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

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One of the problems with producing winter wheat is the use of phytosaniatry products to guarantee high and steady winter wheat yields. Over the course of two years (2021-2022), field tests were carried out at the Federal Research Center Nemchinovka in Russia's Central Non-Black Earth area. With respect to intensity levels, such as basic, intense, and high intensity; this study sought to assess the impact of various phytosanitary agents on the productivity and quality of winter wheat types. Treatments comprised various mixtures and doses of fertilizers, pesticides (fungicides, herbicides, and insecticides), and growth regulators. Winter wheat varieties Nemchinovskaya 85, Moskovskaya 40, and Moskovskaya 27 have all been researched. 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 + Vincite forte 1.5 l/t, and Picus 0.7 l/t + Vantex 50 ml/ha) and fungicides (Impact Exclusive Moskovskaya 27 increased its output from 0.64 to 3.62 t/ha, Moskovskaya 40 from 0.71 to 3.21 t/ha, and Nemchinovskaya 85 from 1.14 to 3.10 t/ha). Results might be used to create winter wheat farming techniques that increase yields and improve grain quality.

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

INTRODUCTION

The most significant component of the global agricultural economy in recent years has been grain. The degree of grain production and a nation's ability to elevate its economic and political status within the international

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community both contribute to its ability to assure its citizens' food security and general well-being (Voronov et al., 2021). Grain is the primary component of the human diet and is necessary for animal feed. The food and agricultural organization of the United Nations estimates that the world produces roughly 770.87 million tons of wheat per year on a harvested area of 220.76 million hectares (accessed on March 12, 2023 at http://www.fao.org/faostat/en/#data). More than half of the world's cereal-growing land is spread between China, India, Russia, and the United States (Pleskachev and Sarychev, 2017).

Wheat is one of the world's oldest crops, according to research (Grădilă et al., 2018); it was first farmed in prehistoric periods in Europe and Asia. More than 6.5 thousand years ago, wheat was known in Iraq, Egypt, and Asia Minor; it was cultivated for 6000 years BC; for 3000 years BC; and there are indications of its cultivation in China, Turkmenistan, Georgia, Armenia, and Azerbaijan (Spengler, 2015; Zhou et al., 2020).

Currently, one of the major producers and exporters of soft wheat is the Russian Federation (Zyukin et al., 2020). According to the Federal State Statistics Service, the combined area of winter and spring wheat is steadily growing and now covers around 28.9 million harvested acres (Available online: accessed on March 18, 2023 at https://rosstat.gov.ru/compendium/document/13276). Due to the introduction and development of new high-yielding wheat cultivars, the yield of winter and spring wheat types has significantly increased during the past 20 years. While spring wheat predominates in the Russian Federation and Canada, winter wheat is mostly sown in Europe and the United States. One of the most significant, lucrative, and fruitful grain crops has been demonstrated to be wheat (Sarychev et al., 2019). The wheat grain is a key source of protein (20%), calories from consumption (19%), and carbohydrates (80%) for the whole world's population. Its importance and need for increased production are well acknowledged (Hawkesford et al., 2013). With spring wheat, it is frequently used in baking, pasta, and confectionery industries.

To increase the grain production from winter wheat harvests, many techniques and precautions should be used. Therefore, the purpose of these management techniques is to provide circumstances that will ensure improved plant safety during the autumn-winter and spring-summer seasons. For the production of high-quality winter wheat to do this and do it at the lowest possible cost, plant protection is essential.

Ever from the first agricultural people, crop security has been a historical concern. Plant extracts were utilized to safeguard grain reserves in the seventh century BC, and biological control techniques were already in use in Chinese orchards. The main focuses of protection tactics at that time were mechanical and biological control. Pathogens spread by commercial growth during the 19th century led to a series of tragic occurrences for crops and inhabitants, emphasizing the necessity for protection. The sale of synthetic drugs at the conclusion of World War II gave rise to fresh hopes for direct conflict and annihilation (Aubertot and Robin, 2013).

Since the middle of the 20th century, chemical management has continued to be the major crop protection strategy. The use of agricultural inputs, particularly synthetic pesticides, has increased significantly over the past 50 years; thanks to the worldwide plan for the expansion of agricultural output, reaching 2.5 million tons annually (Aubertot and Robin, 2013).

High yields and high-quality grain products are guaranteed when all necessary precautions are taken against pests, weeds, and illnesses (Nechaev and Altukhov, 2009; S.I et al., 2012). Winter wheat yield can be boosted by 1.5 to 2 times by employing phytosanitary treatments efficiently (O. V. M et al., 2017).

Winter wheat crop protection appears to be a viable method of crop pest management that satisfies agricultural needs in terms of economy, ecology, and public health. Use of pesticides, fungicides, and herbicides is one of the key contributors to the intensification of cereal production (Aubertot and Robin, 2013).

The purpose of this study is to support the potential for employing plant protection products in the Central Non-Chernozem area of Russia to increase grain production and quality while reducing the negative impacts of the pathogens causing winter wheat disease.

MATERIALS AND METHODS

At the Federal Research Center "Nemchinovskaya's" experimental field station, the study was carried out in 2021 to 2022. The Federal Research Center "Nemchinovskaya" experimental field station is situated in the typical non-Chernozem zone conditions for the Russian Federation's central area.

Soil characteristics

Medium sodo-podzolic loam describes the soil. Samples were randomly selected at intervals of 0 to 15 cm from various sites in order to document the early properties of this soil. Fields 2 and 5 of a rotation of five fields were used for field experiments. A field investigation carried out in 2020 and 2021 revealed that the soil was characterized by a response that was between 4.3 and 5.7 pH salts. Mobile potassium availability was 125 to 181 mg/kg while mobile phosphorus content was 155 to 316 mg/kg.

Climatic conditions

Winter crop growing conditions were usually characterized as favorable. The winter wheat growth season's hydrothermal coefficient was between 1.50 and 1.52, indicating that the water supply year was ideal. An average daily air temperature range of 5 to 9.7°C from September to early November. The plants were healthy throughout the winter, and the springtime weather allowed them to grow properly. The second decade of December saw the establishment of snow cover with daily mean air temperature variations ranging from -3.7 to -5.3°C. 4.90°C is the average yearly temperature. The hot season (May to August) has an average temperature of +15.98°C. The chilly season (November to March) has an average temperature of -5.04°C. 293.3 mm of precipitation on average falls between May and September. 623.75 mm of rain falls on average each year, with 26% of it falling in the fall and 56% in the spring and summer.

Treatments

The experiments were carried out during 2021 to 2022 according to a two-factor scheme. Winter wheat varieties (factor A) were used in experimental versions with varying levels of plant protection product application (factor B): basic technology (1), intense (2), and high-intensity (3). The following standards were followed during sowing: 5 million germination-ready grains per acre for winter wheat.

Characteristics of winter wheat varieties (factor A)

The Nemchinovskaya 85 variety has the following characteristics: mid-season, winter-hardy, waterlogging- and lodging-resistant; able to fend against serious illnesses including septoria, brown rust, powdery mildew, and snow mold. The greatest production was 11.63 t/ha, with an average yield of 8.27 t/ha over the course of three years of testing. Protein concentration in grains is 14.4%, whereas gluten content in flour is 33.8%.

Cultivar Moskovskaya 27 possesses a high level of winter hardiness as well as field resistance to Septoria, brown and stem rust, and powdery mildew. The cultivar produces a bigger grain, more productive shoots per unit area, and is resistant to lodging. The three-year average yield was 8.64 t/ha. Height of plant: 90 to 95 cm. Grain contains 15.5% protein and up to 27.2% gluten. The grain's nature is 816 g/l, and 1000 grains weighed between 44 and 47 g.

Cultivar Moskovskaya 40 is extremely adaptable, short-stemmed, winter-hardy, resistant to lodging, resistant to powdery mildew, common smut, and leaf rust. 15% of grains contain protein, whereas 33.7% of flour contains raw gluten. The greatest yield for the five years was 7.36 t/ha, with 6.74 t/ha on average. Weight of 1000 grains is 45 to 48 g.

Technologies (factor B)

1. Basic technique intended for a 5 to 6 t/ha expected yield. An herbicide, insecticide, and fungicide tank mixture (Lintur 180 g/ha + Danadim 1 l/ha + Impact SC 0.5 l/ha), exclusively administered in the fall, serves as the plant protection system. Protection throughout the springtime as predicted.
2. With intensive technology, a yield of 6 to 8 t/ha is anticipated. Plant protection treatments have been used since the fall, including Lintur 180 g/ha, Vantex 0.06 l/ha, and Impact SK 0.5 kg/ha; in the spring, insecticide Danadim 1 l/ha, Alto super fungicide 0.5 l/ha, and Sapress retardants 0.4 l/ha (GS 21–22). In the spring, Foxtrot 1.0 l/ha + Agroxon 0.5 l/ha, Capress 0.3 l/ha (phase GS 31-32) were employed in the presence of bluegrass weeds. Fungicides Impact Super 0.75 l/ha + Danadim Power 0.6 l/ha. Ear protection according to the forecast.
3. High-intensity technology; 8 to 10 t/ha of anticipated yield. From autumn - use of plant protection products - Accurate Extra 35 g/ha + Danadim Power 0.6 l/ha, Impact Exclusive 0.5 l/ha, in spring - Aton 60 g/ha + Tandem 30 g/ha, Vanteks 60 ml/ha + Capress 0.3 l/ha (phase GS 21 - 22) + Impact Exclusive 0.5 l/ha; Impact Super 0.75 l/ha + Sapress 0.3 l/ha (phase GS 31 - 32) + Foxtrot 1.0 l/ha + Consul 1.0 l/ha + Danadim Power 0.6 l/ha; to protect the flag leaf and ear - Consul 1.0 l /ha + Vantex 60 ml / ha.

The seeds were treated with Vincite forte 1.25 l/t and Picus 1 l/t for all technological choices. Using a machine called the Amazone US-605, crops were sprayed. On September 7, 2020 (field number 5) and September 13, 2021 (field number 2), several winter crop varieties were seeded on the forerunner of annual grasses. 2.0 ha of field space and 1.0 ha of experiment space. The agricultural method for producing winter crops is commonly recognized for the Central part of the non-Chernozem zone. The overall size of the plot is 160 m^2, the accounting area for variety is 30 m^2, and the repetition is four times. Plowing green manure and harrowing were used to get the field ready for sowing and cultivation down to a 10 to 12 cm depth. Mineral fertilizers were used to cultivate the soil to a depth of 4 to 5 cm with rolling (unit "Katros") at the desired production level (basic 4-5 t, intense 6-8 t, high-intensity 8-10 t/ha). With an Amazone D 9 seeder, winter wheat was sowed. Using a Sampo-500 combine, direct combining was used for harvesting.

Observations of the water regime, agrophysical characteristics, nutrients in the soil, phytometric parameters, and photosynthetic parameters of plants (in accordance with widely recognized state norms) were made during the course of the research years. According to accepted practices and GOSTs, crop structure, variety yield, grain quality, protein content, and grain nature were all identified. The following procedures were used to conduct the experiments: "Experimental work in field farming." The writers from the Scientific Research Institute of Agriculture of the TsRNZ wrote "Methodology of State Variety Testing of Agricultural Crops" in Rosselkhozizdat, 1982. 190 p.; "Methodology of State Variety Testing of Agricultural Crops" for cereals, legumes, and fodder crops. Issue 1., M., 1985, 269 p.; Issue 2 M., 1989, 194 p., and considering the appropriate adapters. The computer program "AGROS" 2.07 was used to analyze the study findings statistically in accordance with Armor (1985) recommendations.

RESULTS

Biological effectiveness of insecticides on winter wheat

Analysis of the overwintering findings revealed that the strengthening of protective measures and the nutrient-rich soil enrichment allow for the creation of the best possible circumstances for plants throughout their early stages of life and development. The weather at the time was conducive to the growth of pests including wireworms, bedbugs, ground beetles, leafhoppers, and aphids (particularly on the ears), as well as snow mold, powdery mildew, brown rust, and septoria blight. Picus 0.7 l/t was used to treat seeds, while Vantex 0.06 l/ha was utilized to treat vegetative plants. Leafhoppers, Swedish fly, wireworm, grain striped flea beetles, and other pests caused less harm to winter and spring wheat harvests when seeds were treated with Pikus 1.0 l/t (Table 1).

Wireworm damage to plants fell by 98%, leafhopper damage by 75%, Swedish fly damage by 70%, insect damage by 98%, and other pest damage by 99% when vegetative plants were treated with Danadim Power 0.6 l/ha. For the aforementioned pests, the biological effectiveness of employing Vantex 60 ml/ha against the backdrop of seed dressing Picus 1.0 l/t ranged from 82 to 99%. Thus, reducing plant damage from pests and

Table 1. Biological effectiveness of insecticides on winter wheat, %.

Options	Biological efficiency (%)				
	Wireworm	Bug harmful turtle	Swedish fly	Leaf hoppers	Others
Picus 1.0 l/t	92.5	77	78.5	84.5	95.5
Danadim Power 0.6 l/ha	98	98	70	75	99
Picus 1.0 l/t + Danadim Power 0.6 l/ha	98	99	78	84	99
Picus 1.0 l/t + Vantex 60 ml/ha	95	94	82	96	99
Picus 1.0 l/t + Vincite forte 1.5 l/t	90	78	73	75	95
Picus 0.7 l/t + Vantex 50 ml/ha	91	90	77	91	94
Control (plant damage, %)	19.25	4.15	0.45	21.30	1.70

Table 2. Biological effectiveness of fungicides for winter wheat, %.

Options	Root rot	Snow mold	Powdery mildew	Septoria	Leaf rust	*Fusarium* head blight
Impact Exclusive, 0.75 l/ha	64.5	81.5	78	92.5	85.5	90.5
Alto Super 0.5 l/ha	82.5	91	87	94.5	94.5	93
Consul, KS, 0.8 l/ha + Consul 1.0 l/ha	91	95	98.5	98	99	97.5
Consul, KS, 0.8 l/ha	87.5	90	92	93	95.5	93.5
Control	5.85	14.75	14.8	5.85	8	1.6

preserving the crop are made possible by the use of the medicine Pikus as a seed disinfectant and by treating crops with the insecticides Danadim Power or Vantex throughout the growth season. The crop's structure and the output of winter wheat types mirrored this.

Biological effectiveness of fungicides for winter wheat

After the snow melted in the spring, there was a 14.75% increase in snow mold growth. Powdery mildew was seen at a rate of 14.8% later in the growth season, along with leaf rust at 8%, Septoria at 5.85%, *Fusarium* head blight at 1.6%, and root rot at 5.85%. Utilizing the latest generation fungicides, Impact Exclusive, Alto Super, and Consul significantly prevented the emergence of fungal infections' obituaries. The double application of Consul 0.8 l/ha (booting phase) and Consul 1.0 l/ha (earing phase) produced the highest efficiency. Biological efficacy ranged from 91 to 99% depending on the condition. Efficiency Impact Exclusive 0.75 l/ha significantly reduced the phytosanitary status of Septoria 92.5% and *Fusarium* 90.5%. Good biological efficiency indicators were likewise attained in the version using 0.5 l/ha of the fungicide Alto Super. Diseases developed less often by 82.5 to 94.5% (Table 2).

Winter wheat grown under control developed snow mold at a rate of 14.75%, powdery mildew at 14.8%, leaf rust at 8%, septoria at 5%, and root rot at 5.85%. Biological efficacy varies according to the illness and the fungicide used. Utilizing Consul 0.8 (phase exit into the tube) and Consul 1 l/ha (heading phase) resulted in the highest efficiency. Biological effectiveness ranged from 91 to 99% and depended on the condition.

The effectiveness of herbicides in winter wheat crops

In order to cultivate new crops using contemporary technology, the fight against weeds is important both now and in the future. Weed species found on winter crops have been identified. Weeds of the following kinds were identified: 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 3).

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 in experiments to study the responsiveness of new and promising varieties of winter wheat to herbicides. Tandem 0.03 kg/ha + Foxtrot 1.0 l/ha had a biological efficiency of 96 to 98%, Tandem 30 g/ha + Foxtrot Extra 0.4 l/ha + Agroxon 0.5 l/ha had a biological efficiency of 98 to 99%, Accurate Extra 35 g/ha+ Foxtrot 1.0 l/ha + Agroxon 0.5 l/ha had a biological efficiency of 95 to 98%, Aton 0. Herbicides that were

Table 3. 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	231.5	18	13	92	94
Control	238	238.5	206	–	–

sprayed at the start of earing and throughout full ripening effectively prevented the growth of weeds and guaranteed good biological efficiency. Naturally, this had an impact on the yield. Years of study have shown that employing very efficient herbicides may enhance yields by 0.7 to 1.5 t/ha.

Yields of winter wheat varieties in technologies of varying degrees of intensity

The tested types of winter wheat's yield were increased with the timely use of phytosanitary agents and mineral fertilizers during the planting process. The Moskovskaya 27 variety showed the highest response to phytosanitary treatments and mineral nutrition in the 2021 growing season (Table 4).

It was 6.59 t/ha with the most basic technique; with high intensity, it was 9.9 t/ha with a rise of 3.31 t/ha (or 50%). Moskovskaya 27 had a rise in the amount of grain harvested per hectare as cultivation intensification climbed from 7.21 to 10.83 t/ha. The yield for the fundamental technique was 6.59 t/ha. 2.27 t/ha (41.33%) for the intense and 3.31 t/ha (50%) for the high intensity saw an improvement in yield. The Moskovskaya 27 and Nemchinovskaya 85 cultivars produced on average, over 9 tons of cereal per hectare, or over 2 t/ha more. Grain yield has increased significantly when compared between kinds. The Moskovskaya 40 variety produced between 6.13 and 9.34 t/ha of yield, depending on the technology. The Moskovskaya 40 variety's yield rose from 8.81 to 9.34 t/ha with increasing cultivation intensity; this is a yield improvement of 2.8 to 3.21 t/ha (44-52%) above basic technology.

With an increase in the level of intensification of their farming, the yield of winter wheat cultivars in 2022 rose (Table 4). The level of crop production was significantly influenced by the weather conditions of the year. In general, there is a paucity of grain harvest in years with little precipitation, especially in the summer. However, it was made feasible to guarantee the average yield of winter wheat for types up to 5.85 to 6.61 t/ha of grain, respectively, in technology intensive and high intensity, via the adoption of measures for the use of fertilizers and phytosanitary products. For the intense and high intensities, respectively, the increase in yield was 0.83 (16.53%) and 1.59 t/ha (31.67%).

DISCUSSION

Zhang et al. (2016) demonstrates that imidacloprid and clothianidin seed treatments may minimize yield loss and wheat aphid infestations throughout the winter wheat growing season is supported by the biological efficacy of insecticides on winter wheat results. Plant damage prevention aids in the better development of cultivated plants and the production of grain of superior quality. At a dosage of 1.0 l/t, the medication is most effective. The development and nutrition supply that plants leave behind throughout the winter months assures their success in overwintering.

Genotypes resistant to leaf rust reacted favorably to fungicide treatment, increasing their average production range by 10 to 30%. Genotypes vulnerable to leaf rust saw yield losses ranging from 30 to 60%. (Morgounov et al., 2015). According to Sharma et al. (2016), stripe rust decreased grain yield from 24 to 39% and from 16 to 24% per 1000-kernel weight. Pyraclostrobin and Fluxapyroxad can boost wheat output by around 20% when used as a prophylactic measure against Septoria leaf blotch, which has the potential to reduce wheat yield by up to 60% (Palomar, 2014).

According to Kleczewski et al. (2020), Priaxor had 11 to 18% less activity than the other fungicides when used to treat Powdery mildew (*Blumeria graminis*) on wheat when compared with Caramba, Stratego YLD, Priaxor, Prosaro, and Trivapro. As a stand-alone control strategy, Serenade®ASO by *Bacillus amyloliquefaciens* strain QST 713 suspension concentrate faces problems (Matzen et al., 2019).

Numerous studies have shown various impacts of using fungicides to reduce *Fusarium* species, although in field tests, the effectiveness of fungicides is frequently assessed alone without herbicidal protection. Propiconazole and metconazole (1 l/ha), tebuconazole (1

Table 4. 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		Average Yield	Supplement to base	
			T/ha	%		T/ha	%
	1	6.44	-	-	4.52	-	-
Nemchinovskaya 85	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	-	
	1	7.21	-	-	5.91	-	-
Moskovskaya 27	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	-	
	1	6.13	-	-	4.62	-	-
Moskovskaya 40	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

kg/ha), prochloraz (1.1 l/ha), and prothioconazole (0.8 l/ha) are effective fungicides against *Fusarium* spp. when administered singly, according to Masiello et al. (2019). The most effective method for lowering *Fusarium* spp. in wheat, according to Lozowicka et al. (2022), is to use a sulfonylurea herbicide (26.5 g/ha) along with propiconazole, cyproconazole, and spiroxamine, tebuconazole, and triadimenol (a total of 600 ml/ha) fungicides. According to Xia (n.d), a combination of moderately resistant cultivars and fungicides enhanced yield by 21 to 32% and decreased total deoxynivalenol by 67%, fusarium-damaged kernels by 49%, and fusarium head blight index by 86%. According to Bolanos-Carriel et al. (2020), using Prosaro (prothioconazole + tebuconazole) before the beginning of anthesis is the best way to prevent *Fusarium* head blight and yield loss. According to Scarpino et al. (2015), prothioconazole, an azole fungicide, is the most effective active ingredient for preventing Fusarium head blight and lowering the incidence of mycotoxins such deoxynivalenol that are found in cereal grains. Prosaro (prothioconazole + tebuconazole), when used topically, lowered illness severity by up to 84% (Bhatta et al., 2018).

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), and 0.6 l/t Benefis limited the development of Fusarium disease etiology with an efficiency of 66.8 - 83.5%).

Numerous studies have looked at the efficacy of herbicides for winter wheat. Many researchers have conducted numerous experiments to manage weeds in winter wheat harvests. 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%, and 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 (Shcatula, 2020). According to Bayat and Zargar (2020) states that pyroxasulfone spraying at the wheat tillering stage had a 69 to 90% impact on field bindweed reduction. Trifloxysulfuron, simazine, Smetolachlor, or mesotrione herbicide formulations used in the fall effectively suppressed the spring phenotype of resistant annual bluegrass in 84 to 98% of cases (Breeden et al., 2017). Amicarbazone and terbuthylazine, which reduced *Poa annua* incidence by 50%, were determined to be the most efficient *P. annua* control agents for spring and fall application by Barua et al. (2021). In contrast, pyroxasulfone and s-metolachlor only offered modest control in both the spring and autumn. At 0.43 kg/ha, flumioxazin effectively suppressed up to 95% of annual bluegrass tillers (Flessner et al., 2013).

According to Patton et al. (2019), the availability of methiozolin and bispyribac-sodium would give the *P. annua* control system the requisite alternatives. According to research by Bobrovsky et al. (2022), using a combination of Lastik Top, MKE + Magnum Super, VDG allowed for a yield gain of 1.06 t/ha or 39.6%, whereas using a combination of Lastik Extra, KE + Ballerina Super, SE resulted in a yield decrease of 1.08 t/ha or 40.0% compared to control. According to Mitkov et al. (2017), Pallas 75 WG (150.2 g/kg florasulam + 300.5 g/kg aminopyralid-potassium) + Derby Super (5.78 t ha^{-1}) combined treatment produced the maximum herbicide effectiveness and yield.

It was found that when taking into account how herbicides affect weeds, winter wheat, a crop that is extremely competitive, strengthens the impact of herbicides on weeds, particularly when the wheat plants are given ideal circumstances for growth and development. The competitiveness of wheat plants in regard to weeds and the effectiveness of herbicides are mutually improved in this situation, creating a form of synergistic effect. In order to ensure high biological effectiveness in relation to weeds and to increase with greater technology, herbicides were used in the employed cultivation technologies.

Numerous writers have looked at the yields of winter wheat types using various intensities of technology. Application of 2% imidacloprid controlled-release granule and 0.2% imidacloprid pesticide-fertilizer controlled-release granule on winter wheat showed an efficient technique to increase the pesticide consumption rate and guarantees a sufficient yield by Yuan et al. (2020).

The average yield of wheat harvests grew by more than 98% globally, with an increase in pesticide use being a contributing factor (Hossard et al., 2014). Low-fertilized or unfertilized field yields do not appreciably increase with time (Ahrends et al., 2018). The findings of Sokólski et al. (2020) support our study when they claim that high-input production technologies were more economical due to the rise in wheat seed yield that resulted from them. According to Loyce et al. (2012), production was lost when the amount of N fertilizer, fungicides, and growth regulators were reduced. An increase in the input of external resources such mineral fertilizers and insecticides has often been associated with an increase in wheat production (Hildermann et al., 2009).

According to Rempelos et al. (2018), the use of growth regulators, fungicides, and herbicides lessens the severity of foliar diseases. In their study, Kuznetsov et al. (2020) found that applying pesticides to winter wheat increased grain yield and enhanced grain quality traits, with the best results coming from applying Melafen, a plant growth promoter, along with insecticides, herbicides, and fungicides at various stages of winter wheat growth. Nazih et al. (2020) showed that cultivation technology including fertilizers, pesticides and growth regulators (in different combinations and concentrations) affected productivity (Moskovskaya 40 - 9.65 t/ha, Nemchinovskaya 17 - 8.58 t/ha and Nemchinovskaya 85 - 9.87 t/ha) and wheat grain quality on all varieties studied with the highest protein content (18%) recorded in the Nemchinovskaya 85 variety.

In contrast, Gaba et al. (2016) hypothesized that crop yield might be maintained by lowering pesticide use by up to 50%. According to Bezuglova et al. (2019), the application of the sulfonylurea herbicide caused the winter wheat plants to experience a chemical stress. According to Guo et al. (2018), the usage of pesticides may be significantly decreased with the use of an insect-trapping light provided they are applied promptly and at the proper stage.

Conclusion

Winter wheat yields have increased as a consequence of the development of high-yielding cultivars and increased usage of external inputs like insecticides and nitrogen fertilizer. This study has demonstrated that an integrated system of phytosanitary treatments utilizing a variety of active molecules, namely fertilizers, fungicides, herbicides, insecticides, and growth regulators at the various dosages specified in this article, guaranteed the best possible protection against winter wheat plant diseases and improved grain quality and production performance. The outcomes of this experiment demonstrated that the normative technique must take into account the varietal characteristics, the nutritional needs of the plants, the agrochemical properties of the soil, and climatic aspects when establishing a protective system. Winter wheat farming strategies mostly center on utilizing high-yielding cultivars in conjunction with an intense crop management approach (such as high intensity or intensive technology). The findings of this study provide genuine chances for widespread use of the therapies tried in various Russian Federation areas.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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