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Effect of chemical plant protection products on yield and grain quality of winter wheat in the conditions of Central Non-Chernozem region of Russia

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ABSTRACT

Relevance. The use of phytosanitary means to ensure high and stable yields of winter wheat is one of the tasks of growing winter wheat. Field experiments were conducted in 2021 and 2022 at the Federal Research Center "Nemchinovka" in the central non-chernozem zone of the Moscow region.

Methods. *The aim of the study* is to evaluate the effect of various plant protection preparations on the productivity and quality of winter wheat varieties by intensity levels: basic (the purpose of using the biological potential of the variety by more than 50%), intensive (involving the use of intensive varieties and the creation of conditions for a more complete realization of their biological potential) and high–intensity (a set of measures aimed at ensuring the realization of the potential of the variety is more than 85%).
Treatments included fertilizers, pesticides and growth regulators in various combinations and concentrations.

Results. Three varieties of winter wheat were studied: Nemchinovskaya 85, Moskovskaya 40 and Moskovskaya 27. Insecticides (Picus 1.0 l/t, Danadim Power 0.6 l/ha, Picus 1.0 l/t + Danadim Power 0.6 l/ha, Picus 1.0 l/t + Vantex 60 ml/ha, Picus 1.0 l/t + Vincit forte 1.5 l/t and Picus 0.7 l/t + Vantex 50 ml/ha), fungicides (Impact Exclusive 0.75 l/ha, Alto Super 0.5 l/ha, Consul, CS 0.8 l/ha + Consul 1.0 l/ha and Consul, CS 0.8 l/ha), herbicides (Aton 0.06 kg/ha + Agroxon 0.5 l/ha + Foxtrot 1.0 l/ha, Exactly Extra 35 g/ha + Foxtrot 1.0 l/ha + Agroxon 0.5 l/ha, Tandem 0.03 kg/ha + Foxtrot 1.0 l/ha, Tandem 30 g/ha + Foxtrot Extra 0.4 l/ha + Agroxon 0.5 l/ha and Lintur 180 g/ha) have confirmed their effectiveness. Nemchinovskaya 85 increased yield by 1.14–3.10 t/ha, Moscow 27 — by 0.64–3.62 t/ha, Moscow 40 — 0,71–3,21 t/ha.

Key words: winter wheat, grain yield, phytosanitary products, wheat productivity, wheat varieties, non-chernozem zone

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Научная статья

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Влияние фитосанитарных препаратов на урожайность и качество зерна озимой пшеницы в условиях Центрального Нечерноземья России

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РЕЗЮМЕ

Актуальность. Использование фитосанитарных средств для обеспечения высоких и стабильных урожаев одна из задач выращивания озимой пшеницы. Полевые эксперименты проводились в 2021 и 2022 годах в Федеральном исследовательском центре «Немчиновка» в центральной нечерноземной зоне Московской области.

Методы. *Цель исследования* — оценить влияние различных препаратов защиты растений на продуктивность и качество сортов озимой пшеницы по уровням интенсивности: базовый (цель использования биологического потенциала сорта более чем на 50%), интенсивный (предполагают использование интенсивных сортов и создание условий для более полной реализации их биологического потенциала) и высокоинтенсивный (комплекс мероприятий, направленных на обеспечение реализации потенциала сорта более 85%).
Обработки включали удобрения, пестициды и регуляторы роста в различных комбинациях и концентрациях.

Результаты. Изучены три сорта озимой пшеницы: Немчиновская 85, Московская 40 и Московская 27. Инсектициды (Пикус 1,0 л/т, Данадим Пауэр 0,6 л/га, Пикус 1,0 л/т + Данадим Пауэр 0,6 л/га, Пикус 1,0 л/т + Вантекс 60 мл/га, Пикус 1,0 л/т + Винцит форте 1,5 л/т и Пикус 0,7 л/т + Вантекс 50 мл/га), фунгициды (Импакт Эксклюзив 0,75 л/га, Альто Супер 0,5 л/га, Консул, КС 0,8 л/га + Консул 1,0 л/га и Консул, КС 0,8 л/га), гербициды (Атон 0,06 кг/га + Агроксон 0,5 л/га + Фокстрот 1,0 л/га, Аккурат Экстра 35 г/га + Фокстрот 1,0 л/га + Агроксон 0,5 л/га, Тандем 0,03 кг/га + Фокстрот 1,0 л/га, Тандем 30 г/га + Фокстрот Экстра 0,4 л/га + Агроксон 0,5 л/га и Линтур 180 г/га) подтвердили свою эффективность. Немчиновская 85 увеличила урожайность на 1,14–3,10 т/га, Московская 27 — на 0,64–3,62 т/га, Московская 40 — 0,71–3,21 т/га.

Ключевые слова: озимая пшеница, урожайность зерна, фитосанитарная продукция, урожайность пшеницы, сорта пшеницы, нечерноземная зона

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Введение/Introduction

These last years, grain is the most important part of the world agricultural economy. The food security and well-being of countries are ensured by the level of cereal production as well as the capacity to increase the economic and political importance of the State in the world community [1].

Grain occupies the first place in the human diet and is essential for animal feed. According to the food and agricultural organization of the United Nations[1], world wheat production is about 770,87 million tons on a harvested area of 220,76 million ha. China, India, Russia and the United States occupy more than 50% of the total area of cereals cultivated in the world [2].

Research has shown that wheat is one of the oldest crops on the planet [3]; in Europe and Asia, it began to be cultivated in prehistoric times. More than 6.5 thousand years ago, wheat was known in Iraq, Egypt and Asia Minor, it was sown for 6000 years BC, for 3000 years BC, wheat was sown in China, Turkmenistan, Georgia, Armenia and Azerbaijan, and traces of its cultivation in the 4th millennium BC [4, 5].

The Russian Federation is currently one of the largest producers and exporters of soft wheat [6].

The total area occupied by winter and spring wheat is constantly expanding and amounts to about 28.9 million ha area harvested[2].

There has been a significant increase in the yield of winter and spring wheat varieties over the past two decades, due to the introduction and development of new high-yielding wheat cultivars. Winter wheat occupies the main sowing areas in Europe and the United States, while spring wheat predominates in the Russian Federation and Canada. Wheat has been shown to be one of the most important, valuable, and productive grain crops. The grain of wheat provides a major share of protein (20%), calorie intake (19%) from consumption and carbohydrate (80%) content for the world's population, and the value and need to increase the production is recognized widely [7]. It is widely used with spring wheat, in the bakery, pasta, confectionery industry.

Several measures and methods of caring for winter wheat crops should be applied to achieve a higher grain yield. These maintenance measures and methods therefore aim to create conditions guaranteeing better plant safety during the autumn-winter and spring-summer periods. To achieve this, plant protection is mandatory for the cultivation of high-quality winter wheat to prevent crop losses due to pests, diseases, and weeds at minimal cost.

Crop protection has been an ancestral concern since the first agricultural peoples. In the eighth century BC, plant extracts were used to protect grain stocks and biological control methods were already in use in Chinese orchards. Protection strategies were then essentially based on mechanical and biological control. During the 19th century, pathogens carried by commercial expansion caused a succession of dramatic events for crops and populations, thus reinforcing the need for protection.

At the end of the Second World War, the marketing of synthetic substances generated new hope for direct struggle and extermination. Chemical control has remained the spearhead of crop protection since the middle of the 20th century.

The global strategy for the development of agricultural production has contributed for more than 50 years to a considerable increase in the use of agricultural inputs, in particular synthetic pesticides, to reach today 2.5 million tons used each year.

The use of comprehensive protection measures against pests, weeds and diseases ensures obtaining high yields and high-quality grain products. By effectively using phytosanitary products, the production of food grain winter wheat can be increased by 1.5–2 times. The protection of winter wheat crops appears as a sustainable strategy for plant protection against crop pests, satisfying the economic, ecological and health requirements facing agriculture. The use of herbicides, fungicides and insecticides is one of the important factors in the intensification of cereal production.

The aim of this research is to substantiate the prospects of using plant protection products to improve grain yield and quality of grain and to mitigate the adverse effects of pathogens responsible for winter wheat disease, when grown in the Central Non-Chernozem region of Russia.

Материалы и методы исследований / Materials and methods

The research was carried out in 2021–2022 on the grounds of the Federal Research Center "Nemchinovska" in the Moscow region. The experimental field station of the Federal Research Center "Nemchinovskaya" is in the usual conditions of the non-Chernozem zone for the central region of the Russian Federation.

The soil is medium sodo-podzolic loam. To record the initial characteristics of this soil, samples were taken randomly from different locations at 0–15 cm. Field experiments were conducted on fields no 2 and 5 of a five-field rotation. A field survey conducted in 2020 and 2021 showed that the soil was characterized by a reaction that was within the limits of pHsalt 4.3–5.7.

Mobile phosphorus content was 155–316 mg/kg, mobile potassium availability was (125–181 mg/kg)[3].

Climatic Conditions

Weather conditions for winter crops were generally described as favorable. The hydrothermal coefficient of the winter wheat growing season was 1.50–1.52 i. e. the year of water supply was optimal. In September-early November in 2021–2022, an average daily air temperature of 5–9.7 °C (Fig. 1). In winter, the plants remained in good condition, the spring conditions allowed the plants to develop normally. Snow cover established in the second decade of December with daily mean air temperature fluctuations ranging from -3.7 °C to -5.3 °C. The average annual temperature is +4.90 °C. The average temperature of the hot season (May — August) is +15.98 °C. The average temperature of the cool season (November — March) is -5.04 °C. The average precipitation from May to September is 293.3 mm. The average annual rainfall is 623.75 mm: 56% in the spring-summer season and 26% in autumn.

The experiments were carried out during 2021–2022 according to a two-factor scheme. Varieties of winter wheat (factor A) were placed in experimental variants differing

[1] http://www.fao.org/faostat/en/#data (accessed on 12 March 2023)

[2] Federal State Statistics Service. https://rosstat.gov.ru/compendium/document/13276 (accessed: 18 March 2023).

in the level of application of plant protection products — basic technology, intensive and high-intensity (factor B). Sowing was carried out according to the following norms: winter wheat — 5 million germinating grains per hectare.

Characteristics of winter wheat varieties (factor A):

✓ "Nemchinovskaya 85" has the following qualities: mid-season, winter-hardy, resistant to waterlogging, resistant to lodging. Resistant to major types of diseases, such as snow mold, brown rust, powdery mildew, Septoria. The average yield for 3 years of testing was 8.27 t/ha, the maximum yield was 11.63 t/ha. The content of protein in grain is 14.4%, gluten in flour is 33.8%;

✓ "Moskovskaya 27" has high winter hardiness, field resistance to powdery mildew, brown and stem rust, and *Septoria*. The variety is resistant to lodging, forms a larger grain and a greater number of productive shoots per unit area. The average yield for 3 years was 8.64 t/ha. Plant height — 90–95 cm. Protein content in grain — 15.5%, gluten content up to 27.2%. The nature of the grain is 816 g/l, the weight of 1000 grains was 44–47 g;

✓ "Moskovskaya 40" is highly adaptive, short-stemmed, winter-hardy, resistant to lodging, resistant to leaf rust, powdery mildew, and common smut. The protein content in grain is 15%, raw gluten in flour is 33.7%. The average yield for 5 years was 6.74 t/ha, the maximum — 7.36 t/ha. Weight of 1000 grains — 45–48 g.

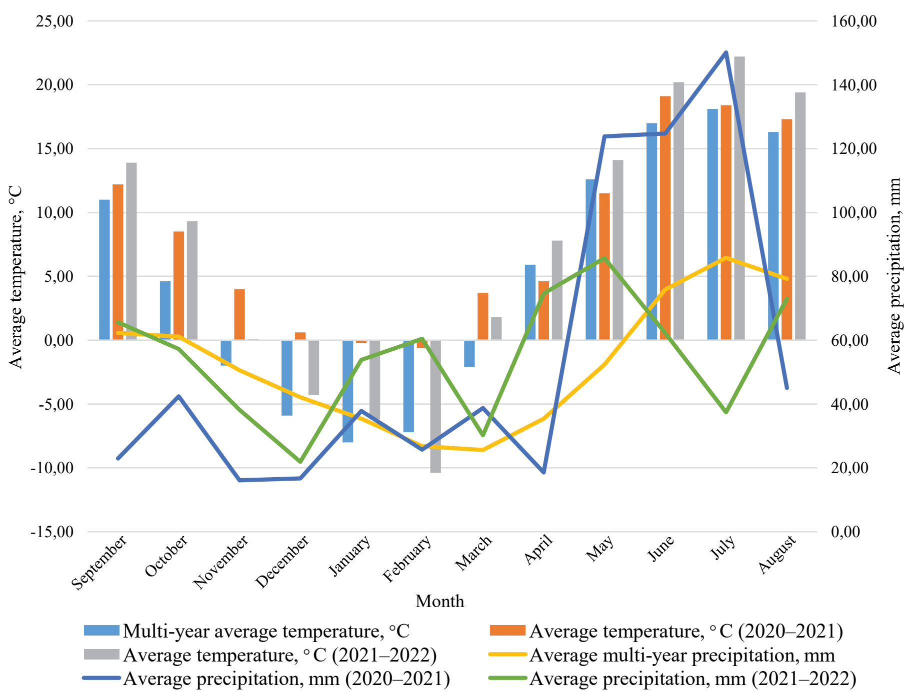
Technologies (factor B):

1. Basic technologies (also called normal technologies) aim at using the biological potential of the variety to more than 50% and their link to specific conditions of the farm is carried out using adapters, which can change depending on the production conditions which prevail. They include technologies that rely on tillage and crop care systems made up of a certain number of techniques, on the use of minimum or optimal doses of fertilizers, on the use of chemical plant protection products, closely linked to economic thresholds of harmfulness of weeds, diseases and pests. Basic technology — designed for a planned yield of 5–6 t/ha. The plant protection system is represented by a tank mixture of herbicide, insecticide, and fungicide (Lintur 180 g/ha + Danadim 1 l/ha + Impact SC 0.5 l/ha), which were applied only in autumn. In the spring protection according to the forecast.

2. Intensive technologies for agricultural crops characterized by production flow, comprehensive application of intensification factors, optimal and efficient mechanization based on the biological characteristics of plant development by phases and stages of organogenesis, taking into account the requirements plants in terms of environmental conditions and satisfying them, making it possible to control the process of crop formation and the quality of products, and to schedule cultivation. Intensive technologies are characterized by the use of rational rates of fertilizers and their fractional application of based on the results of plant diagnostics, powerful chemical protection of plants from weeds, diseases and pests, closely related to the phases of plant organogenesis. Intensive technologies involve the use of intensive varieties and the creation of conditions for more complete realization of their biological potential. Intensive technology — the planned yield is 6–8 t/ha. Since autumn — plant protection products as mentioned in Table 1. Ear protection according to the forecast.

3. High-intensity (high) technologies is a set of measures aimed at obtaining the highest yield of high-quality cereals with compensation for the removal of nutrients by products that recover financial, energy and labor costs using the latest high-intensity variety base, comprehensive plant protection against diseases, weeds and pests as well as the application of fertilizers that ensure the realization of the variety's potential is more than 85%. High technology belongs to the category of precision agriculture which uses modern technologies and medicines as well as information flows. High-intensity technology — planned yield is 8–10 t/ha.

Fig. 1. Weather conditions in 2020–2022 ("Nemchinovka" weather station)[4]



From autumn — use of plant protection products (Table 1).

For all technology options, the seeds were treated with Vincite forte 1.25 l/t (Cheminova, Russia) and Picus 1 l/t (Keminova A/S, Denmark). Spraying of crops was carried out with Amazone US-605 (Eurotechnics, Russia). Varieties of winter crops were sown on the predecessor of annual grasses on September 07, 2020 (field nº 5) and 13, 2021 (field nº 2). Field area — 2.0 ha, under experiment — 1.0 ha. The total size of the plot is 160 m^2, the accounting area for varieties is 30 m^2, the repetition is four times, the agricultural technique for cultivating winter crops is generally accepted for the Central region of the

[3] GOST 26207-91 Determination of mobile compounds of phosphorus and potassium using the Kirsanov method as modified by TsINAO.
[4] Meteorological conditions of the growing season of winter crops. 2021–2022 ("Nemchinovka" weather station).

non-Chernozem zone. Preparation of the field for sowing included plowing green manure and harrowing. Cultivation to a depth of 10–12 cm. Mineral fertilizers were applied at the planned level of yield (basic 4–5 t, intensive 6–8 t, high-intensity 8–10 t/ha), cultivation to a depth of 4–5 cm with rolling (unit "Katros"). Winter wheat was sown with Amazone D9 seeder. Harvesting was carried out by direct combining with a Sampo-500 combine.

During the years of research, observations were made of the water regime, agrophysical properties, the content of nutrients in the soil, phytometric and photosynthetic parameters of plants[5] (according to generally accepted state standards[6]).

The experiments were carried, the structure of the crop[7], the yield of varieties, the quality of grain, protein and the nature of grain were determined according to existing methods determination of nitrogen and crude protein content[8], method of determination of phosphorus content[9] and flame photometric method for determination of potassium content[10].

Результаты и обсуждение / Results and discussion

The intensification of protective measures and the enrichment of the soil with nutrients make it possible to create optimal conditions for plants in the initial period of life and development. The prevailing weather conditions were favorable for the development of snow mold, powdery mildew, brown rust, Septoria blight, and wireworms, bedbugs, ground beetles, leafhoppers, aphids (especially on the ear) prevailed among pests. When treating seeds, Picus 0.7 l/t was used and when treating vegetative plants Vantex 0.06 l/ha.

When seeds were treated with Pikus 1.0 l/t, damage to winter and spring wheat crops by leafhoppers, Swedish fly, wireworm, grain striped flea beetle and other pests decreased (Table 2).

When vegetative plants were treated with Danadim Power 0.6 l/ha, damage to plants by wireworms decreased by 98%, by leafhoppers by 75%, by Swedish fly by 70%, by bug 98% and other pests by 99%. The biological efficiency of using Vantex 60 ml/ha against the background of seed dressing Picus 1.0 l/t was from 82 to 99% for the above pests. Thus, the use of the drug Pikus as a seed disinfectant and the treatment of crops during the growing season with insecticides Danadim Power or Vantex provides a reduction in plant damage by pests and helps to preserve the crop. This was reflected in the structure of the crop and the yield of winter wheat varieties.

Protection of plants from damage contributes to the better development of cultivated plants and the formation of high-quality grain. The drug is most effective at a dose of 1.0 l/t. Plants leave in the winter period developed, with a supply of nutrients, which ensures their successful overwintering. Yield loss of genotypes susceptible to leaf rust varied from 30% to 60% and genotypes resistant responded positively to fungicide protection, with 10–30% average yield range increases [8].

Stripe rust reduced grain yield from 24 to 39% and 1000-kernel weight and from 16 to 24%. Septoria leaf blotch

Table 1. **Technology and means of Chemical plant protection products.**

Technology	Plant protection products	Remark
Basic	Automn — Lintur* 180 g/ha + + Danadim *1 l/ha + + Impact SK* 0.5 l/ha	*Syngenta, Russia * Cheminova, Russia * Cheminova, Russia
Intensive	Automn — Lintur 180 g/ha + + Bantex 0.06 l/ha + + Impact SK 0.5 kg/ha	*Syngenta, Russia * Cheminova, Russia * Cheminova, Russia
	Spring — Danadim 1 l/ha + + Alto Super 0.5 l/ha + + Sappress 0.4 l/ha	*Cheminova, Denmark * Cheminova, Russia August, Russia Phase GS 21–22
	Spring — Foxtrot 1.0 l/ha + + Agroxon 0.5 l/ha, Sappress 0.3 l/ha	*Syngenta, Russia * Cheminova, Russia *August, Russia Phase GS 31–32 In presence of bluegrass weeds
	Spring — Impact Super 0.75 l/ha + + Danadim Power 0.6 l/ha	* Cheminova, Russia * Ceminova, Denmark
High-intensive	Automn — Accurate Extra 35 g/ha + + Danadim Super 0.6 l/ha, Impact Exclusive 0.5 l/ha	* Ceminova, Denmark * Cheminova, Russia
	Spring — Aton 60 g/ha + + Tandem 30 g/ha, Vantex 60 ml/ha + + Sappress 0.3 l/ha	*August, Russia * Agrobiotech , Germany *FMC, Russia *August, Russia Phase GS 21–22
	Spring — Impact Exclusive 0.5 l/ha; Impact Super 0.75 l/ha + + Sappress 0.3 l/ha	* Cheminova, Russia * Cheminova, Russia *August, Russia Phase GS 31–32
	Spring — Foxtrot 1.0 l/ha + + Consul 1.0 l/ha + Danadim Power 0.6 l/ha	* Syngenta, Switzerland * Ceminova, Denmark * Ceminova, Denmark
	Spring — Consul 1.0 l/ha + + Vantex 60 ml/ha	* Ceminova, Denmark *FMC, Russia To protect the flag leaf and ear

* Manufacturer, country.

Table 2. **Biological effectiveness of insecticides on winter wheat, %**

Options	Biological efficiency, %				
	Wireworm	Bug harmful turtle	Swedish fly	Leaf hoppers	Others
Picus 1.0 l/t	92.50	77.0	78.50	84.50	95.50
Danadim Power 0.6 l/ha	98.00	98.00	70.00	75.00	99.00
Picus 1.0 l/t + Danadim Power 0.6 l/ha	98.00	99.00	78.00	84.00	99.00
Picus 1.0 l/t + Vantex 60 ml/ha	95.00	94.00	82.00	96.00	99.00
Picus 1.0 l/t + Vincite forte 1.5 l/t	90.00	78.00	73.00	75.00	95.00
Picus 0.7 l/t + Vantex 50 ml/ha	91.00	90.00	77.00	91.00	94.00
Control (plant damage, %)	19.25	4.15	0.45	21.30	1.70

can cause up to 60% wheat yield loss and preventative application of Pyraclostrobin and Fluxapyroxad can increase approximately 20% wheat yield.

The development of snow mold in the spring after the snow melted was 14,75%. Further in the growing season, powdery mildew was noted about 14,8%, leaf rust 8%, Septoria — 5,85%, Fusarium head blight — 1,6% and root rot — 5,85%. The use of new generation fungicides Impact Exclusive, Alto Super, Consul effectively suppressed the development of epitaphs of fungal diseases. The best efficiency was obtained with the double application of Consul 0.8 l/ha (booting phase) and Consul 1.0 l/ha (earing phase). Biological efficiency varied by disease from 91 to 99%. Efficiency Impact Exclusive 0.75 l/ha

[5] Experienced in field farming. Edited by G.F. Nikitenko. Moscow: Rosselkhozizdat. 1982.
[6] Methodology of the State variety testing of agricultural crops. Moscow: 1989; VIZR methodology. 1985.
[7] GOST 10 106-87 Field experiments with fertilizers. Order of conduct.
[8] GOST 13496.4-93 Feed, compound feed, compound feed raw materials. Methods for determination of nitrogen and crude protein content.
[9] GOST 26657-97 Feed, compound feed, compound feed raw materials. Method for determining phosphorus content.
[10] GOST 30504-97 Feed, compound feed, compound feed raw materials. Flame photometric method for determining potassium content.

to a greater extent contributed to the reduction of the phytosanitary state of Fusarium 90,5% and Septoria 92,5%. Good indicators in terms of biological efficiency were also obtained in the variant with the use of Alto Super fungicide 0.5 l/ha.

The development of diseases was reduced by 82.5–94.5% (Table 3).

The development of snow mold in the control on winter wheat reached 14,75%, powdery mildew 14,8%, leaf rust 8%, Septoria and root rot 5,85%.

The biological effectiveness varied depending on the disease and the applied fungicide. The best efficiency was obtained when using Consul 0.8 (phase exit into the tube) and Consul 1 l/ha (heading phase). Biological efficiency varied depending on the disease and amounted to 91–99%.

Numerous studies showed the different effects of fungicides application on *Fusarium spp*. reduction; but in field experiments, the efficacy of fungicides is often examined exclusively without herbicidal protection.

Xia [9] indicated that combination of moderately resistant cultivars and fungicides reduced total deoxynivalenol by 67%, Fusarium-damaged kernels by 49%, *Fusarium* head blight index by 86%, and increased yield by 21–32%.

Bolanos-Carriel *et al.* [10] suggested that application of Prosaro (rothioconazole + tebuconazole) at early anthesis is the most effective fungicide treatment in reducing Fusarium head blight and yield loss.

The fungistatic activity against pathogens realized by Ниу *et al.* (2016) in vitro against Fusarium spp. demonstrated that the treatment of winter wheat grains with seed disinfectants (Dividend Extreme 0.75 l/t (92 g/l difenokonazol + 23 g/l mefenoksam), Lamador 0.2 l/t (250 g /l protiokonazole + 150 g/l tebuconazole), 0.6 l/t Benefis limited the development of Fusarium disease etiology with an efficiency of 66.8–83.5%.

The fight against weeds in modern technologies for the cultivation of new crops is relevant not only at the present time, but also in the future. We have determined the species composition of weeds on winter crops[11].

The following types of weeds were noted: chicken millet (33.2%), marshwort (11.6%), medium chickweed (10.3%), field violet (7.3%), white gauze (6.5 %), odorless chamomile (5.6%), field bluegrass (4.3%), broomstick (3.0%), pikulnik and gray bristles (2.2%), field yaruka, tenacious bedstraw and pharmacy fumes (1.7%), shepherd's purse (1.3%), roofing skerda, sow thistle species, medicinal dandelion, etc. from 0.4 to 1.3% (Table 4).

In experiments to study the responsiveness of new and promising varieties of winter wheat to herbicides with different cultivation technologies, Aton 60 g/ha, Accurate Extra at a dose of 35 g/ha, Tandem 30 g/ha, Agroxon 0.5 l/ha — high-intensity and intensive technologies, and Lintur 180 g/ha were used with basic technology. The biological efficiency of Tandem 0.03 kg/ha + Foxtrot 1.0 l/ha was 96–98%, Tandem 30 g/ha + Foxtrot Extra 0.4 l/ha + Agroxon 0.5 l/ha — 98–99%, Accurate Extra 35 g/ha + Foxtrot 1.0 l/ha + + Agroxon 0.5 l/ha — 95–98%, Aton 0.06 kg/ha + + Foxtrot 1.0 l/ha — 98–99%, Lintur 180 g/ha — 92—94% (Table 3).

The applied herbicides at the time of the beginning of earing and until full ripening suppressed the development of weeds well and ensured high biological efficiency. This, of course, affected the yield. According to many years of research, it is known that when using highly effective herbicides, yield increases reach 0.7–1.5 t/ha.

Table 3. **Biological effectiveness of fungicides for winter wheat, %**

Fungal diseases Options	Root rot	Snow mold	Powdery mildew	Septoria	Leaf rust	Fusarium head blight
Impact Exclusive 0.75 l/ha	64.50	81.50	78.00	92.50	85.5	90.5
Alto Super 0.5 l/ha	82.50	91.00	87.00	94.50	94.5	93.0
Consul, KS 0.8 l/ha + + Consul 1.0 l/ha	91.00	95.00	98.50	98.00	99.0	97.5
Consul, KS 0.8 l/ha	87.50	90.00	92.00	93.00	95.5	93.5
Control	5.85	14.75	14.80	5.85	8.0	1.6

Table 4. **The effectiveness of herbicides in winter wheat crops**

Options	Number of weeds, pcs/m^2			Biological efficiency, %	
	Before processing	After processing	Before cleaning	After processing	Before cleaning
Aton 0.06 kg/ha + Agroxon 0.5 l/ha + + Foxtrot 1.0 l/ha	229	4	2	98	99
Accurate Extra 35 g/ha + Foxtrot 1.0 l/ha + + Agroxon 0.5 l/ha	236	11	3	95	98
Tandem 0.03 kg/ha + Foxtrot 1.0 l/ha	232	10	5	96	98
Tandem 30 g/ha + Foxtrot Extra 0.4 l/ha + + Agroxon 0.5 l/ha	241	5	2	98	99
Lintur 180 g/ha	231	18	13	92	94
Control	238	238	206	–	–
SSD 5%	7,5				

SSD $_{05}$: the smallest significant difference for the 5% significance level.

The effectiveness of herbicides for winter wheat has been studied by many researchers. Several studies have been carried out by many researchers to control weeds in winter wheat crops. For effective weed control in early planting of winter wheat, wheat seeds should be treated prior to planting with a growth promoter at a rate of 50 ml/t, autumn herbicide Caliber 75 pg application, consumption rate of 50 g/ha + + Trend 90 surfactant consumption rate of 0.2 l/ha in the 3rd leaf phase of wheat and a foliar application of Quantum-Grain microfertilizer at the consumption rate of 1.0 l/ha in the spring period will reduce weeds by up to 91.9% [11].

Autumn applications of herbicide mixtures of trifloxysulfuron, simazine, Smetolachlor, or mesotrione controlled resistant annual bluegrass phenotype 84 to 98% in spring. The results of studies conducted by Bobrovsky *et al*. [12] showed that the use of a mixture of Lastik Top, MKE + Magnum Super, VDG allowed a yield increase of 1.06 t/ha or 39.6% while a mixture of Lastik Extra, KE + Ballerina Super, SE — 1.08 t/ha or 40.0% relativeto control.

The findings of Mitkov *et al.* [13] reported that combine application of Pallas 75 WG (75 g/kg pyroxsulam) + Derby Super (150.2 g/kg florasulam + 300.5 g/kg aminopyralid-potassium) recorded the highest herbicide efficacy and the highest yield (5.78 t. ha^{-1}).

When considering the results of the action of herbicides, we confirmed that winter wheat, as a highly competitive crop, enhances the effect of herbicides on weeds, especially if wheat plants have favorable conditions for growth and development. Here, a kind of synergistic effect arises, in which the competitiveness of wheat plants in relation to weeds and the action of herbicides are mutually enhanced. Therefore, the use of herbicides in the applied cultivation technologies ensured

[11] Species composition of weeds in winter wheat crops (predecessor of perennial grasses) 2019–2022 (in %).

their high biological efficiency in relation to weeds and increased with higher technology.

The use of timely sowing treatments with phytosanitary products and mineral fertilizers ensured an increase in the yield of the studied varieties of winter wheat. In the 2021 year, the best response to phytosanitary products and mineral nutrition was observed in the "Moskovskaya 27" variety (Table 5).

With the basic technology, it was 6.59 t/ha; 9.9 t/ha with an increase of 3.31 t/ha (50%) at high intensity. The grain harvest per hectare of "Moskovskaya 27" increased with an increase in the level of cultivation intensification from 7.21 t/ha to 10.83 t/ha yield was 6.59 t/ha for the basic technology. The increase in yield was 2.27 t/ha (41.33%) for the intensive and 3.31 t/ha (50%) for the high intensity. On average, the "Moskovskaya 27" and "Nemchinovskaya 85" varieties gave more than 9 tons of cereals per hectare, or more than 2 t/ha more. In comparison between varieties, there is a significant increase in grain yield. The yield of the "Moskovskaya 40" variety by technology ranged from 6.13 to 9.34 t/ha. With an increase in cultivation intensity of the "Moskovskaya 40" variety, its yield increased from 8.81 t/ha to 9.34 t/ha, and the yield increase was 2.8–3.21 t/ha (44–52%) compared to basic technology.

Table 5. **Yields of winter wheat varieties in technologies of varying degrees of intensity, 2021 and 2022**

Variety (Factor A)	Technology (Factor B)	2021			2022		
		Average Yield	Supplement to base T/ha	%	Average Yield	Supplement to base T/ha	%
Nemchinovskaya 85	1	6.44	–	–	4.52	–	–
	2	9.15	2.71	42	5.66	1.14	25.2
	3	9.54	3.10	48	6.43	1.91	42.2
Average by variety		7.65	–		5.53	–	
Moskovskaya 27	1	7.21	–	–	5.91	–	–
	2	9.96	2.75	38	6.55	0.64	10.8
	3	10.83	3.62	50	7.15	1.24	20.9
Average by variety		8.56	–		6.53	–	
Moskovskaya 40	1	6.13	–	–	4.62	–	–
	2	8.81	2.68	44	5.33	0.71	15.3
	3	9.34	3.21	52	6.24	1.62	35.0
Average by variety		7.44	–		5.39	–	
Average Factor B		1	2	3	1	2	3
		6.59	9.31	9.90	5.02	5.85	6.61
Supplement to base							
T/ha		–	2.27	3.31	–	0.83	1.59
%		–	41.33	50.0	–	16.53	31.67

SSD 5% (by factor A) = 0.12 t/ha
(by factor B) = 0.10 t/ha
(according to experience) = 0.20 t/ha

The yield of winter wheat varieties in 2022 increased with an increase in the level of intensification of their cultivation (Table 4).

The climatic conditions of the year had a decisive influence on the level of crop yields. Years characterized by a lack of precipitation, especially in summer, as a rule, there is a shortage of grain harvest. However, the implementation of measures for the use of fertilizers and phytosanitary products made it possible to ensure the average yield of winter wheat for varieties up to 5.85–6.61 t/ha of grain respectively in technology intensive and high intensity. The increase in yield was 0.83 t/ha (16.53%) for the intensive and 1.59 t/ha (31.67%) for the high intensity.

Yields of winter wheat varieties in technologies of varying degrees of intensity has been studied by many authors.

The findings of Yuan *et al.* [14] identified application of 2% imidacloprid controlled-release granule and 0.2% imidacloprid pesticide-fertilizer controlled-release granule on winter wheat as an effective way to enhance the pesticide utilization rate and ensure adequate yield. Pesticides used to treat winter wheat increased grain yield and improved grain quality characteristics, with the best results obtained when the treatment included the plant growth promoter.

Melafen in combination with the insecticide, herbicide and fungicide at different stages of winter wheat growth. Nazih Y. Rebouh *et al.* [15] showed that cultivation technology including fertilizers, pesticides and growth regulators (in different combinations and concentrations) affected productivity ("Moskovskaya 40" — 9.65 t/h, "Nemchinovskaya 17" — 8.58 t/h and "Nemchinovskaya 85" — 9.87 t/h) and wheat grain quality on all varieties studied with the highest protein content (18%) recorded in the "Nemchinovskaya 85" variety.

Выводы/Conclusion

The use of plant protection preparations has resulted in higher yields for winter wheat. This study has shown that a system of integrated phytosanitary treatments using several active molecules, fungicides, herbicides and insecticides at the different concentrations mentioned in this article, therefore ensured optimal protection against winter wheat plant diseases, insects and weeds, increased yield performance and grain quality.

Farmers' practices in winter wheat crops mostly focus on combining high-yielding cultivars with an intensive crop management system (such as intensive or high intensity technology).

All authors bear responsibility for the work and presented data.

All authors have made an equal contribution to this scientific work.
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