IMPROVEMENT OF WEEDS MANAGEMENT SYSTEM AND FERTILISERS APPLICATION IN WINTER WHEAT (*TRITICUM AESTIVUM* L.) CULTIVATION TECHNOLOGIES

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Wheat production plays a central role in the Russian agricultural system and significant land area is dedicated to this strategic crop. However, the wheat enterprise is highly constrained by weed interference which cause serious yield losses hence minimizing production income. The main objective of the study was to assess the efficacy of three various cultivation technologies as basic, intensive, and highly intensive systems on wheat biological efficiency. Three weed species *Echinochloa crus-galli*, *Stellaria media*, and *Viola arvensis*, and three winter wheat (*Triticum aestivum* L.) varieties Moscovskaya 40 (V1), Nemchinovskaya 17 (V2) and Nemchinovskaya 85 (V3) were studied. The data was analysed as a randomized complete block design with three replicates. Weed density, biological efficiency, yield performances, and selected qualitative parameters (measured through protein and gluten contents) were determined as affected by different cultivation technologies. The results showed that the high intensive cultivation technology (T3) was the most effective in reducing weed infestation levels as follows (0.3 plant/m² *Echinochloa crus-galli*, 0.5 plant/m² *Stellaria media* and 0.4 plant/m² *Viola arvensis*) with biological efficiency of 96%, while 81% and 90% were recorded with basic and intensive cultivation system respectively. Moreover, the highest wheat yield 10.6 t/ha was obtained by T3, with the greatest grain quality 5% higher than basic cultivation technology designated in T1. The results were variety-dependent revealing the intrinsic genetic performances and the different patterns of high competitive ability. The current results open real opportunities concerning the implementation of potent wheat production systems.

Key words: gluten content, herbicide, proteins content, weed, wheat varieties, yield

Chemical method plays a key role in controlling weeds that infest wheat fields. Herbicides are the most effective weed control tools developed recently in all over the world, suppressing 90–99% of weeds (Talgre *et al.* 2008). Nevertheless, herbicide

resistance particularly in major field crops (wheat, rice, maize, soybean), has become a widespread problem posing a formidable challenge for global food production systems (Beckie *et al.* 2000; Ibrahim *et al.* 2016; Pansu *et al.* 2018). Currently many

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weed species are developing resistance to herbicides from different modes of action, and becoming more difficult and expensive to be controlled. Several studies in the recent years revealed that continued use of herbicides with the same mode of action (MOA) applies selection pressure on the weed population, this increases the genotype frequency of resistant individuals that eventually becomes the dominant component of the population (Mohammadi *et al.* 2018). As a solution, chemical management strategies such as rotating active ingredients with the different MOAs and combining (tank mix) herbicides from the various chemical families have been established to evade herbicide resistance. The selection of such herbicides should be based on biological knowledge of all dominant weed species in the field, while maintaining a balance between herbicide costs, weed thresholds, and environmental impacts (Nazarko *et al.* 2005; Chhokar *et al.* 2012).

In addition to the chemical methods, other control practices were developed to control weeds in farming systems. For example, increasing weed-crop competition, through the development of crop varieties with the high competitive ability can be illustrated. Previous studies reported that some crop genotypes had a high competitive ability against weeds (Mason *et al.* 2007; Fragasso *et al.* 2013). Hence, De Vita *et al.* (2017) investigated the effects of inter-row spacing as a cultural method on wheat competition against weeds. Mentioned study demonstrated that competitive ability directly depends on the wheat cultivars, thus, crop rotation was performed to control weed populations. It has been reported that crop rotation reduces growth, fecundity, and weed establishment by disrupting their life cycle (Nichols *et al.* 2015). Furthermore, it was observed that monoculture or continuous cropping within a field increases weeds density, whereas breaks in the cropping sequence with other crops often significantly diminish weeds interference (Hosseini *et al.* 2014).

Crop production for the purpose of human consumption such as wheat is of paramount importance worldwide (Polityko *et al.* 2020). Weeds are one of the major constraints causing serious losses in wheat yields and quality (Van der Meulen *et al.* 2017). Moreover, weed communities possess high phenological plasticity which enables them to adapt

to new management techniques (Vila-Aiub *et al.* 2019). Almost, direct yield losses due to weed infestations are ranged 20–40% in the global wheat production (Fahad *et al.* 2015; Gharde *et al.* 2018). For mentioned reasons, cropping systems need new management strategies, including cultural practices and genetic engineering technique (development of new varieties) to suppress weed growth and spread that cause wheat yield losses. The optimization of weed management systems, therefore, is becoming indispensable in wheat production systems to ensure high yields and better grain quality.

A three year study was carried out to investigate the effectiveness of three cultivation technologies included fertilisers, herbicides, and growth regulators in different combinations and doses to control weeds in order to estimate their influence on winter wheat yield and grain quality.

MATERIAL AND METHODS

Experimental site

Experiments were conducted over three wheat growing seasons (2016–2017, 2017–2018, and 2018–2019) at the Moscow Research Institute of Agriculture “Nemchinovka”, Odintsovo district, Russia (55° 45' N, 37°37' E and 200 m altitude).

Climatic conditions

The climate in the Moscow region was mid-continental characterized by mild winter, occasional thaw, and warm damp summer. The mean annual temperature was 6.3°C. The average temperature of the warm-season (May–October) was 13.5°C; the average monthly temperature in January and July was –8.40°C and 18.10°C, respectively. Positive ambient temperatures are experienced for an average of 215 days. Moreover, temperatures above 10°C (vegetation season) occur for an average of 130 days. The average cool season (November–March) temperature was –5.70°C. Mean annual precipitation was 628 mm: 56% in the spring-summer season and 26% in autumn. The average precipitation rate from May to September was 339 mm.

Weed density estimation

Weeds were investigated in three to five leaves stage of winter wheat. The dominant weed species

during three years of the experiment were: *Viola arvensis*, *Stellaria media* and *Echinochloa crus-galli*. These species typically germinate in autumn and spring in the condition of Moscow region. The weed density was calculated manually before treatments and after treatments (28 days after treatments). The weed density was expressed as number of plant/m² in each plot according to the cultivation technology. The total area of the experimental field was 700 m². The total area was sub-divided into three blocks; each block was further subdivided into nine plots in which the total area of each plot was 25 m². The experiment was performed in three replications for each treatment.

Experimental design and treatments

For three years of the study, the experiments were laid out as Randomized Complete Block Design with three replications. Three cultivation technologies [basic (T1), intensive (T2) and high intensive (T3)] were examined as the main plots whilst wheat varieties [Moskovskaya 40 (V1), Nemchinovskaya 17 (V2) and Nemchinovskaya 85 (V3)] were as sub-plots.

A description of experimental inputs for all three cultivation technologies is presented in Table 1. The herbicides were applied to wheat seedlings at the three-five leaves stage. The fertilisation was carried out in pre-sowing with top dressing, at the tillering and earing stages.

Sowing was done at the beginning of September with a planter (seeder SN 16 PM) at a rate of 5 million seeds/ha.

A modern combine harvester was used to harvest wheat (Polityko *et al.* 2020). The wheat was harvested around the mid-August at ripening stage.

The crop rotation implemented in the experimental field was as legumes, spring cereals and winter cereals. Particularly, the crop that preceded the winter wheat investigated in the study was peas.

Tillage operations were done before each growing season after harvesting the predecessor crop, with a ploughing depth of 20–22 cm.

Biological efficiency

The biological efficiency effectuated by the cultivation technologies was calculated manually 28 days after treatment and before harvest of winter wheat. Weed density was investigated and calculated as number of plant/m² in each experimental plot, according to the cultivation technologies applied, using the following formula (Polityko *et al.* 2020):

$$BE [\%] = 100 - (Nbr.a \times 100 / Nbr.b) \quad (1)$$

BE – biological efficiency [%]; Nbr.a – number of plant/m², after treatment; Nbr.b – number of plant/m², before treatment; 100 – conversion coefficient [%].

T a b l e 1

Applied herbicide and fertilisers in different cultivation technologies

Cultivation technologies	Fertilisers [kg/ha]	Crop protection details
1. Basic (T1)	Basal application N (30), P ₂ O ₅ (30), K ₂ O (90) [kg/ha] in pre-sowing and N (30) [kg/ha] at the tillering phase	• Herbicide: Lintur 180 [g/ha]
2. Intensive (T2)	Basal application N (60), P ₂ O ₅ (60), K ₂ O (120) [kg/ha] in pre-sowing, Top dressing, at the tillering phase, N (30) [kg/ha]	• Herbicide: Accurate Extra 25 [g/ha] • Growth regulator: Sapress 0.3 [L/ha]
3. High Intensive (T3)	Basal application N (90), P ₂ O ₅ (90), K ₂ O (150) [kg/ha] in pre-sowing, Top dressing, at the tillering and earing phases, N (30) and N (30) [kg/ha], respectively	• Herbicide: Accurate Extra 35 [g/ha] + Tandem 25 [g/ha] • Growth regulator: Sapress 0.3 [L/ha]

Determination of protein and gluten content

Selected qualitative parameters (determined via protein and gluten content) were measured for all winter wheat varieties.

The percentage of protein content was analysed by calculating the total nitrogen concentration in grain using the Kjeldahl method (Kjeldahl 1883), the following formula was used:

$$\text{Protein [\%]} = [(N \times 100) / (100 - W)] \times K \quad (2)$$

N – the nitrogen content in the grain [%]; W – the moisture content of the grain or its processed products [%]; K – conversion coefficient of nitrogen content to protein, equal to: 5.7 for wheat.

The gluten content in wheat grain was calculated by hand washing method (Polityko *et al.* 2020). The amount of raw or dry gluten in the grain %, calculated to the first decimal place, for dry-to the second decimal place by the following formula:

$$\text{Gluten [\%]} = \text{MG} / \text{Mg} \times 100 \quad (3)$$

MG – the number of raw or dry gluten [g]; Mg – the number of the sample of ground grain [g]; 100 – conversion coefficient [%].

Statistical analysis

Data analysis was performed using Statview 4.02 software (Abacus Concepts Inc., Berkeley, CA, USA). Values for each variable were expressed as the mean $\pm$ SEM (Standard Error of Mean). Variables used for comparison purposes were the three weed species abundance as influenced by the three cultivation technologies: Basic (T1), Intensive (T2), and High Intensive (T3). Differences between treatments (wheat yield, gluten content, and proteins content) were assessed using Analysis of variance (ANOVA) at a significance of p -value < 0.05, and Tukey's test was used for mean comparisons in each treatment that was significant. Linear regression was used to evaluate the relationship between biological efficiency of cultivation technologies, wheat yield and grain quality.

RESULTS

Weed infestation

Figure 1 shows weed infestation of the three winter wheat species after treatments. Weed infestation levels were highest before treatment application as *Echinochloa crus-galli*, *Stellaria media* and *Viola arvensis* 30, 18 and 16 plant/m², respectively. However, after treatment, a significant weed reduction

Figure 1. Influence of the cultivation technologies (T1 – basic, T2 – intensive and T3 – high intensive) on weed infestation levels of the three studied species

T a b l e 2

Grain yield and quality variation of each wheat varieties under different studied cultivation technology

Cultivation technology	Varieties	Year	Yield	Protein	Gluten
T1 – basic	Moscovskaya 40 variety (V1)	2017	9.5±0.23 ^b	14.1±0.05 ^c	30.4±0.11 ^c
		2018	5.2±0.05 ^d	16.4±0.05 ^b	32.8±0.08 ^b
		2019	7.8±0.20 ^{bc}	16.1±0.05 ^b	32.2±0.10 ^b
	Nemchinovskaya 17 variety (V2)	2017	9.7±0.11 ^{ab}	14.2±0.11 ^c	28.3±0.15 ^c
		2018	6.4±0.05 ^c	14.5±0.05 ^c	29.1±0.11 ^c
		2019	7.4±0.03 ^c	16.9±0.11 ^b	33.8±0.10 ^c
	Nemchinovskaya 85 variety (V3)	2017	9.9±0.28 ^b	14.8±0.05 ^c	31.2±0.05 ^c
		2018	7.1±0.06 ^c	15.1±0.05 ^c	30.2±0.10 ^c
		2019	7.4±0.03 ^c	17.6±0.11 ^b	35.2±0.15 ^{ab}
T2 – intensive	Moscovskaya 40 variety (V1)	2017	10.5±0.24 ^{ab}	15.4±0.05 ^b	31.5±0.05 ^c
		2018	8.4±0.11 ^b	17.7±0.05 ^b	36.7±0.15 ^{ab}
		2019	8.2±0.10 ^b	19.1±0.05 ^{ab}	38.2±0.15 ^a
	Nemchinovskaya 17 variety (V2)	2017	10.4±0.23 ^{ab}	15.6±0.10 ^b	33.2±0.08 ^b
		2018	7.1±0.14 ^c	16.1±0.05 ^b	32.2±0.15 ^b
		2019	7.9±0.11 ^{bc}	17.8±0.11 ^b	37.6±0.15 ^a
	Nemchinovskaya 85 variety (V3)	2017	13.1±0.17 ^a	15.6±0.05 ^b	32.5±0.05 ^b
		2018	7.3±0.05 ^c	16.4±0.05 ^b	32.8±0.10 ^b
		2019	8.3±0.05 ^b	18.9±0.11 ^{ab}	37.2±0.15 ^a
T3 – high intensive	Moscovskaya 40 variety (V1)	2017	14.1±0.17 ^{ab}	15.5±0.05	33.4±0.20 ^b
		2018	9.03±0.17 ^b	18.3±0.05 ^{ab}	36.6±0.10 ^{ab}
		2019	8.7±0.1 ^b	19.6±0.11 ^a	39.2±0.10 ^a
	Nemchinovskaya 17 variety (V2)	2017	13.3±0.17 ^a	16.8±0.05 ^b	35.1±0.05 ^{ab}
		2018	8.2±0.11 ^b	16.9±0.17 ^b	33.4±0.08 ^b
		2019	8.03±0.14 ^a	18.9±0.05 ^{ab}	39.8±0.05 ^a
	Nemchinovskaya 85 variety (V3)	2017	13.3±0.16 ^a	16.5±0.05 ^b	33.9±0.10 ^b
		2018	7.6±0.11 ^{bc}	16.8±0.05 ^b	33.6±0.10 ^b
		2019	8.7±0.05 ^b	19.4±0.11 ^{ab}	39.8±0.05 ^a
<i>p</i> -value	Cultivation technology		≤0.002	≤0.002	≤0.002
	Variety		≤0.003	≤0.002	≤0.003
	Year		≤0.002	≤0.004	≤0.002
	Cultivation technology × Variety		≤0.002	≤0.003	≤0.005
	Cultivation technology × Year		≤0.006	≤0.005	≤0.004
	Variety × Year		≤0.003	≤0.007	≤0.006
	Cultivation technology × Variety × Year		≤0.004	≤0.005	≤0.008

Values represent the average of 3 replicates ± SE (standard errors), *p*-values from ANOVA (cultivation technology, variety, year, cultivation technology × variety, cultivation technology × year, variety × year and cultivation technology × variety × year).

Different letters in column indicate significant difference between means and they were determined by Tukey test

value was observed for all three species. High intensive cultivation technology T3 determined as the most effective treatment in weed control, attaining 0.3 plant/m² *Echinochloa crus-galli*, 0.5 plant/m² *Stellaria media* and 0.4 plant/m² in *Viola arvensis*. Cultivation technologies 1 and 2 also showed high efficacy in reducing weed densities, since the weed control was ranged 75–80% and 85–93%, respectively.

Figure 2 exhibits the effects of the three applied cultivation technologies during the study (2017,

2018, and 2019). Cultivation technology (T3, high intensive) was the most effective in controlling weeds during the trial, since the weed density decreased over the years as shown by the following values 0.6 plant/m² ± 0.02, 0.3 plant/m² ± 0.02, and 0.2 plant/m² ± 0.01 in 2017, 2018 and 2019, respectively.

The biological efficiency of the investigated cultivation technologies is shown in Figure 3. The highest biological efficiency was obtained when cultivation technologies 2 and 3 were used with

Figure 2. Effect of the three cultivation technologies (T1 – basic, T2 – intensive and T3 – high intensive) on biological efficiency during the study period (2017, 2018 and 2019)

Figure 3. The biological efficiency of the investigated cultivation technologies to control weed (T1 – basic, T2 – intensive and T3 – high intensive)

90% and 96%, respectively. The cultivation technology 1 also seems to be effective in suppressing weeds, since 87, 81, and 88% weed biomass was reduced in *Echinochloa crus-galli*, *Stellaria media*, and *Viola arvensis*, respectively.

Yield performance and grain quality

Figure 4 displays yield performances of the three winter wheat varieties attributed to the cultivation technologies. High intensive cultivation technology

(T3) gave the best yields whatever the considered wheat variety. It is noted that there was no significant difference in the yield potential of all studied varieties. Moscovskaya 40 variety (V1), Nemchinovskaya 17 variety (V2) and Nemchinovskaya 85 variety (V3) yielded 10.6 ± 0.14 t/ha, 9.8 ± 0.39 t/ha and 9.9 ± 0.21 t/ha respectively throughout the study. On the other hand, the lowest yield was recorded when the basic cultivation technology was

Figure 4. Yield performances of the three studied winter wheat varieties (Moscovskaya 40 variety (V1), Nemchinovskaya 17 variety (V2), and Nemchinovskaya 85 variety (V3)) as influenced by the cultivation technologies (T1 – basic, T2 – intensive and T3 – high intensive)

Figure 5. Protein and gluten contents of the three studied winter wheat varieties (Moscovskaya 40 variety (V1), Nemchinovskaya 17 variety (V2), and Nemchinovskaya 85 variety (V3)) attributed to the cultivation technologies (T1 – basic, T2 – intensive and T3 – high intensive)

implemented (T1) in all wheat varieties 7.5 ± 0.45 (V1), 7.8 ± 0.29 (V2) and 8.1 ± 0.27 t/ha (V3).

Grain quality was analysed based on protein and gluten contents in the different wheat varieties. The results showed that the protein and gluten content increased significantly by intensity of cultivation technologies (Figure 5). The highest protein and gluten content were observed when the high intensive cultivation technology was performed (T3) for all tested varieties in the values $17.8\% \pm 0.30$ (V1), $17.5\% \pm 0.32$ (V2) and $17.6\% \pm 0.42$ (V3) for protein content and $36.4\% \pm 0.90$ (V1), $36.1\% \pm 0.59$ (V2) and $36.7\% \pm 0.63$ (V3) for gluten content.

In Table 2, the analysis of variance for grain yield and quality (protein and gluten content) revealed that the cultivation technology, variety, and year had a highly significant effect on the yield and grain quality ($p \leq 0.05$). In addition, the yield and grain quality were significantly affected by the interaction between all studied treatments (cultivation technology $\times$ variety, cultivation technology $\times$ year, variety $\times$ year, and cultivation technology $\times$ variety $\times$ year) ($p \leq 0.05$).

Figure 6 shows the relationship between biological efficiency of treatments, wheat yield, and grain quality by using linear regression. The biological efficiency of cultivation technologies is not correlated with grain yield $r^2 = 0.05$, however protein and gluten contents enhance with increasing biological efficiency of treatments $r^2 = 0.50$ and $r^2 = 0.52$, respectively.

DISCUSSION

Weeds are a serious challenge in wheat production. They generate colossal yield losses through the competition for nutrients with crops. An effective weed management system in modern agriculture is indispensable for the achievement of high grain yield. Here we demonstrate the practicability of varied levels of cultivation technologies in enhancing crop competitive ability against the weeds, hence, minimizing crop losses and simultaneously augmenting grain quality. Precursory studies evaluating the effect of herbicides and fertilisers in controlling

Figure 6. The relationship between biological efficiency of cultivation technologies, wheat grain yield, protein and gluten contents

weeds have illustrated that compliance with the doses of inputs and timely application improve wheat yield and grain quality (Latati *et al.* 2019; Rebouh *et al.* 2019).

Herbicides have become one of the most used methods for weed control. The present study was designed to determine the effect of three cultivation technologies, which also embraced the use of herbicides to control weeds in the winter wheat crop. The results showed that the studied cultivation technologies had favorable biological efficiency to control *Echinochloa crus-galli*, *Stellaria media* and *Viola arvensis*. The high intensive cultivation technology was the most effective among all experimental treatments, since 87, 81 and 88% efficiency was obtained for *Echinochloa crus-galli*, *Stellaria media* and *Viola arvensis* suppression, respectively. This was likely due to the presence of florasulam and tribenuron-methyl belonging to triazolopyrimidine class, which impedes the biosynthesis of branched-chain amino acids (leucine, isoleucine and valine) by inhibiting the enzyme ALS also known as AHAS (Weis *et al.* 2008).

Baghestani *et al.* (2007) and Zand *et al.* (2010) reported that florasulam and tribenuron-methyl were very effective for the management of *Echinochloa crus-galli*, *Stellaria media* and *Viola arvensis*, their findings are in agreement with those reported in the current study. High intensive cultivation technology including florasulam and tribenuron-methyl (Tandem), belonging to triazolopyrimidine, significantly reduced weed density 1.8 plant/m², 1.9 plant/m² and 1.2 plant/m² for *Echinochloa crus-galli*, *Stellaria media* and *Viola arvensis*, respectively.

Murphy and Lemerle (2006) have shown that the type and rate of fertilisers used play an important role in weed population shifts and an inappropriate dose of fertilisers significantly affects the abundance of weeds in crops. For example, the number of weed individuals decreases and their biomass increases with enhancing nitrogen fertiliser levels (Mahn *et al.* 1988; Tang *et al.* 2014).

In the current study, the implemented fertiliser rates [N (60–150), P₂O₅ (30–90), K₂O (90–150)] were balanced which promoted wheat crop growth, resulting in closed crop stands and limited light for weed communities. In addition, winter wheats (Moskovskaya 40, Nemchinovskaya 17 and Nem-

chinovskaya 85) seem to have the high competitive ability, which resulted in reduced weed pressure and diffusion in the cropping system. These results corroborate the findings of a great deal of the previous works, which demonstrated the importance of the competitive ability of the cultivated genotypes in weed management (Bastiaans *et al.* 2008; Andrew *et al.* 2015).

Weed resistance to herbicides is increasingly becoming problematic in crop production systems across the globe. The repeated use of herbicides with the same mode of action ultimately leads to the rapid spread of the resistant genotypes in the weed population (Heap *et al.* 2018; Nakka *et al.* 2019). The established spatio-temporal analysis to study the effect of cultivation technologies on weed species abundance carried out over three years of trials (Figure 2) showed that the investigated cultivation technologies reduced weeds infestation levels over the years. This is probably due to the combined effect of crop rotation and tillage before the sowing season, which optimized the efficacy of herbicides in weed control. These results were in consistent with the findings reported by Mishra and Singh (2012), whereby tillage followed by herbicide application increased biological efficiency and reduced the chances of the weeds developing resistance to applied herbicides. Messaoudi *et al.* (2020) and MacLaren *et al.* (2021) also noticed that the combined tillage-crop rotation provides better weed control results than tillage-monoculture combination, which leads us to conclude that weed management depends on several factors that constitute cultivation technology such as herbicide, crop rotation, tillage, fertilisation, genetic characteristics of cultivars and others.

Previous studies demonstrated that herbicide use generally does not affect wheat yields, but increases grain quality of crops (Storkey *et al.* 2003; Benjamin *et al.* 2010; Gaba *et al.* 2016). This study was premised on assessing the efficacy of the herbicides both in weed control and enhancement of wheat yield and the grain quality. The analyses of the relationship between biological efficiency of treatments, wheat yield and grain quality by using the linear regression did not show any relationship between wheat yields and herbicide use ($r^2 = 0.05$), however, there is a moderately positive relationship

between protein, gluten content, and biological efficiency of herbicide $r^2 = 0.50$, $r^2 = 0.52$, respectively (Figure 6). This is probably due to the competitive ability of the cultivated genotypes, which increases their nutrient uptake rate, thus improving grain quality (Van der Meulen *et al.* 2017; Polityko *et al.* 2020). Moreover, our findings from the previous study where we explored the nutrient use efficiency of the winter wheat cultivars investigated in the current work exhibited that Moskovskaya 40, Nemchinovskaya 17 and Nemchinovskaya 85 had high nutrient uptake capacity (Rebukh *et al.* 2019).

CONCLUSIONS

Weeds are one of the major constraints in crop yields and quality, causing huge economic losses. The present study showed that the weed management systems by the using several factors including fertilisers and growth regulators, at indicated rates, offered optimal weed reduction (96%) and increased grain yield by 3 t/ha. Moskovskaya 40, Nemchinovka 17 and Nemchinovka 85 expressed high competitive ability. Thus, the obtained results in our study indicated that balanced fertilisation and rational use of herbicides could be used as an effective method to suppress weeds, which allows not only maintenance of a stable crop yield but also greatly reduce weed reproduction. The current results open real opportunities for large-scale performing the cultivation technologies in different regions of Russia and exhibited new varieties that could offer high performance and weed-crop competitive ability.

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