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# Effect of different pesticides combined with Melafen on grain yield and quality of winter wheat

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**Abstract.** The use and search for new pesticides ensuring high and stable yields is one of the topical issues in winter wheat growing. The aim of the study was to develop theoretical foundations and farming practices for highly productive winter wheat through the use of pesticides of different groups in the southern forest-steppe of the Republic of Bashkortostan. An experiment (2016–2019) with 4 main blocks was conducted to determine the optimal combination of pesticides in cultivation of winter wheat. The pesticides were used at the tillering ((ZGS) 25) and heading stages ((ZGS) 59) of wheat growth. The experiment was replicated 4 times. The study results show that pesticides used to treat winter wheat increased grain yield and improved grain quality characteristics. The best results were reached in the block where treatment included Melafen plant growth promoter combined with the insecticide, herbicide and fungicide at different stages of winter wheat growth. The pesticides used in the experiment confirmed their efficiency. On the whole, the block of variants that used seed treatment produced a yield of 3.33–6.37 t $ha^{-1}$. The new plant growth promoter Melafen worked well in the experiments on winter wheat, especially in combination with pesticides in different variations. It produced the highest grain yield (6.36–7.41 t $ha^{-1}$). All experiment variants demonstrated positive economic efficiency. The study results may be useful in developing winter wheat cultivation practices aimed at increasing yields and improving grain quality.

**Key words:** winter wheat, herbicide, insecticide, fungicide, plant growth promoter, Melafen.

## INTRODUCTION

Crop farming produces more than 50% of all agricultural products in Russia. Grain farms take the leading position in crop farming. Grain crops have occupied 57.7–58.1% of all cultivated areas of the country over the past ten years. The Russian Federal State Statistics Service reported that as of 2019 the average annual wheat yield was 1.77–3.12 t $ha^{-1}$ for 2008–2018 (Federal State Statistics Service, 2019). The low grain yields are due to the fact that the applied farming practices were not adapted for use in specific soil and climatic conditions of farms. The choice of the integrated pest, weed and disease management is particularly important (Sandukhadze, 2016).

Winter wheat is one of the most important, most valuable and high-yielding grain crops (Litke et al., 2019). Wheat grain contains 11–20% protein, 63–74% starch, about

2% fat and the same amount of fibre and ash. The most important indices characterizing the quality of wheat are protein and gluten values (Litke et al., 2018). The protein content determines the use of wheat. For instance, grain with 14–15% of protein is required for breadmaking and grain with 17–18% of protein is required for producing pasta (Posypanov et al., 2006).

The current market conditions as well as various ways of wheat use and the need to meet the country's requirements are key factors for increasing grain yield and quality and developing innovative technologies that ensure environmentally safe products and better production efficiency (Pomortsev, 2019). Pesticides are widely used in European crop production to stabilize yields and mitigate losses from weeds, diseases and insects. Substantial crop yield and associated economic losses can occur if weeds are not adequately controlled (Pacanoski & Mehmeti, 2019). While all farmers use herbicides and fungicides in winter wheat, the dairy farmers use significantly fewer insecticides and plant growth regulators in winter wheat. Farmers cultivating more than 150 ha had higher pesticide intensity than farmers with small farms, which was observed for both sandy and clay soil farmers (Jørgensen et al., 2019).

The use of plant growth promoters is a promising and rapidly growing area in farming development (Masterov et al., 2017). Plant growth promoters improve the efficiency of using the genetic potential of crops and high soil fertility (Kargin et al., 2011). Synthetic growth promoters as counterparts of natural phytohormones are of particular interest. The substances have a specific range of physiological activity that reduces many properties of phytohormones on the one hand and enhances the protective effect on the other hand (Kochmin & Bogomazov, 2016). Currently, there are about 40 winter wheat growth promoters recommended for use in the Russian Federation. Among them are Agrostimulin, Vitazim, Cherkaz, Obereg, Symbionta, Vympel, AgroStimul, Agropon C, Albit, Novosil, Alfastim and others (List of pesticides and agrochemicals approved for use on the territory of the Russian Federation: reference edition, 2019).

A lot of scientists from different regions of the Russian Federation are engaged in studies of plant growth promoters. The studies consider the plant growth promoters as substances that increase yield and productivity of wheat and improve grain quality (Lapa, 1998; Ismagilov et al., 2018). One of the studies focused on a synthetic plant growth promoter 'Moddus'. The study was conducted in the forest-steppe of the Middle Volga by Kochim & Bogomazov (2016). They pointed out that the use of the plant growth promoter in spraying of winter wheat crops increased in the leaf surface area by 2.9–5.6 thousand square metres per hectarecompared to the control. The plant growth promoter Moddus increased the 1,000 kernel weight by 0.41–2.50 g. It reduced the height of crops, strengthened the stem and thus increased the crop resistance to lodging. The plant growth promoter Moddus increased the winter wheat yield depending on the treatment time and rate by 5.5–8.6% compared to the control practice. The crop treatment increased the grain bulk density by 14–16 g on average. Profitability rose from 86 to 124% (Kochmin, 2015).

Gruznova et al. (2018) revealed that plant growth regulators had the potential to reduce the effect of heavy metals on winter wheat crops. They studied the influence of a natural plant growth regulator Ribav–Extra and ions of heavy metals (HM) Pb2+, Cu2+, Zn2+ and Ni2+ on the physiological and biochemical indices of the winter wheat (*Triticum aestivum* L.) cultivar 'Mironovskaya 808'. The wheat plants, whose seeds had been treated with Ribav-Extra, were heavier metal-resistant than the untreated ones (Gruznova et al., 2018).

Zhang et al. (2019) found that a plant growth regulator had a positive effect on winter wheat effectiveness. Plant growth regulators also increased the grain filling rate during the 14 days after anthesis, thereby increasing grain weight. The grain number per spike, 1,000-kernel weight, and yield per plant after harvest were also significantly enhanced ($p < 0.05$). Thus, spraying plant growth regulators at the booting stage relieved the adverse effects on physiological activity in wheat flag leaves caused by chilling stress, and 6-BA and SA were particularly effective (Zhang et al., 2019).

Korshunov et al. (2015) studied the effect of synthetic growth promoters (Bigus, Carvitol) on winter wheat. The study was conducted on the farm 'Barsuk T.L.' in Pavlovsky district of the Northern zone of Krasnodar Krai in 2011–2013. Treatment of seeds with the study promoters increased the density of standing plants by 4–8% compared to the control; it enhanced the energy of germination and germination rates. The treatment increased the energy of germination and germination rates and improved productive plant stand. Bigus and Carvitol growth promoters increased this plant density by 50 and 64 number of stems $m^{-2}$ or by 10.1 and 13.0%. The study growth promoters increased the yield by 0.201–0.451 t $ha^{-1}$ (4.51–10.0%) compared to the control. The study found that protein and gluten values rose, grain bulk density and vitreous aspects improved as well (Korshunov et al., 2015).

It should be borne in mind that most of the currently used plant growth promoters are classified as chemical compounds and pollute the environment. They are toxic substances that have a cumulative effect, in some cases they produce a mutagenic effect and may lead to cancer. In this regard, environmentally safe practices of growing agricultural crops prefer growth promoters of the plant origin (Kuznetsov et al., 2019). Also, particular attention should be paid to the application methods and crop treatment mechanisms (Gabitov et al., 2018).

Ecosil is a plant growth promoter of natural origin. It activates metabolic processes, immunity, resistance to diseases and adverse environmental conditions, increases productivity and improves product quality. Ecosil is designed for pre-sowing treatment of seeds and sowing material, as well as for spraying of cultivated and ornamental plants during the growing season. It is recommended for use on 28 cultivars. Masterov et al. (2017) studied the influence of the product on winter wheat. The study was conducted on the educational and experimental crop rotation plot of the Arable Farming Department on the territory of ‘Experimental fields of Bashkir State Agricultural Academy’ in 2009–2014. The plant growth promoter Ecosil increased grain yield by 0.20–0.24 t $ha^{-1}$, these were the average data for the study years.

Ishkov (2017), studied treatment of winter wheat with plant-based growth promoters Narciss and Stabilan. The study was conducted on dark gray forest soils of the experimental field, the Soil Science, Arable Farming and Crop growing Department at Kursk State Agricultural Academy in 2013–2014. The study results demonstrated that pre-sowing seed treatment improved wheat grain quality. The study revealed an increase of 5.1–5.4% in gluten with Stabilan, and an increase of 6.7–7.0% in gluten with Narciss. The combined use of Vincent, SC (2.0 L $t^{-1}$) + Narciss, aq.sol. (1 L $t^{-1}$) increased the productive tillering capacity by 24.5–25.0%, the number of kernels per head by 30.9–31.2%, the kernel weight taken from one head by 0.31 – 0.36 g compared with the control. Combination of Vincent, SC (2.0 L $t^{-1}$) + Narciss, aq.sol. (L $t^{-1}$) produced a higher yield of winter wheat. The yield gain was 0.95 t $ha^{-1}$, the figure exceeded the control variant by 19.5–19.8%. The variant where the fungicide Lamador (0.2 L $t^{-1}$) and the plant growth promoter Stabilan, aq.sol. (2.0 L $ha^{-1}$) were applied at the pre-sowing stage showed the best technological quality indices at the stage of tillering and stem extension. Gluten value reached 26.3%, exceeding the control variant by 2.5–2.8% (Ishkov, 2017).

Soft red winter wheat (SRWW) is an important crop in the mid-Atlantic (Kleczewski& Whaley, 2018). The use of growth regulators such as trinexapac-ethyl (TE) applied with nitrogen applications at pseudo-stem erection [Zadocks (ZGS) 30] has gained more interest in the region as a means to potentially reduce lodging and improve yields. Fungicide use has also increased, with many growers applying fungicides at ZGS 30 and again at ZGS 37 or 60 (Zadoks et al., 1974). These results indicate that TE can be used safely in SRWW production when applied alone or when tank mixed with a fungicide; however, the effect on plant height reduction and potential impact on lodging may be reduced in situations where fungicides are used (Kleczewski & Whaley, 2018).

Synthesis of new preparations with a wide range of biological activity is of great interest. A synthetic plant growth promoter Melafen is a product developed at Institute of Organic and Physical Chemistry named after A.E. Arbuzov (Kazan research centre of the Russian Academy of Sciences. The product is melamine salt of bis (oxymethyl) phosphinic acid. Melafen belongs to nanotechnological preparations. The concentration of the active substance in the solution when exposed to seeds varies between 10–9 – 10–8%. Melafen regulates energy metabolism during seed germination, creating a favorable energy balance, increases the biological usefulness of seeds. Processing of winter wheat seeds with a solution of the drug ‘Melafen’ in the optimal concentration, strengthens the shaping processes, rational redistribution of accumulated assimilates into economically valuable organs and, thus, increases the yield and quality of grain (Fattakhov et al., 2014).

The review of studies on application of various growth promoters in winter wheat arouses great interest for the issue. In this regard there was a need for a comprehensive study on combined treatment of crops with insecticides, fungicides and herbicides. The aim of the study was thus to develop theoretical foundations and farming practices for highly productive winter wheat through the use of pesticides of different groups in the southern forest-steppe of the Republic of Bashkortostan. The experiment used pesticides for various purposes: Imidor-insecticide system action to combat a wide range of pests on potatoes, cucumbers, tomatoes, sugar beets, cereals, pastures. Active substance Imidacloprid, 200 g $L^{-1}$, water-soluble concentrate. The chemical class is neonicotinoids. Polaris is a fungicidal mordant intended for pre-sowing treatment of grain seeds. Active substance - (100 g $L^{-1}$ prochlorase + 25 g $L^{-1}$ limazalil + 15 g $L^{-1}$ tebuconazol), microemulsion. Chemical class-imidazoles + triazoles. The title Duo is a systemic fungicide designed to combat a wide range of diseases on grain crops. The active substance is propiconazol + tebuconazol. Preparation form: concentrated colloidal solution. Garnet is a post-emergence herbicide of systemic action for control of dicotyledonous weeds, including those resistant to 2,4-D and MSRA, in crops of grain crops. Water-dispersible granules containing 750 g $kg^{-1}$ tribenuron-metil. Studies conducted by Rebouh et al. (2019) and Khaibullin et al. (2018) support the chosen direction of our research.

In accordance with this, the research was aimed at solving a number of problems, including: - determining the optimal use of pesticides for the production of high-quality grain; - determining the quality indicators of winter wheat grain and commodity class; - determining the economic efficiency of winter wheat crops.

## MATERIALS AND METHODS

We conducted field experiments on the experimental field of the Department of Crop Growing, Plant Selection and Biotechnology (Bashkir State Agrarian University) in Ufa district of the Republic of Bashkortostan in 2016–2019. The experiments focused on determining the effect of seed treatment on productivity and quality of winter wheat grain. Soil characteristics were leached Chernozem of heavy loamy granulometric composition. Leached chernozems are characterized by a dark color of the humus horizon, its considerable stretch, lumpy-grained structure with nut-like separations in the sub-arable layer.The capacity of the humus horizon is 45–50 cm, the humus content is 9.7%, the pH of the salt extract is 5.6, the sum of the absorbed bases is 56 mg – equivalent at 100 g, the degree of saturation of the bases-89.2%. The conventional agricultural machinery typically used for the area was used in the experiment. The fallow land was used in the experiment.

Object of the study. The object of research was soft winter wheat (Volzhskaya K variety).

The experiment used a recognized winter wheat variety Volzhskaya K, recommended for the southern forest-steppe zone of the Republic of Bashkortostan. Brief description of the variety used. Originator: OOO NPTs [LLC Research Production Centre] 'Selektsiya'. Breeding record: The variety was bred by individual selection from the population obtained from crossing VSGI winter wheat variety with Kinelskaya 4 variety (1983). The variety entered the State Register of Varieties [2004] for the North - West (2), Central (3), Volga - Vyatka (4), Central Black Earth (5), Middle Volga (7), Ural (9) and Far East (10) regions. The variety is medium-ripening. The genus is erythrospermum. The wheat has good baking qualities; the variety is high-value wheat. The overall baking score is 4.1 points. Variety is of intensive type, winter-hardy (3.7–4.0 points), and drought-resistant (4.1 points). The wheat is susceptible to brown rust (16%). It is highly susceptible to Fusariummold (39%) and Fusarium head blight. The wheat has medium resistance to mildew (14%).

The seeding rate was 5.0 million pieces of seeds per hectare. The sowing depth was 4–6 cm. The territory of the experimental field belongs to a relatively warm, medium-moist area. Climatic conditions could be characterized as continental with dry air and a high level of solar energy. The area features sharp changes in air temperature (Table 1).

The variants were put in an order so that the plots were arranged one after another in one line. The experiment was replicated 4 times. The length of the plot was 3 meters, the width was 1.6 m, the distance between variants was 40 cm, and the protective strip was 2 m. The total area of a variant was 20.8 $m^2$ and the registration area was 1 $m^2$. The area under experiment was 800 $m^2$. Before sowing the seeds were treated according to the experiment pattern. Melafen was applied at of 10 ml $t^{-1}$, Klen-PSB-0.1seed treater was used to apply Polaris fungicidal chemical at 1.5 L $t^{-1}$. Cz-3.6 drill was used to seed the crops. SCCS-6A rollers attached to DT-75M tractor were used after the sowing. The following seed treatment was done under the experiment pattern: Granat systemic herbicide at 25 g ha$^{-1}$, Imidor insecticide at 60 mm ha$^{-1}$, Titul Duo fungicide at 250 mm ha$^{-1}$, Melafen growth promoter at 5 mm ha$^{-1}$ and Polaris fungicidal chemical (100 g L$^{-1}$ prochlorase + 25 g L$^{-1}$ imazalil + 15 g L$^{-1}$ tebuconazole). The first H+I+M treatment was carried out at the tillering stage, the second I+F+M treatment was at the heading stage. Doses of applied pesticides are generally recommended for winter wheat crop in the Russian Federation (List of pesticides and agrochemicals allowed for use in the territory of the Russian Federation, 2019).

Southern forest-steppe belongs to the area with insufficient humidity. The total effective temperature is 2,110–2,290 °C. Annual rainfall is 475–570 mm. The distribution of precipitation is extremely uneven. The hydrothermal coefficient is 1.10–1.24. The down-coming active photosynthetic radiation ranges from 1,920 to 2,880 kcal ha$^{-1}$. The capacity of the humus horizon was 43–48 cm, the entire moisture content in the meter layer of the soil reached 311–347 mm. The arable layer contained the average 8.2–9.1% of humus, total nitrogen of 0.48%, phosphorus of 0.18%, potassium of 0.67%.

The following observations were done based on the conventional methods.

1. Phenological observations of wheat growth stages and determining interstage periods were taken every 10 days.

2. The linear plant growth was studied every 10 days from the shooting stage till crop harvesting by measuring the height of the plants: measurement was done at ten plot points of two discontinuous replicated variants and the average value was found.

3. The number of plants was counted on the fixed sites with an area of 0.25 m$^2$ in 2-fold repetition The plant stand was assessed in the period when the shoot formed completely and before harvesting.

4. Weeding of the planted area was assessed using quantitative and weight method at wheat growth stages.

5. Leaf surface was determined based on the stages of wheat growth. Leaf area was found using the contour method.

**Table 1.** The experiment pattern

| Seq. no. | Variant | Planted area | Tillering stage | Heading stage |
|---|---|---|---|---|
| | Control | C1 | - | - |
| | | C2 | H+I | - |
| | | C3 | - | I+F |
| | | C4 | H+I | I+F |
| | Seed Treatment | ST1 | - | - |
| | | ST2 | H+I | - |
| | | ST3 | - | I+F |
| | | ST4 | H+I | I+F |
| | | ST5 | H+I+M | - |
| | | ST6 | H+I+M | I+F |
| | | ST7 | H+I+M | I+F+M |
| | | ST8 | H+I | I+F+M |
| | | ST9 | - | I+F+M |
| | Melafen | M1 | - | - |
| | | M2 | H+I | - |
| | | M3 | - | I+F |
| | | M4 | H+I | I+F |
| | | M5 | H+I+M | - |
| | | M6 | H+I+M | I+F |
| | | M7 | H+I+M | I+F+M |
| | | M8 | H+I | I+F+M |
| | | M9 | - | I+F+M |
| | Seed Treatment + Melafen | ST+M1 | - | - |
| | | ST+M2 | H+I | - |
| | | ST+M3 | - | I+F |
| | | ST+M4 | H+I | I+F |
| | | ST+M5 | H+I+M | - |
| | | ST+M6 | H+I+M | I+F |
| | | ST+M7 | H+I+M | I+F+M |
| | | ST+M8 | H+I | I+F+M |
| | | ST+M9 | - | I+F+M |

Note: ST stands for seed treatment, M for Melafen, H for herbicide, I for insecticide, F for fungicide, C for Control.

6. Yield formula for winter wheat. We determined the number of productive stems, plant height, head length, number of spikelets per head, number of kernels per height, grain weight per head.

7. The chemical composition of grain and grain vitreousness were analysed in the laboratory of the Bashkir State Agrarian University (the National Standard GOST 54478-2011 method for determining the quantity and quality of gluten in grain, the National Standard GOST 10987-76 method for assessing grain vitreousness.

8. Grain bulk density was measured under the national standard GOST 10840-2017. A litre grain-unit scale was used to measure the grain bulk density: a 2 kg sample of cleaned grain taken from the mean sample was weighed. Each sample was measured twice and the average value with an accuracy of 1 g was obtained.

9. Grain class was determined under GOST 9353-90 for wheat, storage and shipment requirements. We conducted our study in accordance with the procedural guidelines developed by Dospekhov et al. (1987), the state commission for testing agricultural crop varieties (Fedyn, 1983) and the Methodology instructions developed by the Russian Academy of Agricultural Sciences (1997). Statistical methods (dispersion, regression and correlation analyses) were used to analyse experimental results. STATISTICA 5.0 software package for Windows was employed (Rushninsky, 1971).

## RESULTS AND DISCUSSION

Our study revealed that the winter wheat stand density tended to decrease as the crop matured. In the tube exit phase (ZGS 40) the index ranged from 615 stems $m^{-2}$ in variant 1 (Control) to 917 stems $m^{-2}$ in variant 14 (Melafen). By the milk maturity stage (ZGS 75) variant 5(ST) and variant 1 (C) showed the lowest indices of 284 stems $m^{-2}$ and 396 stems $m^{-2}$, respectively, they lagged behind the variant with the highest index by 576 stems $m^{-2}$ and 464 stems $m^{-2}$, respectively. Variant 14 (M) showed the best result of 860 stems $m^{-2}$. The high performance of variants with growth stimulant treatment is confirmed by the results of Jørgensen L.N., Kudsk P. & Ørum J.E. (2019).

At the complete maturity stage the plant stand density varied from 260 stems $m^{-2}$ in variant 5 (ST) to 820 stems $m^{-2}$ in variant 14 (M). Among the variants that used pre-sowing treatment variant 14 (M) had the highest index of stand density, the index was 820 stems $m^{-2}$ and the value was 2.8 times higher than variant 1 (Control). Application of herbicide+insecticide at the tillering stage resulted in that variant 15 treated with Melafen reached the value of 756 stems $m^{-2}$, thus demonstrating the optimal index with the treatment pattern. Variant 24 (ST+M) had the lowest index of 564 stems $m^{-2}$.

The analysis of the correlation dependence of the density of standing on the pesticides used in the experiment and their combination according to the experimental scheme revealed a number of relationships. Variant (Control) has a dependence above the average (r = 0.693–0.701), variant (Seed Treatment) - above the average (r = 0.685–0.691), variant (Melafen) has a high dependence (r = 0.825–0.854), variant (Seed Treatment + Melafen) - above average and high (r = 0.781–0.829).

The study showed that in 2018 winter wheat had different standing height depending on the growth stage and treatment type. At the booting stage the indices varied from 39.9 cm (ST+M) to 58.2 cm (C). At the heading stage variant 20 (M) and variant 31 (ST+M) showed the highest indices of 92.6 cm and 91.9 cm, respectively. At the milk maturity stage variants where pre-sowing ST+M treatment was done demonstrated the optimal results: variant 26 had the height of 100.0 cm and variant 23 had the height of 98.1 cm. The lowest indices were found in variant 3 (Control) at 79.9 cm and variant 10 (ST) at 80.8 cm. At the complete maturity stage, the indices varied depending on the treatment from 110 cm in variant 19 (M), to 84 cm in variant 3 (Control). Variant 19 (M) showed the best index of winter wheat height at 110 cm treated with H+I+M at the tillering stage and with I+F at the heading stage. Seed treatment produced the best results when the crop was H+I+M treated at the tillering stage (variant 9) and I+F+M treated at the heading stage (variant 13). ST+M treatment reached the greatest results when the crop was H+I treated at the tillering stage and I+F treated at the heading stage (variant 26).

Our research shows a positive effect of the growth stimulant Melafen on the growth processes of winter wheat. However, in the studies of Korshunov et al. (2015), the use of the growth stimulator Modus led to a decrease in the height of winter wheat plants, which we explain not by rational redistribution of accumulated assimilates, since the regulators have different chemical composition. The behavior of the growth regulator can be influenced by the weather factor, as our previous research shows.

The issue of grain quality is one of the major issues in grain production as the quality has a direct effect on the cost of grain. To improve wheat grain quality is particularly relevant as the grain protein and gluten values tend to drop over the past few years. The grain quality in winter wheat was determined by the year conditions at the waxy maturity stage. For instance, low temperatures and high precipitation in 2018 resulted in a longer ripening period. This had a negative effect both on the grain bulk density due to feeble and shriveled grain and the gluten weight ratio and quality (Table 2).

**Table 2.** Quality indices of winter wheat grain (Scientific training centre at Bashkir State Agrarian University, 2016–2019)

| Seq. no. | Crude gluten weight ratio, % | Gluten quality group | Grain bulk density, g $L^{-1}$ | Vitreousness, % | Class |
|---|---|---|---|---|---|
| 1 | 28.04 | Group 2 | 671 | 98 | 3 |
| 2 | 29.72 | Group 2 | 746 | 97 | 3 |
| 3 | 30.84 | Group 3 | 717 | 90 | No class |
| 4 | 32.28 | Group 2 | 749 | 97 | 3 |
| 5 | 31.60 | Group 2 | 708 | 96 | 3 |
| 6 | 28.80 | Group 2 | 740 | 98 | 3 |
| 7 | 28.56 | Group 2 | 749 | 97 | 3 |
| 8 | 27.64 | Group 2 | 751 | 98 | 3 |
| 9 | 28.32 | Group 2 | 752 | 95 | 3 |
| 10 | 29.36 | Group 2 | 748 | 95 | 3 |
| 11 | 26.92 | Group 2 | 758 | 99 | 3 |
| 12 | 29.60 | Group 2 | 754 | 98 | 3 |
| 13 | 30.80 | Group 2 | 752 | 96 | 3 |
| 14 | 28.12 | Group 2 | 734 | 96 | 3 |
| 15 | 29.52 | Group 2 | 750 | 97 | 3 |
| 16 | 28.84 | Group 2 | 767 | 97 | 3 |
| 17 | 28.24 | Group 2 | 754 | 97 | 3 |
| 18 | 29.00 | Group 2 | 754 | 97 | 3 |
| 19 | 29.00 | Group 2 | 770 | 97 | 3 |
| 20 | 29.84 | Group 2 | 765 | 97 | 3 |
| 21 | 29.60 | Group 2 | 759 | 94 | 3 |
| 22 | 28.80 | Group 2 | 772 | 97 | 3 |
| 23 | 31.00 | Group 2 | 757 | 99 | 3 |
| 24 | 28.96 | Group 2 | 741 | 97 | 3 |
| 25 | 28.84 | Group 2 | 762 | 97 | 3 |
| 26 | 30.44 | Group 2 | 763 | 96 | 3 |
| 27 | 28.12 | Group 2 | 756 | 96 | 3 |
| 28 | 29.56 | Group 2 | 752 | 97 | 3 |
| 29 | 28.52 | Group 2 | 761 | 97 | 3 |
| 30 | 29.24 | Group 2 | 761 | 97 | 3 |
| 31 | 29.00 | Group 2 | 763 | 96 | 3 |

Note: red colour stands for class 1, blue colour for class 1–2 and yellow colour for class 3.

Variant 4 had the highest gluten weight ratio index of 32.28%, the index is characteristic of the first quality group; the rest belonged to the second quality group. All variants except variant 8 and variant 11 had the indices of strong wheat; variants 8 and 9 had the indices of high-value wheat. All of the treated variants except for variant 3 belonged to wheat class 3 based on quality indices such as gluten weight ratio, grain bulk density and vitreousness. This is due to the fact that based on the gluten weight ratio the variants belong to the second group, i.e. wheat class 3, though most of the variants suit wheat class 1 or 2 based on grain bulk density and vitrousness indices.

**Table 3.** Economic efficiency of winter wheat grain (Scientific training centre at Bashkir State Agrarian University, 2016–2019)

| Seq no. | Variant | Yield, t ha$^{-1}$ | Gross output value, rouples per hectare | Production costs per 1 hectare | Notional net return from 1 hectare, roubles | The cost price of 1 centner (100 kg) of grain, rubles | Profitability, % |
|---|---|---|---|---|---|---|---|
| | C1 | 4.54 | 39,952.0 | 27,165.0 | 12,787.0 | 598.4 | 47.0 |
| | C2 | 5.00 | 44,000.0 | 27,635.0 | 16,365.0 | 552.7 | 59.2 |
| | C3 | 4.21 | 37,048.0 | 27,576.0 | 9,472.5 | 655.0 | 34.3 |
| | C4 | 4.85 | 42,680.0 | 26,922.0 | 15,758.0 | 555.1 | 58.5 |
| | ST1 | 3.33 | 29,304.0 | 27,328.0 | 1,975.6 | 820.7 | 7.2 |
| | ST2 | 4.78 | 42,064.0 | 27,913.0 | 14,151.0 | 584.0 | 50.7 |
| | ST3 | 5.15 | 45,320.0 | 27,990.0 | 17,330.0 | 543.5 | 61.9 |
| | ST4 | 6.15 | 54,120.0 | 28,521.0 | 25,599.0 | 463.8 | 89.7 |
| | ST5 | 6.01 | 52,888.0 | 28,271.0 | 24,617.0 | 470.4 | 87.0 |
| | ST6 | 5.92 | 52,096.0 | 28,696.0 | 23,400.0 | 487.7 | 81.5 |
| | ST7 | 6.26 | 55,088.0 | 28,931.0 | 26,157.0 | 462.2 | 90.4 |
| | ST8 | 6.37 | 56,056.0 | 28,743.0 | 27,313.0 | 451.2 | 95.0 |
| | ST9 | 6.21 | 54,648.0 | 28,313.0 | 26,335.0 | 455.9 | 93.0 |
| | M1 | 6.36 | 55,968.0 | 27,572.0 | 28,396.0 | 433.5 | 102.9 |
| | M2 | 6.54 | 57,552.0 | 28,014.0 | 29,538.0 | 428.3 | 105.4 |
| | M3 | 7.00 | 61,600.0 | 28,089.0 | 33,511.0 | 401.3 | 119.3 |
| | M4 | 7.19 | 63,272.0 | 28,519.0 | 34,754.0 | 396.6 | 121.8 |
| | M5 | 6.67 | 58,696.0 | 28,223.0 | 30,473.0 | 423.1 | 107.9 |
| | M6 | 7.15 | 62,920.0 | 28,723.0 | 34,197.0 | 401.7 | 119.0 |
| | M7 | 7.41 | 65,208.0 | 28,958.0 | 36,250.0 | 390.8 | 125.1 |
| | M8 | 7.32 | 64,416.0 | 28,747.0 | 35,669.0 | 392.7 | 124.0 |
| | M9 | 7.09 | 62,392.0 | 28,298.0 | 34,094.0 | 399.1 | 120.4 |
| | ST+M1 | 6.31 | 55,528.0 | 27,881.0 | 27,647.0 | 441.9 | 99.1 |
| | ST+M2 | 6.32 | 55,616.0 | 28,295.0 | 27,321.0 | 447.7 | 96.5 |
| | ST+M3 | 6.87 | 60,456.0 | 28,383.0 | 32,073.0 | 413.1 | 113.0 |
| | ST+M4 | 6.36 | 55,968.0 | 28,738.0 | 27,230.0 | 451.9 | 94.7 |
| | ST+M5 | 6.26 | 55,088.0 | 28,483.0 | 26,605.0 | 455.0 | 93.4 |
| | ST+M6 | 6.39 | 56,232.0 | 28,938.0 | 27,294.0 | 452.9 | 94.3 |
| | ST+M7 | 6.10 | 53,680.0 | 29,115.0 | 24,566.0 | 477.3 | 84.3 |
| | ST+M8 | 5.89 | 51,832.0 | 28,879.0 | 22,953.0 | 490.3 | 79.4 |
| | ST+M9 | 6.41 | 56,408.0 | 28,536.0 | 27,872.0 | 445.2 | 97.6 |

Economic efficiency of cultivating winter wheat varieties was measured and a positive effect was marked in all variants. Table 3 shows that the gross output value was determined by the yield obtained in the experiment. The control variant had 4.21–4.85 t $ha^{-1}$or 37.0–44.0 thousand roubles per hectare. Variant 2 (Control) with H+I treatment at the tillering stage showed the best efficiency. Seed treatment with Polaris chemical increased grain yield to 4.78–6.37 t $ha^{-1}$ when crops were treated with pesticides during the growing season; the chemical reduced the yield to 3.33 t $ha^{-1}$ in variant 5 compared to the control index of 4.54 t $ha^{-1}$. As a result, the gross output value amounted to 29.3–56.0 thousand roubles in this block. Variant 12 with ST +HI (tillering stage)+IFM (heading stage) reached the highest gross output value. There was a decrease of 0.09 t $ha^{-1}$ in efficiency in the block with Melafen applied at the tillering stage.

Treatment of winter wheat seeds with the ST chemical combined with the plant growth promoter resulted in an increase of 39.9–41.6% in crop yields up to 5.89–6.87 t $ha^{-1}$. Variant 25 with ST+M (pre-sowing stage)+IF (heading stage) had the top indices in this block. There was a decrease in grain yields with Melafen applied during the growing season in variants 27, 29 and 30, an increase of 0.08 and 0.1 t $ha^{-1}$ was revealed in variants 28 and 31. The results of the research are consistent with the results obtained by Korshunov et al. (2015). In their experiments, the use of growth regulators increased the yield by 0.20–0.45 $ha^{-1}$ (4.51–10.0%) in relation to the control. Also increased indicators of protein and gluten in the grain, its nature and vitreous.

The block where seeds were treated with Melafen showed the highest crop yields. The grain yield was 6.36–7.41 t $ha^{-1}$, the index exceeded the control by 51.4–52.7%. Two leading variants were found in the block: variant 20 M (pre-sowing stage)+HIM (tillering stage)+IFM (heading stage) had the grain yield of 7.41 t $ha^{-1}$ and variant 21 M (pre-sowing stage)+HI (tillering stage)+IFM (heading stage) had the grain yield of 7.32 t $ha^{-1}$. Variant 20 and variant 21 had also the highest gross output values of 65.2 and 64.4 thousand roubles per hectare, respectively.

Production costs exceeded 26 thousand roubles in all variants and ranged from 26.9 to 29.1 thousand roubles per hectare. Variant 29 ST (pre-sowing stage)+HIM (tillering stage)+HIM (heading stage) had the highest production costs. Production costs had an effect on the cost price of 1 centner of grain. The cost price of grain ranged within 390.8–820.7 roubles per centner. Variant 5 in the block where seeds were treated with Polaris chemical had the highest cost price of 820.7 roubles per centner compared to the control of 552.7–655.0 roubles per centner. The block where seeds were treated with Melafen plant growth promoter had the lowest cost price of 390.8–433.5 roubles per centner. Variant 20 had the optimal index in the experiment.

In terms of the efficiency of cultivating winter wheat it should be noted that all variants had a positive outcome as notional net return from 1 hectare amounted to 1.9–36.2 thousand roubles. The control block had the index of notional net return at 1.9–27.3 thousand roubles, the index was 28.3–36.2 thousand roubles in the block with Melafen application, the figure was 22.9–32.0 thousand roubles in the block with ST+M treatment. Variant 20 and variant 21 had the highest notional net return.

Profitability is the key indicator in assessing the economic efficiency. In the experiment indices were 7.2–125.4%. The control block had profitability indices of 34.2–59.2%. The indices were 7.23–95.0% when seeds were treated with Polaris fungicide, the figures ranged within 102.9–125.7% in the block where seeds were treated with Melafen plant growth promoter; seed treatment combined with Melafen ST+M produced 79.4–113.0%

Variants 16–22 had profitability of 107.9–125.1% demonstrating thereby stable high efficiency. Variant 2 M (pre-sowing stage) +HIM (tillering stage)+IFM (heading stage) showed the best economic efficiency.

Today, more than ever before application of pesticides in winter wheat is an urgent issue. The use of plant growth promoters is increasingly supported by scientists and manufacturers (Peng et al., 2019). At the same time, other areas of pesticide use in winter wheat are being tested (Moss et al., 2019).

In this regard, experience of Iranian researchers Shourbalal et al. (2019) may be of interest The important results of this research work are: 1) sowing winter wheat as spring wheat (vernalization not required) resulted in optimum yield amounts by priming and spraying techniques using gibberellins, kinetin and 6-benzyl adenine. This is of significance, with respect to the issue of global warming. 2) Shortening vernalization in winter wheat, which is especially important under arid and semi-arid conditions, as the plant is subjected to different stresses including drought. 3) Improving wheat grain quality by the increased rate of protein and gluten. It is possible to plant winter wheat under arid and semi-arid conditions using gibberellins, kinetin and benzyl adenine. Such a method results in alleviating the adverse effects of global warming on wheat production. It is also possible to plant winter wheat under different stresses including drought and cold by controlling the vernalization process (Sayed Shourbalal et al., 2019).

So plant growth promoters have the capacity both to speed up plant growth and slow it down. Kumar et al. (2019) conducted the experiment with retardants and had impressive findings. This study was conducted during winter season of 2016–17 and 2017–18 at Rajasthan Agricultural Research Institute, Durgapura, and Jaipur to evaluate the effect of nutrient management and growth retardants on wheat (*Triticum aestivum* L.). Results revealed that the application of 150% RDF+FYM led to higher plant height and dry matter accumulation of wheat at all the growth stages (60 days after sowing (DAS), 90 DAS and at harvest) except at 30 DAS (where it was maximum with 150% RDF). The grain, straw and biomass yields of wheat due to different growth retardant treatments were found statistically at par. The application of 150% RDF+ FYM increased the gross return by 50.74, 13.10 and 3.83% and mean net returns by 60.56, 12.96 and 3.13% over control, 100% RDF and 150% RDF, respectively (Kumar et al., 2019).

The plant growth promoter was further tested on various crops in different regions of the Russian Federation (Ulyanovsk, Kurgan, Ryazan regions, Krasnodar territory) and in Bulgaria for a number of years. The tests were conducted on winter rye, winter and spring wheat and barley, peas, fodder crops (Sudanese grass, fodder millet, spring rape), etc. The studies found that treatment of seeds with Melafen plant growth promoter increased yields from 10.0 to 34.0%. It was also found that under the influence of Melafen there was a more intense absorption of elements of mineral nutrition, it significantly increased the resistance of winter crops to stresses in the autumn and winter period and improved the quality of crop products. Melafen provided a relatively stable increase in crop yields and accelerated ripening of the crop. The plant growth promoter enhanced the tillering stage of winter wheat. Longer wheat heads and larger number of kernels per head resulted in the increased grain weight per plant. The experiments reported an increase of 12.0–12.8% in yields (Fattakhov et al., 2014).

Our experiments confirmed that application of the plant growth promoter applied for winter wheat was efficient. Melafen plant growth promoter combined with pesticides in different variations produced the maximum grain yield of 6.36–7.41 t $ha^{-1}$ while the control index was 4.21–5.00 t $ha^{-1}$. The experiment also confirmed the improved gluten quality and higher bulk density in grain due to the plant growth promoter. In contrast to previous experiments, we studied various options for the use of pesticides in combination with the growth promoter. We observed a negative effect of wheat seed treatment and a better effect that the seed treatment had when combined with Melafen plant growth promoter. The study proved that maximum efficiency of crops was achieved when the plant growth promoter was applied at all treatment stages Melafen (pre-sowing stage) + (herbicide+insecticide+Melafen (tillering stage)) + (insecticide+fungicide+Melafen (heading stage)).

## CONCLUSIONS

The study findings let us conclude that pesticides used in the experiment to increase grain yield of winter wheat and grain quality have confirmed their efficiency. High economic efficiency was characterized by the use of the growth stimulant Melafen. The control variants reached yield indices of 4.21–5.00 t $ha^{-1}$. Seed treatment with Polaris chemical led to lower yield indices in some variants, the indices were 3.33–6.37 t $ha^{-1}$ in the block with seed treatment. The plant growth promoter Melafen worked well in the experiment on winter wheat, especially in combination with pesticides in different variations. It produced the highest grain yield (6.36–7.41 t $ha^{-1}$). All experiment variants demonstrated positive economic efficiency. The notional net return from 1 hectare ranged from 1.9 thousand roubles to 36.2 thousand roubles. The control block had notional net return at 1.9–27.3 thousand roubles, the index was 28.3–36.2 thousand roubles in the block with Melafen application, and the figure was 22.9–32.0 thousand roubles in the ST + M block. Variant 20 showed the best economic efficiency in the experiment: Melafen (pre-sowing stage) + (herbicide + insecticide + Melafen (tillering stage)) + (insecticide +fungicide +Melafen (heading stage)).

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