliable at p ≤ 0.01, ** – reliable at p ≤ 0.001

4. Conclusion

On average, for the studied varieties, early sowing of spring durum wheat (May 7) contributed to the formation of increased values of the following indicators:

– thousand grain weight (37.3 g for fallow and 36.6 g for cereals);
– grain hardness (67.4% for fallow and 66.3% for cereals);
– gluten (14.7% for fallow and 13.9% for cereals);
– protein (15.0% for fallow and 14.2% for cereals);
– color of dry pasta according to fallow precursor (4.2 points).

Later sowing of spring durum wheat (from May 14 to 28) contributed to the formation of increased values of the following indicators:
– yield (from 2.0 to 2.5 t/ha for fallow and from 1.0 to 1.3 t/ha for cereals);
– grain unit (for fallow – from 738.8 to 749.9 g/l; for cereals – from 747.2 to 752.5 g/l);
– color of dry pasta according to non-fallow precursor (4.1 points).

On average in the studied varieties later sowing is recommended for spring barley. Sowing on May 14 contributed to the formation of increased values of the following indicators:
– yield (4.11 t/ha for fallow and 3.35 t/ha for cereals);
– protein content (13.71% for fallow; 12.33% for cereals).

When sowing on June 4, the spring barley varieties had increased quality indicators:
– protein content (13.51% for fallow; 12.87% for cereals);
– oil content (3.67% for fallow and 2.62% for cereals).

Fallow sowing provides for increased yield and grain quality of spring durum wheat and spring barley.

The hydrothermal conditions of the study periods had a significant impact on the yields of spring durum wheat and spring barley.

Jemchujina Sibiri exceeded Omskij corund in terms of yield (+0.35 t/ha for fallow and +0.26...+0.34 t/ha for cereals), in terms of grain hardness (+1.8...+3.7% for fallow; +1.2...+4.5% for cereals), in terms of grain unit (+12 and +14.7 g/l for fallow), in terms of gluten content (+1.4% for fallow; +0.7 and +2.1% for cereals), in terms of protein content (+0.37...+0.64% for fallow; +0.32...+0.61% for cereals), in terms of the color of dry pasta at the sowing dates on May 7 and 14 for fallow (+0.7 and +0.4 points). Omskij corund variety was characterized by larger grain (+1.7 g for fallow on May 7 and 14; +0.8...+1.5 g for cereals from May 7 to 28) compared to the Jemchujina Sibiri and had increased values of this indicator at the sowing dates from May 21 to June 4 for cereals (+0.3 and 0.4 points).

In relation to Beatrice the Omskij 90 variety had yield gain (+0.12...+0.53 t/ha at sowing from May 14 to 28 for fallow; 0.37 t/ha at sowing on May 7 and 28 according to cereals precursor); protein content during sowing on May 7 and from May 21 to June 4 (+0.23...+1.57%); fall-ploughing – from May 7 to 28 (+0.17...+1.01%) and in terms of oil content according to non-fallow precursor from May 7 to 28 (+0.02...+0.75%) relative to Beatrice variety. The Beatrice variety was characterized by increased fallowed starch at seeding times on May 14 and 28 (+0.33 and +0.44%); for cereals – May 7 (+0.66%) and oil content at all sowing periods for fallow precursor (+0.33...+1.17%) in relation to Omskij 90.

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