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THE INFLUENCE OF DIFFERENT TILLAGE SYSTEMS ON THE MORPHOLOGICAL, PRODUCTIVE CHARACTERISTIC AND GRAIN YIELD OF TWO WINTER WHEAT VARIETES

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Abstract. The study on the influence of reduced cultivation technology on the morphological and productive traits of winter wheat was conducted at the ,,Radmilovac" experimental field, managed by Faculty of Agriculture, University of Belgrade. The field trial was set up and carried out during the 2022/23 season, as twofactorial, with three replications, on soil type classified as chernosem luvic. The size of each elementary plot was 6 m2. The first factor (A) was the tillage system, with three following variants: Convetional tillage (CT) that represents plow ploughing to a depth of 25cm, as well as pre-sowing cultivation with disc harrow and harrow; Mulch tillage (MT) performed by chisel plow, to a depth of 25cm without inverting the soil, leaving over 30% of crop residues on the soil surface; The third tillage system is based on manual direct sowing, without preliminary tillage, leaving all crop residues on the soil surface. The second investigated factor (B) involved two selected winter wheat cultivars (NS Zvezdana & NS Rajna), grown in a four crop rotation with maize as preceding crop. In all plots, basic fertilization in autumn was performed using NPK (15:15:15) fertilizer at a rate of 600 kg ha-1. Additional nitrogen fertilization was applied in the form of ammonium nitrate (AN) at a rational rate of 60 kg/ha N. Sowing was carried out on October 7th 2022 and harvesting took place in early July 2023. On average, the greatest stem lenght was recorded in the no-tillage system (94,09 cm) while the lowest was observed in the mulch tillage system (82.36 cm), which represents a statistically highly significant difference. The longest average spike length occurred in the mulch tillage system (8.85 cm), whereas the shortest was in the conventional tillage system (7.96 cm), however, the difference between these values was not statistically significant. In terms of grain weight per plant, the highest average value was recorded in the no-tillage system (11.9 g), although this did not differ significantly from the lowest average value found in the conventional system (10.1 g). The highest average grain yield was also observed in the no-tillage system (5.42 t ha−1), which was not statistically significantly different compared to the lowest yield in the conventional tillage system (4.54 t ha−1). The application of rational nutrient inputs and conservation tillage systems can result in satisfactory yields and favorable morphological characteristics, thereby supporting the principles of sustainability, preserving key resources, and enhancing the production of winter wheat.

Keywords: cultivar, fertilization, tillage systems, sustainability

1. Introduction

Agriculture represents the foundation for food production, serving both human and animal populations. With the continuous growth of the global population, the demand for food has also increased, leading to the intensive exploitation of key natural resources. However, careless and improper use of these resources results in their depletion and degradation. Crop production today relies heavily on various mechanized operations, as well as the application of irrational quantities of fertilizers and plant protection products, which ultimately disrupt both economic and ecological stability.

To reduce the risks associated with these issues, new and improved agricultural technologies have been developed, alongside reductions in existing systems that call for modifications to current cultural practices. These modifications aim to align with the principles of sustainability by limiting the intensive use and consumption of resources and reducing environmental pollution.

Since the earliest days of agricultural production, humans have recognized that appropriate soil tillage systems can improve certain soil properties, enhance fertility, and provide favorable conditions for plant growth. This, in turn, enables high and stable yields while protecting the soil from weeds, insects, and various pathogens, and maintaining its productive capacity. Consequently, soil tillage is considered the oldest agrotechnical measure. Diverse experiences in soil management have led to the development of numerous technical systems that are applied based on various factors [1].

Tillage must be adapted to the local climate, soil type, topography, fertilization practices, production system, erosion risk, crop variety, previously cultivated crops, and other site-specific conditions [2]. A well-chosen tillage system is a crucial factor which, when combined with proper crop rotation and fertilization, ensures high efficiency and the rational use of soil fertility.

As one of the key agrotechnical practices, soil tillage is intended to create optimal conditions for the growth and development of cultivated plants. It is therefore essential to prepare the land for cultivation and to utilize its productive capacity regularly throughout each growing season. The reduction of conventional tillage systems has been driven by the need to simplify cultivation processes and by the development of new tools and technologies aimed at lowering production inputs, ultimately reducing the cost of the main agricultural product. Moreover, reducing the number of tillage operations does not negatively impact productivity, while increasing overall efficiency and producing several positive outcomes. These include improved soil structure, preservation and enhancement of fertility, and reduced labor, costs, and time required for individual operations. However, some drawbacks still exist, mostly related to the application of organic and mineral fertilizers, as well as weed, pest, and disease control [3].

In addition to proper tillage, meeting the nutritional needs of crops is essential. To preserve and enhance the soil's capacity to support high yields and favorable morphological traits, it is necessary to regularly or periodically replenish nutrients lost through harvest, leaching, and other processes. This must be done in a way that does not harm the soil or negatively affect the cultivated plants [4].

Considering the importance of winter wheat in agricultural production and human nutrition, and the fact that its cultivation requires the application of various agrotechnical practices, the objective of this study is to determine the effects of reduced tillage technologies on the morphological and productive traits and grain yield of two winter wheat cultivars.

2. Material and Methods

This research was conducted at the ,,Radmilovac" experimental field, managed by the Faculty of Agriculture, University of Belgrade. The field trial was established and carried out during 2022/23 growing season as twofactorial with three replications, on a chernosem luvic soil type. The selected wheat cultivars were grown within a four crop rotation system, with maize as preceding crop, The surface of each elementary plot was 6 m2.

For the purpose of this study, three soil tillage systems were applied, representing factor A of the experiment:

1. Conventional Tillage (CT): this included plow ploughing to a depth of 25cm, as well as pre-sowing cultivation with disc harrow and harrow;
2. Mulch Tillage (MT): Soil was tilled using chisel plow, to a depth of 25cm without soil inversion, leaving over 30% of crop residues on the soil surface, followed by discing and harrowing;
3. No Tillage system (NT): Which is based on manual direct sowing, without preliminary tillage, leaving all crop residues on the soil surface.

Primary tillage operations were carried out in early October, followed immediately by pre-seeding cultivation.

Basal fertilization was conducted simultaneously using NPK fertilizer (15:15:15) at a rate of 600 kg ha-1. On March 10th 2023. all treatments were top-dressed with nitrogen in the form of ammonium nitrate (AN) at rational rate of 60 kg ha-1 N

For the cultivation of winter wheat, two carefully selected winter wheat cultivars were selected (NS Zvezdana & NS Rajna), representing factor B of this experiment. NS Zvezdana responds well to elevated nitrogen levels and exhibits good lodging resistance, whereas NS Rajna requires higher input levels and more intensive agrotehnical measures. Under optimal growing conditions, both cultivars are capable of achieving yields exceeding 9 t/ha.

Weed control was carried out with Maton in tillering if stem elongations were 1.0 l ha−1 (in the CT plot) or 0.5 l ha−1 (in the MT and NT plots). Unify in an amount of 0.8 l ha−1, and Ison in an amount of 0.6 l ha-1, were used to protect plants against fungal diseases.

Sowing was performed on October 7th 2022, the sowing density of wheat was 550 seeds per m2. Harvesting took place in early July 2023, when wheat samples were also collected.

The collected data on morphological and yield related traits were statistically analysed using analysis of variance (ANOVA), while individual treatment comparisons were conducted using the LSD test.

2.1 Meteorological conditions during experiment

Meteorological conditions at the experimental site are presented graphically in Figure 1. The climatediagram is constructed using data provided by the Republic Hydrometeorological Servise of Serbia (RHMZ) for the Belgrade area, covering the period from October 2022 to June 2023.

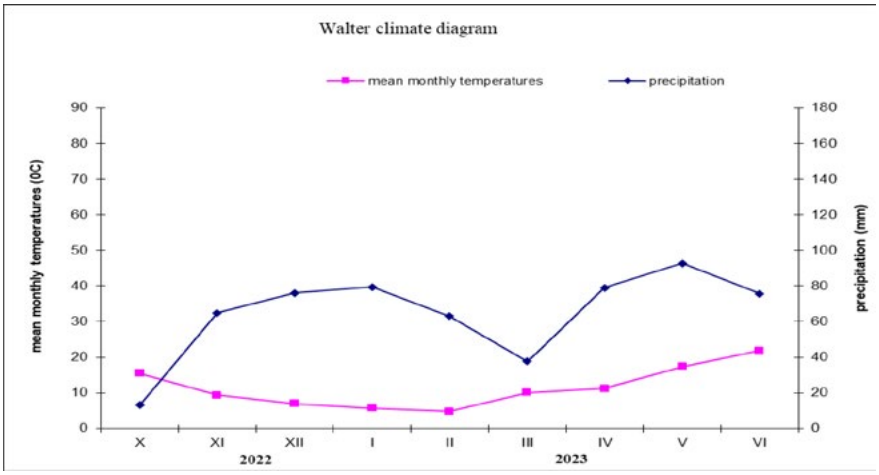

Figure 1: Climatediagram for the Belgrade Area (October 2022 – June 2023)

The average monthly temperature during investigated period was approximately 11^{0}C, while the total precipitation amounted to about 581 mm over the vegetation period. From the climate diagram presented in Figure 1, a dry period can be observed in October, characterized by high temperature and low precipitation. This period coincided with the timing of primary tillage, pre-sowing preparation and sowing. Adequate soil moisture during this phase is essential for proper seed germination and early plant development. However, such condition were lacking in October, leading to delayed emergence and poor root establishment of wheat, despite the fact that more favorable weather conditions occured in November.

In the subsequent months, temperatures remained within the optimal range for wheat development, altough some extremes were recorded, such as unusually warm and relatively wet December. These atypical conditions may have negatively influenced certain morphological traits of the plant. The lack of rainfall in March coincided with a critical period of intensive wheat growth, which adversely affected the final grain yield, resulted in lower than expected productivity.

3. Results and disscussion

Data on the impact of different soil tillage systems on the morphological and productive traits of the selected wheat cultivars are presented in Table 1.

Table 1. Effect of different tillage systems on morphological and productive traits of selected wheat cultivars

Tillage systems (A)	Winter wheat cultivars (B)		Average A
	NS Zvezdana	NS Rajna	
	Average AB		
CT	80.87	85.18	83.03
MT	79.39	85.33	82.36
NT	99.37	88.81	94.09
Average B	86.54	86.44	
Spike lenght (cm)			
CT	7.44	8.49	7.96
MT	8.91	8.79	8.85
NT	7.7	8.87	8.28
Average B	8.02	8.72	
Grain mass per plant (g)			
CT	5.87	14.33	10.01
MT	6.53	16.46	11.49
NT	11.1	12.7	11.9
Average B	7.83	14.49	

Table 2. Thresholds of significance depending on the examined factor

Stem lenght		
LSD	0.05	0.01
A	4.648	6.375
B	3.795	5.205
AB	6.574	9.016
Spike lenght		
A	1.011	1.386
B	0.825	1.312
AB	1.429	1.961

Grain mass per plant		
A	3.093	4.242
B	2.525	3.463
AB	4.374	5.998

The thresholds of significance depending on the examined factor are representented in Table 2.

On average, the greatest stem length is recorded under the no tillage system (94.09cm), while the shortest stems are observed under the mulch tillage system (82.36 cm), which represents a statistically highly significant difference. When considering the average stem length by cultivar, no statistically significant differences are found. However, cultivar NS Zvezdana exhibit the longest stem under no tillage system (99.37 cm), which is significantly longer compared to NS Rajna under thr same system (88.81 cm) representing a highly significant difference. The shortest stem is observed in NS Zvezdana under the mulch tillage system (79.39 cm), but the comparison with the shortest stem of NS Rajna (85.18 cm) did not reveal a statistically significant difference.

Regarding spike length, the highest average value is recorded under the mulch tillage system (8.85 cm), while the lowest average spike length is found under the conventional tillage system (7.96 cm), however, this difference isn`t statistically significant. The longest spike is recorded in NS Zvezdana under the mulch tillage system (8.91 cm), closely followed by NS Rajna under the no-tillage system (8.87 cm), The difference between these values is not statistically significant. The shortest spike is found in NS Zvezdana under the conventional tillage system (7.44 cm). For NS Rajna, the shortest spike also occurr under the same tillage system, with a length of 8.49 cm, again, the difference between these values is not statistically significant.

If we compare the data on spike length with findings of [5] it can be concluded that the spike length of the NS Dragana variety, which measured 9.22 cm under conventional tillage, is greater than the average spike length of the varieties examined in this study, which was 7.96 cm. However, the spike length of NS Dragana in the no tillage system was 7.60 cm, which is shorter than the spike lengths of the cultivars investigated in this study (8.28 cm). Based on the obtained data, it can be stated that soil tillage, soil type, different meteorological conditions, and variety selection all have an influence on spike length.

Regarding grain mass per plant, the highest average value is observed under the no tillage system (11.9 g), altough there is not statistically significant difference when it comes to the lowest average value, recorded under conventional tillage system (10.1 g). On average, NS Rajna produced a higher grain mass per plant (14.49 g), which is statistically highly significant when compered to NS Zvezdana, which has an average grain mass of 7.83g per plant. The lowest grain mas is recorded in NS Zvezdana under the convencional tillage system (5.87 g), while the highest was observed in NS Rajna under the mulch tillage system (16.46 g), this difference is statistically highly significant.

Data about grain yield of selected wheat cultivars is represented in Table 3, while you can find the thresholds of significance for this examined factor in Table 4.

Table 3. Effect of Different Tillage Systems on the Grain Yield of Selected Wheat Cultivars

Cultivars			
Tillage systems (A)	Wheat cultivars (B)		Average A
	NS Zvezdana	NS Rajna	
	Average AB		
CT	3.23	5.79	4.54
MT	3.59	6.69	5.14
NT	6.11	4.73	5.42
Average B	4.31	5.74	

Table 4. The thresholds of significance for grain yield

LSD	0.05	0.01
A	1.615	2.215
B	1.318	2.284
AB	1.808	3.132

On average, the highest grain yield is recorded under the no tillage system (5.42 t ha−1), although this value is not statistically significantly different from the lowest yield observed under the conventional tillage system (4.54 t ha−1). The cultivar NS Rajna produced a significantly higher average yield (5.74 t ha−1) compared to NS Zvezdana (4.13 t ha−1), which represents a statistically significant difference.

The highest yield is achieved by NS Rajna under the mulch tillage system (6.69 t ha−1), and this was statistically significantly higher than the yield of NS Zvezdana under the same tillage system (3.59 t ha−1). The lowest yield is recorded for NS Zvezdana under the conventional tillage system (3.23 t ha−1), which is statistically highly significantly lower when compared to the highest yield of NS Rajna, and also statistically significantly lower when compared to the highest yield of NS Zvezdana, achieved under the no tillage system (6.11 t ha−1).

According to [6], who investigated the influence of year and location on winter wheat yield, the highest yields were obtained at the Pančevo site in 2017 (9.64 t ha−1), while the lowest yields were recorded in the same year at the Požarevac location (5.92 t ha−1). Compared to the cultivars tested in this study, the yields reported by [6] were significantly higher, which can be attributed to different meteorological conditions, locations, and cultivar selection.

According to [7], the average yield of certain wheat cultivars under conventional tillage in a trial conducted during the 2003/04 – 2004/05 seasons was 3.51 t ha−1, while the yield with top-dressing of 60 kg ha-1 N was 2.93 t ha−1 .These yields are significantly

lower than those obtained in the present study, where the average yield was 4,54 t ha−1. A similar trend was observed for the mulch tillage system, where [7] reported average yields of 2.75 t ha−1and 2.48 t ha−1with 60 kg ha-1 N top-dressing, respectively. For the no-tillage system, average yields were 2.32 t ha−1without and 2.01 t ha−1 with nitrogen top-dressing. In contrast, the current study recorded yields of 5.14 t ha−1 under mulch tillage and 5.42 t ha−1 under no-tillage. These differences in yield can be attributed to innovations in tillage practices as well as more favorable weather conditions during the experimental period, given that the trials were conducted in different years. Furthermore, conventional tillage systems require more intensive inputs and tend to produce higher yields than conservation tillage systems when higher fertilizer rates are applied. However, this advantage is only temporary. Over the long term, the drawbacks of conventional tillage become apparent, particularly its detrimental effects on soil health [8].

According to [9], the grain yield of winter wheat was highly influenced by tillage system tehnology. The grain yield of winter wheat was higher in CT plots than at MT and NT plots. The highest grain yield was in in the CT system with a high N dose (5.91 t ha−1), and the lowest was in the NT system with a reduced N dose (4.65 t ha−1). We have different case in the current experiment. When it comes to NS Zvezdana, the highest grain yield is represented in no-tillage system (6,11 t ha−1t/ha), while the lowest yield is in CT system (3.23 t ha−1). NS Rajna cultivar reached the highest grain yield in the MT system (6.69 t ha−1) and the lowest one is in NT system (4.73 t ha−1).

4. Conclusion

Based on the results of this study, it can be concluded that both soil tillage systems and wheat cultivars must be chosen rationally and carefully to achieve the desired outcomes. Lower yields and poorer morphological traits were obtained under the conventional tillage system, which may be attributed to the long-term use of this method. All examined morphological and productive traits showed higher values under no-tillage and mulch tillage systems, which was the main objective of the study. Therefore, it is necessary to adapt production technology to innovative approaches and reduced tillage systems.

The key to success lies in adhering to the principles of sustainable agriculture and selecting cultivars that can achieve desired yields and traits without requiring special soil management conditions or excessive fertilizer inputs. This was demonstrated in the current study, as nitrogen top-dressing was applied at a rational dose, yet significant yields and positive characteristics were achieved.

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