Yield and quality of wheat grains in crop rotation in the southern forest-steppe of Western Siberia

A V Lomanovskiy and I A Korchagina
Omsk Agrarian Scientific Center, 26, Koroleva ave., Omsk, 644012, Russia
E-mail: sacha-071287@mail.ru

Abstract. The influence of soil treatment systems on the upper layer of chernozem soil and intensification agents in the cultivation of spring wheat after rapeseed and soybean precursor on the yield and quality of grain in the southern forest-steppe of Western Siberia was revealed. At the present stage the increase of the productivity and sustainable production of grain in the arid conditions of Omsk region implies the development of low-cost agricultural technologies and the sound use of intensification agents in growing new high-yielding varieties. The soy precursor contributed to the improvement of technological quality indicators against intensive background in terms of protein content by 6.7% (11.9-12.7%), gluten – by 8.4% (23.8-25.8%) and grain yield – by 23% (2.69-3.30 t/ha) than rapeseed, which is mainly associated with soil enrichment with digestible forms of nitrogen after soy precursor. The positive effect of combined soil treatment in combination with complex application of chemical agents on wheat grain productivity and quality after soybean and rapeseed precursors was established. It is noted that the largest thousand grain weight, protein and gluten content for both precursors were observed in case of flat-cut soil treatment with the improvement of technological parameters during complex chemization. In the southern forest-steppe cultivated lands of Western Siberia the rational integrated use of chemization tools and resource-saving flat-cut and combined soil treatment systems in field crop rotation when growing spring wheat after rapeseed and soybean precursors optimize the quality of soil and grain, stabilize and increase crop productivity by 1.19-3.30 t/ha (14-23%). Soy and rapeseed are promising crops and the areas below them will increase in the region, and the agricultural technology of spring soft wheat after these precursors has not been sufficiently studied and presents a significant interest.

1. Introduction
Agroecosystems of grain crops occupying 2 million hectares in Omsk region have low resistance to diseases, pests and weeds. Despite the effective work of breeders, the majority of modern varieties of spring wheat have limited resistance potential against harmful organisms in agroecosystems. The yield of grain crops is integral and largely depends on the variety, its responsiveness to the intensification agents, adaptation to external environment. The production of high and sustainable yields is only possible if a whole range of agrotechnical measures is observed, the basis of which includes zonal soil treatment systems, crop turnover, the use of mineral fertilizers and plant protection agents [1].

In 2000-2013 the area of wheat crops in the Russian Federation ranged from 22.2 to 28.7 million hectares (3rd place in the world after India and China). The gross output reached 45 million tons with...
an average relatively low grain yield of winter wheat amounting to 2.20 t/ha and 1.41 t/ha – spring wheat [2].

Located in the Siberian Federal District Omsk region has rich and diverse gene pool of crop varieties [3]. In the structure of grain crops, the share of spring soft wheat in our region is high and amounts to 71-78%. The main cultivated lands (75%) are concentrated in arid forest-steppe and steppe agrolandscapes. With an average yield of 1.37 t/ha, the gross grain output reaches 3 million tons. More than half of the range of varieties accounts for the share of strong wheat [2].

The territory of Omsk region is located in the south of the West Siberian lowland along the middle course of the Irtysh River and borders with the Republic of Kazakhstan in the south, with the Tyumen in the west and south-west, with Novosibirsk and Tomsk regions in the east [4]. Most of the territory of the Siberian plain is characterized by limited soil-climatic resources. Chernozem soils in our region occupy only 24% of the area.

The development and implementation of resource-saving intensive technologies and the rational use of intensification agents to produce environmentally sound products are crucial in solving the problem of increasing the productivity of the spring wheat. Over the last 30 years the analysis of grain productivity in Omsk region shows that it is largely dependent on the hydrothermal conditions of the territory and is stabilized at the level of 1.4-1.5 t/ha, which is largely determined by the material and technical support of producers and the state of agriculture efficiency [1].

According to Khamova O.F. et al. (2019), the use of mineral fertilizers in the southern forest-steppe of Western Siberia in rational doses activates the life of soil microorganisms, but this does not lead to significant changes in the microbial biota of chernozem. The increase of crop productivity in crop rotation is caused by effective fertility, which determines the formation of potentially possible grain yields under certain conditions [5].

At the present stage the productivity increase and sustainable production of grain in the arid conditions of Omsk region involves the development of low-cost agricultural technologies and the reasonable use of intensification agents in growing new high-yielding varieties [6].

In the conditions of the southern forest-steppe of Western Siberia, soil protection tillage with the rational use of chemicals contributes to increased productivity of agrophytocenosis of spring soft wheat [7].

The studies conducted by Saituarova A.D. et al. (2019) in the southern forest-steppe of Western Siberia showed that the determining factors of grain yield are the growing conditions (75.4%), the genotype contribution made 11.7%, the interaction of various factors – from 1.1 to 4.9% [8].

A complex of harmful organisms has a great influence on reducing the productivity of grain crops. A more flexible approach in determining the feasibility, strategy and tactics of protective measures will not only increase wheat yields, but also reduce the environmental risks associated with the unreasonable use of chemical plant protection products. Therefore, effective protection of grain crops against leaf-stem diseases is becoming ever more urgent [9].

Rapeseed production is increasing intensively in developed agricultural countries, especially in temperate climate zones. The experience of European countries and Canada shows that the problem of protein for the feed processing industry may increase oil production through the development of rapeseed culture. In Western Siberia, the most important source of replenishment of vegetable oil and feed protein resources is wide introduction of the most valuable oil and feed culture. At the beginning of the 21st century the rapeseed crops began to expand including due to the completion of the construction of the Taurian Rapeseed Processing Plant. So, if in 2009 the area of cultivation of the crop per oil seed in the region amounted to 21.5 thousand hectares, in 2015 – 56.9 and in 2018 it reached 155 thousand hectares or over 10 years increased 7.2 times with a yield of less than 1.0 t/ha [10]. Mainly after rapeseed, spring soft wheat is sown, but the corresponding agricultural technology has not been studied enough and seems quite relevant.

The purpose of the study is to establish the efficiency of agronomic approaches in combination with the use of intensification agents for the productivity and quality of spring wheat grains in crop rotation after soybean and rapeseed precursors.
2. **Conditions, objects and methods of study**

The study of technological approaches to the cultivation of spring soft wheat was carried out in 2011-2015 in the Laboratory of Resource-Saving Agricultural Technologies in the south-forest-steppe zone of Omsk Agrarian Research Center in Omsk region.

Spring soft wheat (Omsk 36 variety) was sown in a four-year crop rotation with succession cropping: soybeans – spring wheat – spring rape – spring wheat.

The two-factor stationary test studied 3 soil treatment systems and 5 versions of the use of intensification agents.

The soil treatment systems included the following:

1) moldboard plowing (ploughing every 20-22 cm, annually);
2) combined plowing (without basic treatment for rape, ploughing for soy, flat cutting for spring wheat);
3) flat-cut (ploughing every 10-12 cm, annually).

The variants using chemical agents included control (without chemization), application of herbicides in various combinations (graminicides+dicoticides), fungicide against leaf-stem diseases, and a growth regulator to reduce lodging. Crop treatment with ОP-2000 with fluid flow rate amounting to 200-300 l/ha.

The spring wheat was planted in May 20-25 by row cropping SZ-3.6 with a seeding rate of 160 kg/ha (4.5 million viable seeds per hectare), single-phase harvesting with SAMPO-130 machine. The experiment was performed four times.

3. **Results and discussion**

Long-term observations showed that the efficiency of different intensity soil treatment systems in crop rotation is largely determined by the use of chemicals, precursor and hydrothermal conditions of the year.

The studies revealed that with the increase in the number of agents, the yield of spring wheat grain increases. Thus, on the rape precursor, the use of herbicides and fertilizers increased the crop productivity by 0.61 t/ha or 51.3%, when using complex chemization the increase made 1.50 t/ha (126%) compared to the control version. The spraying of wheat crops with fungicides and retardant allowed obtaining an increase of 0.89 t/ha (49.4%) relative to the herbicide and fertilizer version. Considering soybean as a precursor, this culture allows obtaining the largest increase of wheat grain by almost 1.3-1.5 times compared to rapeseed when using intensification agents (Figure 1).

When wheat is grown after rapeseed without the use of chemical agents, higher productivity was obtained in versions with moldboard and flat-cut soil treatment in crop rotation – 1.25-1.22 t/ha, with an excess of up to 0.13-0.16 t/ha (12-15%) above the combined one. The greatest productivity of spring wheat in the moldboard version is associated with better aeration, reduction of impurities, improvement of nutritive regime and soil mineralization in relation to resource-saving treatments (Figure 2).

Against the background of complex application of chemical agents, the greatest productivity was obtained in resource-saving combined version – 2.78 t/ha.

The cultivation of spring wheat after soy precursor under control (without chemization) or limited optional use of chemical agents shows a clear decrease of productivity as the intensity of soil treatment decreases from moldboard to flat-cut version by 0.38-0.62 t/ha or by 15.6-35.6%. Against the background of complex application of chemization agents, the highest grain yield was obtained in moldboard soil treatment system – 3.55 t/ha with an excess of 0.60 t/ha or 20.3% above the flat-cut version.
Thus, with different intensity of effects on the soil, a pattern for changing grain yields was revealed. Soy precursor contributed to higher productivity of wheat grains by 0.22-0.67 t/ha (11.6-35.0%) than rapeseed.
The gain of wheat grain after rapeseed (t/ha) from the use of chemicals amounted to: herbicides – 0.48 (40.3%), fertilizers – 0.55 (46.2%), herbicides and fertilizers – 0.61 (51.3%), fungicides – 0.59 (32.8%), retardants – 0.30 (12.6%), complex chemization – 1.50 or 2.26 times higher than the control.

The gain of wheat grain after soybean from the use of chemical agents amounted to: herbicides – 0.82 t/ha (60.3%), fertilizers – 0.51 (37.5%), herbicides and fertilizers – 1.02 (75.0%), fungicides – 0.53 (22.3%), retardants – 0.39 (13.4%) and their complex combination – 1.94 t/ha or 2.43 times higher than the control (without chemization).

Table 1. Quality of spring wheat grain from different soil treatment variants according to extensible background and complex chemization, 2011-2015

| Variant          | Extensive background | Intensive background | Rapeseed precursor | Soy precursor |
|------------------|----------------------|----------------------|--------------------|--------------|
|                  | thousand grain weight, g | natural weight, g/l | protein, % | gluten, % | yield, t/ha | thousand grain weight, g | natural weight, g/l | protein, % | gluten, % | yield, t/ha |
| Moldboard        | 31.4                 | 724                  | 10.3             | 19.8       | 1.25       | 35.4                     | 728                  | 11.9       | 23.4       | 2.64       |
| Combined         | 31.4                 | 724                  | 10.8             | 19.8       | 1.09       | 35.8                     | 732                  | 12.0       | 23.8       | 2.78       |
| Flat-cut         | 32.1                 | 724                  | 11.1             | 22.4       | 1.22       | 37.0                     | 738                  | 11.7       | 24.1       | 2.65       |
| Average          | 31.6                 | 724.0                | 10.8             | 20.7       | 1.19       | 36.1                     | 732.7                | 11.9       | 23.8       | 2.69       |

The grain quality is the grain production intensification factor, which includes the genotype of the variety, weather and agrotechnical conditions of spring wheat cultivation. During the study, the technological properties of wheat grains were influenced by the precursor, the chemization agents and the soil treatment system (Table 1).

The significance of the precursor in wheat sowing in the production of high-grade grain is quite high.

When cultivating spring soft wheat after soy precursor compared to rapeseed, the technological quality indicators against intensive background increased in terms of protein content in grain – by 6.7% (11.9-12.7%), gluten – by 8.4% (23.8-25.8%) and grain yield – by 23% (2.69-3.30 t/ha), which is mainly caused by soil enrichment with available forms of nitrogen after soy precursor.

The use of resource-saving soil treatment systems does not deteriorate the main parameters of spring wheat quality for both precursors, balanced nutrition during the growing season made it possible to increase the gluten content by 15% (20.7-23.8%) and by 25% (20.6-25.8%).

4. Conclusion

Thus, the productivity of spring soft wheat cultivated after soybean and rapeseed precursors in the forest-steppe of Western Siberia is determined by the level of agrotechnologies, the use of intensification agents within the soil treatment system in crop rotation. The technological methods had a significant impact on the state of agrophytocenosis. The resource-saving combined soil treatment system holds the leading position (2.78 t/ha) with the integrated use of intensification agents and a significant increase in the yield of spring wheat after the rapeseed precursor (an average of 2.69 t/ha). After the soy precursor, the grain productivity was higher, so on average within complex chemization it made 3.30 t/ha, with moldboard energy-consuming soil treatment system being ahead – 3.55 t/ha.
The largest thousand grain weight, protein content and gluten content for both precursors were observed in a flat-cut version of soil treatment with the improvement of technological parameters during complex chemization.

In the southern forest-steppe agrolandscapes of Western Siberia, the rational integrated chemical management and resource-saving flat-cut and combined soil treatment systems in field crop rotation when growing spring wheat after rapeseed and soybean precursors, optimize soil and grain quality, stabilize and increase crop productivity by 1.19-3.30 t/ha (14-23%).

References
[1] Khramtsov I F and Yushkevich L V 2013 *Steam field resources in the forest-steppe of Western Siberia* (Omsk)
[2] Belan I A, Rosseeva L P, Nemchenko V V and Ketov A A 2015 Comprehensive breeding and seed breeding in the conditions of Western Siberia and the Urals *Bulletin of Altai State Agrarian University* 1(123) 5-10
[3] Popolzukhin P V and Vasilevsky V D 2014 Formation of a modern system of seed farming of grain crops in Western Siberia: achievements, problems and prospects *Role of phytosanitary inspection for modern technologies of plants protection and the system of seed farming as a basis of effective agricultural production: information-analytical materials for the meeting of branches of the Federal State Budgetary Institution Rosselkhoztsentr Ch. 4.4* pp 71-77 (Omsk)
[4] Koshelev B S, Stukach V F and Khramtsov I F 2011 *Multicultural agriculture of the region: state, development prospects* (Omsk: OmSAU)
[5] Khamova O F, Yushkevich L V, Voronkova N A, Boyko V S and Shuliko N N 2019 *Biological activity of meadow-chernozem soils of Omsk Irtysh Land* (Omsk: Omskblankizdat)
[6] Lomanovsky A V, Korchagina I A, Yushkevich L V and Malinina A I 2016 Agrotechnology and development of root rot of spring wheat in the forest-steppe of Omsk region *Bulletin of Omsk SAU* 4(24) 26-33
[7] Yushkevich L V and Ershov V L 2015 Optimization of soil protection agricultural technologies in the forest-steppe agricultural landscapes of Western Siberia *Bulletin of Omsk SAU Special issue* 2 64-67
[8] Seituarova A D, Popolzukhina N A, Khamova O F and Popolzukhin P V 2019 *Effectiveness of diazotrophic bacterization of spring soft wheat* (Omsk: Omskblankizdat)
[9] Yushkevich L V, Schitov A G and Ershov V L 2016 Comparative productivity of spring wheat in resowing in the southern forest-steppe of Western Siberia *Bulletin of Omsk SAU* 2(22) 25-31
[10] Kubasova E V 2016 Factors for regulating the number of rapeseed flowers in the southern forest-steppe of Western Siberia *Bulletin of Omsk SAU* 3(23) 63-67