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Impact of cultivation technologies on yield and grain quality of winter wheat *Triticum aestivum L.* in Moscow region

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Abstract. The current study is aimed at evaluating the reaction of winter wheat varieties according to cultivation technologies at a different level of intensity i.e. basic, intensive and high intensive. The cultivation technologies included fertilizers, pesticides and growth regulators at different combinations and concentrations. The experiment was established in order to determine the optimum conditions of winter wheat cultivation. Three winter wheat varieties were studied: Moskovskaya 40 (V1), Nemchinovskaya 17 (V2) and Nemchinovskaya 85 (V3). Yield performances and grain quality (measured through protein and gluten content) were determined according to the tested cultivation technologies. The results showed that the cultivation technology affected grain wheat productivity and quality on all varieties studied, since the highest yields were obtained using high intensive cultivation technology for all varieties studied, Moskovskaya 40 — 9.65 t/h, Nemchinovskaya 17 — 8.58 t/h and Nemchinovskaya 85 — 9.87 t/h. However, according to the basic technology, the yield was lower by 20…64 %. The tested cultivation technologies demonstrated that high intensive cultivation technology increased wheat quality. The highest protein content (18 %) was recorded in Nemchinovskaya 85 variety. The present results give real opportunities for a large-scale application of the tested cultivation technologies in different agricultural lands of Russia.

Keywords: cultivation technology, fertilizer, pesticides, wheat productivity, wheat varieties

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Introduction

Winter wheat occupies a significant proportion in the whole agricultural system, this crop is grown in an area of 10 million hectares in the Central Non-black region [1]. This crop is considered as the most important food crop in Russia, providing daily protein and food calories [2]. The new cultivation technologies used provide to obtain 10 t/ha yield or more through decreasing pests damage, disease infections and weed populations, since, direct yield losses caused by phytopathogens are between 30 and 65 % of global agricultural productivity [3].

Modern cultivation technologies include a set of agricultural techniques aimed at reducing the negative effects of climate conditions, development of diseases and pests [4]. In this case, new approaches are used in application of scientific modern methods for regulating growth and plant development. They include the use of mineral fertilizers, considering the need for basic plant nutritive elements based on soil and plant diagnostics, the use of modern plant protection products, compliance with optimal grain seeding standards for the cultivated variety, and the use of retardants [5].

Influence of different cultivation technologies on winter wheat varieties grown on sod-podzolic soils of the Central non Chernozem region was studied [5, 6]. It was found that using optimal cultivation technologies improves soil agrochemical and agrophysical indicators, phytosanitary condition of fields and plants, and increases fertility of sod-podzolic soil [4—14].

The rational use of agrotechnical methods, mineral fertilizers and plant protection chemicals contributes to obtaining desired yield with high grain quality [9—10]. In this case, such technological approaches as fertilization based on soil and plant diagnostics, development of an integrated plant protection system, use of biological agrochemicals and other technological solutions are considered.

Thus, the research was aimed to study the impact of three cultivation technologies on winter wheat varieties. Three different cultivation technologies identified as basic, intensive and high intensive with different pesticide combinations, fertilizers and growth regulators were investigated. Yield and protein content were measured in three winter wheat varieties.

Materials and methods

Plant Material. In the experiment, three winter wheat varieties were studied: Moskovskaya 40 (V1), Nemchinovskaya 17 and Nemchinovskaya 85 (V3).

Experimental Field. Intensive farming was conducted during 2016—2019 under the conditions of nonchernozem zone at Nemchinovka Research Institute of Agriculture located in Moscow region, Odintsovskiy district, Russia. (55° 45′ N, 37° 37′ E and 200 m altitude).

Soil Characteristics. Samples were taken randomly from different spots at 0…15 cm to record the initial soil characteristics. The soil was typically loamy with 1.73 % organic matter. Soil pH was within the limits of 5.6…6.1. P_2O_5 concentration was from 105 to 350 mg/kg and K_2O from 65 to 125 mg/kg characterizing the soil as mid and high provided with phosphorus and mid and low provided with potassium.

Climatic Conditions. The climate in the Moscow region is mid-continental with soft winter, occasional flaw and warm damp summer. The average annual temperature is +4.20 °C. The average temperature of warm season (May — October) is +14.40 °C; and the average monthly temperature in January and July is –10.40 °C and +18, 10 °C, respectively. The average time of a positive air temperature period is near 215 days. The average period with temperature more than +10 °C (vegetation season) is 130 days. The average temperature of cool season (November — March) is –6.70 °C. The average annual precipitation is 628 mm: 56 % in spring-summer season and 26 % in autumn. The average precipitation rate from May to September is 339 mm (Fig. 1).

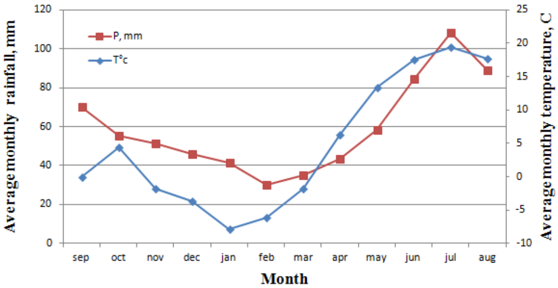

Fig. 1. Average monthly rainfall and temperature during 2016—2019 in the Moscow region

Cultivation technologies. Experiments were conducted during three years from 2016 to 2019. Three different cultivation technologies were tested: basic, intensive and highly intensive which included fertilizers, fungicides, herbicides, insecticides and growth regulators at different combinations and concentrations (Table 1).

Table 1

Applied treatments in cultivation technologies

Cultivation technology	Fertilizers, kg ha^{-1}	Crop protection details
1. Basic T1	Basal application $N_{30}P_{40}K_{60,}$ kg ha^{-1}, in pre-sowing and N_{30}, kg ha^{-1}, in the germination phase	• *Fungicide*: Vincyt Forte 1.25 l/t + Fundazol 0.5 kg /h • *Insecticide*: Picus 1 l/t+DITOX 1.0 l/ h • *Herbicide*: Lintur 180 g/h
2. Intensive T2	Basal application $N_{30}P_{90}K_{120}$, kg ha^{-1}, in pre-sowing, Top dressing, at germination and tillering phases, N_{60} and N_{30}, kg ha^{-1}, respectively	• *Fungicide*: Vincyt Forte 1.25 l/t (+ Impact 0.5 l/h + Super Alto 0.5 l/h + Consul 1 l/h • *Insecticide*: Picus 1 l/t + Danadim Expert 1.0 l/h + Danadim Power 0.6 l/h + Danadim Expert 0.6 l/h • *Herbicide*: Ditox 1.0 l/h + Accurate Extra 25 g/h • *Growth regulator*: Perfect 0.3 l/h + Perfect Retarders
3. High Intensive T3	Basal application $N_{30}P_{120}K_{180}$, kg ha^{-1}, in pre-sowing, Top dressing, at germination, tillering and elongation of stem phases, N_{60}, N_{30} and N_{30}, kg ha^{-1}, respectively	• *Fungicides*: Vincit Forte 1.25 l/t +Exclusive Impact 0.5 l/h + Super Impact 0.75 l/h + CONSUL 1.0 l/h • Herbicide: Accurate Extra 35 g/h +Foxtrot 1.0 l/h • *Insecticide*: Picus 1 l/t + Danadim Power 0.6 l/h + Vantex 60 ml/h • *Growth regulator*: SAPRESS0.3 l/h + Perfect 0.3 l/h

The experiment was carried out in a systematic way, repetition blocks consisted of 160 m^2 plots, replication was triple, with seeding rate of 5 million grains/ha. After the previous harvest (2015—2016), tillage was done by a BDT-10 disc truck in a single lane. Seeding was realized with a SN16 PM seeder. The harvesting was carried out with Sampo-500 tractor.

Results and discussions

Yield and productivity of the winter wheat varieties according to the tested cultivation technologies. Yield performance of the three studied winter wheat varieties according to the three tested cultivation technologies (T1 — basic, T2 — intensive, T3 — highly intensive) was shown in the figure 2. When comparing wheat varieties according to cultivation technology 3 (T3, highly intensive), Nemchinovskaya 85 (V3) showed the highest values (9.87 t/ha), Moskovskaya 40 (V1), Nemchinovskaya 17 (V2), yielded 9.65 t/ha 8.58 t/ha, respectively. However lowest yield was achieved using basic technology for all studied varieties — Nemchinovskaya 85 (V3) (7.81 t/ha), Moskovskaya 40 (V1) (7.72 t/ha), Nemchinovskaya 17 (V2) (7.28 t/ha).

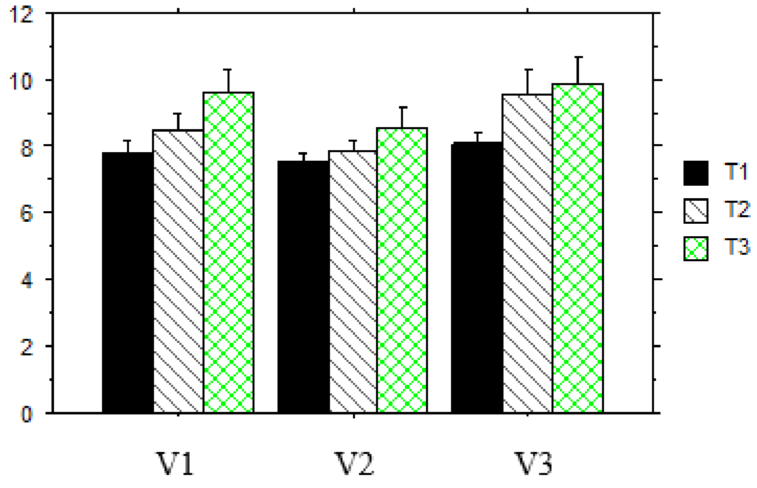

Fig. 2. Yields of winter wheat varieties (V1 (Moskovskaya 40), V2 (Nemchinovskaya 17), V3 (Nemchinovskaya 85)) according to the tested cultivation technologies (T1 (basic), T2 (intensive) and T3 (high-intensive)) in 2016—2019

The results showed that the cultivation technologies had a significant effect on yield in 2017, 2018 and 2019: P ≤ 0,01, $P \leq 0{,}001$, $P \leq 0.001$, respectively. It was shown that the variety also affected grain yield, since P-values were $P \leq 0.01$, $P \leq 0.01$ and $P \leq 0.001$ for 2017, 2018 and 2019, respectively. However, the interaction cultivation technologies-variety had a significant effect on yield in all studied years 2017, 2018 and 2019 — $P = 0.04$, $P \leq 0.01$ and $P = 0.03$ respectively (Table 2).

Table 2

Yield of durum wheat varieties under different cultivation technologies. Values represent the average of 4 replicates ± SE (standard errors). *P*-values from ANOVA (cultivation technology, variety and cultivation technology × variety)

Cultivation technology	Variety	Y2017	Y2018	Y2019
T1	V1	6.8±0.05[d]	6.7±0.04[d]	6±0.05[d]
	V2	9±0.02[d]	9.5±0.06[bc]	7.2±0.02[d]
	V3	8.3±0.05[cd]	10.5±0.04[bc]	8.2±0.06[c]
T2	V1	11±0.02[bc]	8.3±0.05[c]	6.7±0.06[d]
	V2	10.6±0.05[c]	10.7±0.05[bc]	8.4±0.03[c]
	V3	10.8±0.04[c]	11.4±0.06[b]	10.9±0.1[b]
T3	V1	11.7±0.05[b]	9.5±0.04b[c]	7.6±0.06[c]
	V2	12.3±0.03[b]	12.7±0.04[b]	9.01±0.01[bc]
	V3	13.6±0.05[ab]	13.3±0.05[a]	13.6±0.1[a]
p value	C.tech	≤0.01	≤0.001	≤0.001
	Variety	≤0.01	≤0.01	≤0.001
	C. tech×Var	0.04	≤0.01	0.03

Winter wheat crop occupies the largest area among other crops worldwide; it is one of the leading food sources [15—22]. Increasing grain yields to supply food to the world's ever growing population is one of the main goals [8]. Many researchers have determined that achieving high winter wheat grain yields depends on the use of fertilizers, growth regulators, and crop protection products [4, 6, 7, 16—22, 24].

To obtain a high winter wheat yield, it is necessary to use the optimal nitrogen fertilizer doses in the soil. Ma C. et al. [21] recommends the combined use of organic fertilizers with 150 kg/ha of nitrogen fertilizers. Our results were similar to those reported by this author, since we used 150 kg/ha of nitrogen fertilizers in cultivation technology 3 (high intensive technology), this allowed to obtain high yield for all studied varieties 9.65 t/ha (V1T3), 8.58t/ha (V2T3) and 9.87 t/ha (V3T3), this is probably due to the influence of nitrogen fertilizers on photosynthesis physiology [17]. However, compared to the high insensitive technology, the obtained wheat yield recorded using the basic technology (T1) was lowest when applying 60 kg/ha of nitrogen — 7.76 t/ha (V1T1), 7.48 t/ha (V2T1) and 8.034 t/ha (V3T1).

Many studies showed that growth regulators significantly improved root growth and leaf biomass. They also increased photosynthesis, stomatal conductivity, transpiration rate, and water use efficiency [20]. In our study, the growth regulator (perfect (phase GS21—22), Sapress (phase GS31—32)) from the active molecule Trinexapac ethyl was used in intensive and high-intensity technologies, which explains the high yield compared to the yield obtained by applying the basic technology, without growth regulators. On the other hand, it was previously shown that high-intensive technology is most effective for controlling phytopathogens in winter wheat crops, which explains the high yield achieved with this technology, since optimal protection from phytopathogen increases grain quality and productivity [9].

Protein Content of the winter wheat varieties according to the tested cultivation technologies. The grain quality was evaluated on the basis of protein and gluten content in the different varieties according to the tested cultivation technologies. The results showed that no significant difference was observed using cultivation technology 1 and 2 regardless of the investigated variety (Fig. 3). However, cultivation technology 3 seems to increase systematically protein content in the three winter wheat varieties studied.

According to the tested technologies, the protein content in the grain of winter wheat varieties was the highest using the high intensive technology, since 18.33 % (V1T3), 16.14 % (V2T3) and 17.16 % (V3T3). However, the lowest protein content was observed using the basic technology16.45 % (V1T1), 14.30 % (V2T1) and 15.30 % (V3T1) (Fig. 3).

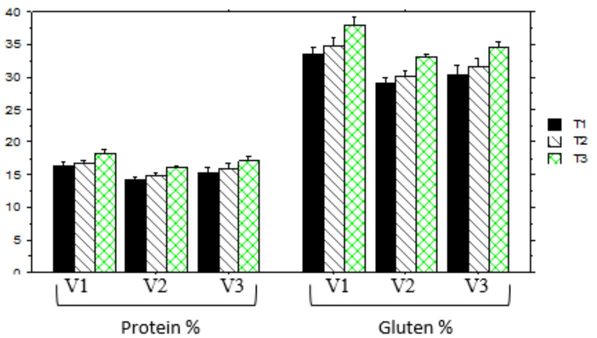

Fig. 3. Protein and gluten content of winter wheat varieties (V1 (Moskovskaya 40), V2 (Nemchinovskaya 17), V3 (Nemchinovskaya 85)) according to the tested cultivation technologies (T1 (basic), T2 (intensive) and T3 (high-intensive)). 2016—2019

The ‘cultivation technology’ and ‘variety’ had a significant effect on protein and gluten contents in the three year trials ($P \leq 0.001$), however the analysis reveals that the interaction ‘variety-cultivation technology’ is not significant for protein and gluten content in 2017 ($P = 0.9$), while on 2018 and 2019 the effect was significant on the protein and gluten content ($P \leq 0.001$) ($P = 0.02$), respectively (Table 3).

Table 3

Protein content observed in wheat varieties under different studied cultivation technologies. Values represent the average of 4 replicates ± SE (standard errors). *P*-values from ANOVA (cultivation technology, variety and cultivation technology × variety)

Cultivation technology	Variety	Y2017	Y2018	Y2019
T1	V1	16.45±0.4^{ab}	15. 80±2^{a}	15.95±0.6^{ab}
	V2	14.30±0.4^{cd}	14.70±0.5^{b}	14.60±0.3^{b}
	V3	15.30±1.1b	15.90±0.7^{b}	16.10±0.2^{ab}
T2	V1	16.66±0.7^{cd}	16.10±0.3^{c}	16.78±0.2^{b}
	V2	14.76±1.1^{c}	14.20±0.7^{c}	14.96±0.04^{c}
	V3	15.86±0.6^{cd}	15.95±0.3^{d}	16.10±0.04^{c}
T3	V1	18.33±0.9^{c}	18.10±0.3^{c}	18.65±0.001^{c}
	V2	16.14±0.4^{d}	16.26±0.1^{d}	16.75±0.07^{c}
	V3	17.16±0.4^{d}	17.15±0.1^{d}	17.60±0.001^{c}

End of Table 3

Cultivation technology	Variety	Y2017	Y2018	Y2019
p value	C.tech	≤0.001	≤0.001	≤0.001
	Variety	≤0.001	≤0.001	≤0.01
	C. tech×Var	0.9	≤0.001	0.02

Grain quality (especially protein and gluten content) and high yield are the main goals in the wheat crop production [1, 3—11, 15—24] achievable by managing water resources, applying nitrogen, and controlling plant pathogens. The results showed that using basic and intensive technology, no significant differences were observed regardless of the studied varieties (Fig. 3). However, under high-intensive technology, it seems that the protein and gluten content in the three studied varieties of winter wheat increased systematically.

The results obtained (Fig. 3) showed that the high content of protein and gluten in the grain for all studied varieties was observed in high-intensive technology, where the use of nitrogen (N) was increased in pre-sowing processing, during tillering, stem elongation of and earing stage. Therefore, the obtained results are similar to those reported by Marino et al. [24] and Ercoli et al. [19] testing the effect of nitrogen application on protein and amino acid composition of wheat. These authors showed that increasing doses of nitrogen could significantly increase protein content of wheat grains. However, recent research by Curci et al. [18] where they studied wheat performance under nitrogen deficiency showed that quality of wheat grain evaluated on the basis of protein content was mediocre. This is similar to the results obtained, since the protein content in wheat was significantly reduced in plants grown under the basic technology.

Vaccino et al. [12] also reported that grains infested by pests record low content of protein and gluten. In our previous study, where we investigated the impact of three cultivation technologies on pest infestation rate, protein content in wheat decreased significantly at the highest percentages of pest infestation [10], this was associated with negative effects on plant growth and development, as reported by Wratten [13] which explains the high protein content value obtained under high intensive technology in the current study.

Conclusions

With an increase in intensity of cultivation of winter wheat varieties, grain quality and yield performance increased by 3.8 t/ha. This was observed in all varieties studied. The results showed that setting up a production system, normative method should consider varietal features, conditions of plant nutrition, agrochemical characteristics of soil and meteorological factors. The current results open real opportunities for a large-scale application of the tested cultivation technologies in different regions of Russia and pointed out new varieties — Nemchinovskaya 85 that could offer high productivity.

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Влияние трех технологий возделывания на урожайность и качество зерна озимой пшеницы *Triticum aestivum* L. в условиях Московского региона

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Аннотация. В условиях Московского региона на дерново-подзолистой почве изучена реакция сортов озимой пшеницы на три уровня минерального питания и систем защиты растений — базовая, интенсивная и высокоинтенсивная технологии, которые включали удобрения, средства защиты растений и регуляторы роста в различных комбинациях и концентрациях. Эксперимент был поставлен с целью создания оптимальных условий возделывания разных сортов озимой пшеницы. Были изучены три сорта — Московская 40 (V1), Немчиновская 17 (V2) и Немчиновская 85 (V3). Показатели урожайности и качества зерна, измеряемые по содержанию белка и клейковины, определялись в соответствии с испытанными технологиями возделывания. Результаты показали, что урожайность и качество зерна пшеницы изменились, самые высокие урожаи получены при применении высокоинтенсивной технологии у сорта Немчиновская 85 — в среднем за последние три года она составила 9,87 т/га, с потенциалом — 14,8 т/га, у сорта Московская 40 — 9,65 т/га, Немчиновская 17 — 8,58 т/га. По базовой технологии урожайность была ниже на 20…64 %. При высокоинтенсивной технологии у сорта Немчиновская 85 содержание белка достигало 18 %. Представленные результаты дают реальные возможности для масштабного применения апробированных технологий возделывания в различных сельскохозяйственных угодьях России.

Ключевые слова: технологии возделывания, сорта, удобрения, средства защиты растений, урожайность, белок, клейковина

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