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EFFECT OF TILLAGE SYSTEMS ON THE YIELD AND QUALITY OF WINTER WHEAT GRAIN

Alexandra LEONTE[1], Simona Florina ISTICIOAIA[1], Lorena Diana POPA[1], Andreea Sabina PINTILIE[1], Margareta NAIE[1], Alina ȘIMON[2]

[1]Agricultural Research and Development Station Secuieni, 377 Principala Street, Secuieni, Neamt, Romania
[2]Agricultural Research and Development Station Turda, 27 Agriculturii Street, Turda, Cluj, Romania

Corresponding author email: simonapochi@yahoo.com

Abstract

Thus, the paper presents the results of the research carried out on the winter wheat crop, in the period 2020-2023, in the pedoclimatic conditions from A.R.D.S. Secuieni-Neamț, regarding the influence of three tools, namely, the plough, the chisel, and the disk, works carried out at four working depths (15 cm, 20 cm, 30 cm and 30 cm + 10 cm) and two working modes (work done out in every year in alternation: one - two - three years), and two working modes (work done out in every year in alternation: one - two - three years). During the three years of experimentation, the averages of the winter wheat yield varied within quite large limits, from 4676 kg ha^{-1}, in the variant where the land was permanently worked with the disk at a depth between 12-15 cm, and the maximum of 5936 kg • ha^{-1}, in the version in which the work carried out was to plow at 30 cm + 10 cm. Regarding the content of protein, oil, and starch, they had close values between the variants, the tillage not influencing these quality indices.

Key words: *growth, soil, tillage, winter wheat, working depths, yield.*

INTRODUCTION

Straw cereals, especially wheat (*Triticum aestivum* L.), are the most widely cultivated plant in the world, grown in over 100 countries, and are a prime commercial source (Voinea, 2023).
In the last decades, numerous kinds of research in the field of working processes of agricultural machines intended for work have been methodically directed toward experimental or theoretical-empirical research (Al-Suhaibani et al., 2010; Kushwaka et al., 1996; Naderloo et al., 2009; Ranjbar et al., 2013; Moeenifar et al., 2014; Singh et al., 2018; Al-Shamiry et al., 2020; Elsheikha et al., 2021).
Winter wheat is one of the most important crops in the world of particular economic importance, bread made from wheat flour being the essential food, also ensuring about 20% total calories consumed. Identifying a technology that ensures a superior quality, but also a high and stable production of the wheat crop by choosing: the right tillage system, the optimal level of fertilization and the treatment to combat diseases and pests is one of the priorities of agricultural research (Chiriță et al., 2023).
The conservation of soil fertility requires a tillage system that optimizes the plant needs through soil modifications (Al-Kaisi et al., 2020; Rinaldi et al., 2022), and ensures the improvement of soil properties to obtain large and constant crops (Busari et al., 2015; Mango et al., 2017; Bechmann et al., 2021).
The yields were influenced by the factors studied (scarified, nonscarified; the working depth of the basic soil works), but also by the climatic conditions recorded during the research time (Dinuță and Marin, 2023).
In the conventional tillage system, due to the long removal of vegetation, the lands are directly exposed to the action of precipitation and wind (Gao et al., 2016), causing the particles to detach and the erosion phenomenon to begin (Kaplan et al., 2020). Instead, covering the soil with a layer of vegetable mulch protects the soil from large temperature variations (El-Beltagi et al., 2022), reduces the amplitude of thermal oscillations (Mahdavi et al., 2017) avoids water loss by evaporation, and prevents weed growth (Cordeau et al., 2020; Derrouch et al., 2020; Fonteyne et al., 2020; Landers et al., 2021; Tataridas et al., 2021).

During the last years, in the Romanian agricultural practice, the alternatives of soil minimum tillage and no-tillage are very much applied in the winter wheat crop. During droughty autumns, when the soil is very dry and we can't have any plowing or the result of plowing would beclods very hard to chop, preparing the field by minimum tillage or direct sowing are preferred to plowing in order not to delay the wheat sowing, but also from an economic point of view (Chețan et al., 2017).
The forward speed influences the intensity of the tillage draft force on the entire machine and the working part. The influence becomes clearer if the variance and standard deviation of the tillage draft force are used (Cârdei et al., 2023).
By excessive processing of agricultural land by plowing and overturning the soil furrow (Bechmann et al., 2021) some of the diseases and pests are controlled (Poggi et al., 2021; Kuka et al., 2022), but there are also negative effects through a greater loss of water (Telak et al., 2020), weaker mineralization of plant residues (deeply incorporated) (Busari et al., 2015), favoring hardpan formations, breaking the continuity of capillarity (drainage) (Ghaley et al., 2018), and, if plowing on sloping land is performed along the line of the greatest slope, it will favor soil erosion (Mango et al., 2017).
Increasing the productivity of machine tractor units when cultivating the field is achieved by reducing the work time, which usually relates to seeking the shortest path of the unit in the field. Reducing the length of headland turns, which account for the largest proportion of the unit non-working moves, will result in higher productivity as well as less soil compaction in the headland (Trendafilov et al., 2023).
The national and international research results reinforce the conclusion that the influence of technological measures is enhanced, positively or negatively, by the type of soil, the characteristics of the cultivar, and the climatic conditions of the area (Petcu et al., 2000; Bailey-Serres et al., 2019).
The interaction of environmental factors with anthropogenic land conditions influenced with many soil degraded by erosion or temporaly excess moisture (Rusu et Gus, 2007) which imposes restrictions on the structure of the system, machine, and tractor station to ensure the mechanization of the slope.

MATERIALS AND METHODS

The research was carried out during three vegetation periods 2020-2021, 2021/2022, and 2022/2023, in the experimental field at the Agricultural Research and Development Station Secuieni (A.R.D.S. Secuieni). The experiment was located according to the method of subdivided blocks, in four repetitions, being contained in a three-year crop rotation (winter wheat - soybeans - maize), on a type of Chernozem soil which is characterized as being well supplied in phosphorus (P_2O_5-39 mg/kg) and mobile potassium (K_2O-161mg/kg), moderately supplied with nitrogen, the soil nitrogen index being 2.1, weakly acidic, with pH values (in aqueous suspension) of 6.29 and poorly fertile, with a humus content of 2.3% (Leonte et al., 2021). The winter wheat crop had as its predecessor the soybean crop, the crop that left the land clean of weeds through the application of various pre-emergent and post-emergent herbicides, tilling the soil and sowing easily.
In the experience, the types of tools used for basic soil work, working depths, as well as their combinations, were studied.
The basic works were carried out in autumn with aggregates consisting of a Deutz tractor, a reversible plow with three furrows, a chisel with MC - 2.5 rigid bodies, and a disk harrow GD - 3.2.
The present paper presents even the interaction between the depth and the tillage system on the momentary supply of water from the soil at sunrise but also at harvest in the winter wheat crop, as well as the yield and quality elements.
The obtained data were processed and statistically interpreted according to the variance analysis method (Ceapoiu, 1968).

RESULTS AND DISCUSSIONS

The data recorded by the Secuieni-Neamț Meteorological Station indicate a monthly and annual temperature increase throughout the growing season of the wheat crop, starting from the sunrise phase.

In September 2020 - 3.5°C, January 2021 - 3.2°C, February 2022 - 4.5°C, and March 2023 - 3.2°C, the recorded temperatures exceeded the multiannual average by more than 3°C (Figure 1).

In the period from sowing to harvesting the wheat crop, the months of April - 2021 and 2023, May - 2021, and October - 2021 recorded temperatures below the multiannual average (Figure 1).

Over the past three years, the average monthly April temperature has fallen by 1.2°C, and January and February have seen temperature increases of 4.2°C and 3°C, with temperatures exceeding the 60-year multiannual average.

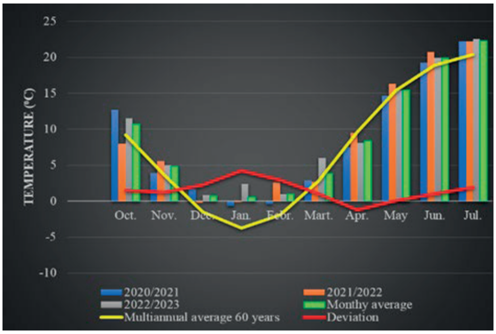

Figure 1. Thermal regime during October - Julie, 2020-2023 at Secuieni-Neamț

The rainfall during the research period shows that the rainfall is lower than the multiannual average of 60 years, (Figure 2) a deficit of more than 40 mm being recorded in May 2022, respectively 2023, June 2023, and July 2022.

From a rainfall point of view, the period from sowing to harvest, in the three years studied, was classified as very dry (Figure 2).

Figure 2. The rainfall regime during October - Julie, 2020-2023 at Secuieni-Neamț

Water is a primary element for agriculture, especially from precipitation, and, falling in different forms, leads to crop yield. In conditions of the loosening of the soil, water from precipitation infiltrates in depth more easily, and the soil shows a greater capacity to retain it (Niu et al., 2015).

After the emergence of the winter wheat crop, determinations were made regarding the momentary supply of water in the soil, in the 0-100 cm soil layer (Table 1). From the three years studied, the lowest momentary supply of water, 331 cm/ha (cubic meters/ha), was recorded in the year 2022/2023, where the land was worked with the chisel, in the soil layer of 0-20 cm. The highest water supply, of 637 cm/ha, was recorded in the version worked with the chisel, in the 20-40 cm soil starting, in the year 2021/2022.

Following the determinations made on the current soil water supply (cm/ha), the soil water reserve for the last year under study was also determined, 2022-2023. The largest water deficit of 115 cm/ha was recorded in the 60-80 cm soil depth, where the mechanical work performed was plowing to a depth of 20 cm. In the starting soil 80-100 cm, a surplus of 27 cm/ha was recorded, in the version in which the land was worked with the chisel (Table 1).

Table 1. Interaction between the depth and the tillage system on the current water supply (cubic meters/ha), and the water reserve at rising

Depth	Kind of tools	2020/ 2021	2021/ 2022	2022/ 2023	Ave- rage	Soil water reserve (c.m/ha) 2022/2023
0 – 20	Plowing 30-10 cm	511	451	348	437	-85
	Plowing 30 cm	483	466	357	435	-76
	Plowing 20 cm	480	450	382	437	-51
	Chisel	444	479	331	418	-102
	Disk 12-15 cm	491	450	345	429	-88
20 – 40	Plowing 30-10 cm	528	520	400	483	-103,5
	Plowing 30 cm	564	529	411	501	-92,5
	Plowing 20 cm	610	581	447	546	-56,5
	Chisel	579	637	390	535	-113,5
	Disk 12-15 cm	553	591	393	512	-110,5
40 – 60	Plowing 30-10 cm	472	558	408	479	-81
	Plowing 30 cm	513	588	419	507	-70
	Plowing 20 cm	512	594	392	499	-97
	Chisel	562	607	405	525	-84
	Disk 12-15 cm	557	601	398	519	-91
60–80	Plowing 30-10 cm	420	485	409	438	-80
	Plowing 30 cm	430	527	384	447	-105
	Plowing 20 cm	413	551	374	446	-115

	Chisel	406	599	404	470	-85
	Disk 12-15 cm	565	554	390	503	-99
80-100	Plowing 30-10 cm	386	367	379	377	-10
	Plowing 30 cm	391	391	365	382	-24
	Plowing 20 cm	378	388	370	379	-19
	Chisel	394	463	416	424	27
	Disk 12-15 cm	449	402	351	401	-38

When harvesting the wheat crop, the current water supply recorded values between 292 cm/ha, in the soil layer of 80-100 cm, where the land was plowed to a depth of 20 cm, and the maximum was recorded in the soil layer of 0-20 cm, of 535 cm/ha, where the work with the chisel was applied, values that were obtained in 2023.

Table 2. Interaction between the depth and the tillage system on the current water supply (cubic meters/ha), and the water reserve at harvast

Depth	Kind of tools	2020/ 2021	2021/ 2022	2022/ 2023	Average	Soil water reserve (c.m/ha) 2022/2023
0–20	Plowing 30-10 cm	402	307	472	394	39
	Plowing 30 cm	508	376	513	466	80
	Plowing 20 cm	509	468	510	496	59
	Chisel	514	409	535	486	32
	Disk 12-15 cm	476	490	514	493	81
20–40	Plowing 30-10 cm	398	341	328	356	-175.5
	Plowing 30 cm	425	346	442	404	-61.5
	Plowing 20 cm	415	545	459	473	-44.5
	Chisel	390	441	489	440	-21.5
	Disk 12-15 cm	372	350	397	373	-106.5
40–60	Plowing 30-10 cm	391	367	342	367	-147
	Plowing 30 cm	399	404	358	387	-131
	Plowing 20 cm	391	592	346	443	-143
	Chisel	374	402	389	388	-100
	Disk 12-15 cm	371	339	361	357	-128
60–80	Plowing 30-10 cm	353	367	339	353	-150
	Plowing 30 cm	334	360	341	345	-148
	Plowing 20 cm	380	344	365	363	-124
	Chisel	354	359	366	360	-123
	Disk 12-15 cm	351	346	341	346	-139
80-100	Plowing 30-10 cm	322	340	301	321	-88
	Plowing 30 cm	326	297	309	311	-80
	Plowing 20 cm	335	321	292	316	-97
	Chisel	336	306	337	326	-52
	Disk 12-15 cm	313	306	314	311	-75

Realizing also the soil water reserve, for the year 2022-2023, a deficit of 175.5 cm/ha can be observed where plowing was applied at a depth of 30-10 cm, but in the soil layer of 0-20 cm, a water surplus of 81 cm/ha was recorded, where the work was done with the disk at a depth of 12-15 cm (Table 2).

When harvesting the winter wheat crop, a series of morpho-physiological determinations were made, and some of them were to determine the number of grains, but also the weight of the grains per ear. Correlating the two determinations, it can be seen that between them the correlation was indirect and without statistical interpretation (Figure 3).

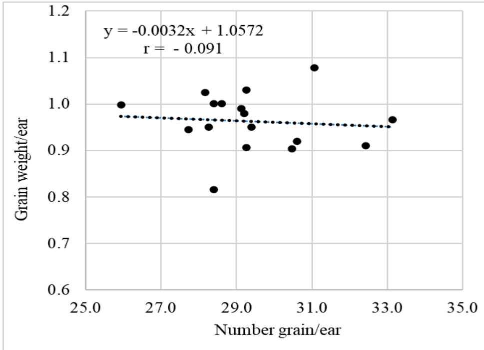

Figure 3. Correlation between the number of grains and grains weight/ear, average 2020-2023

On average, in the three years of experimentation, the thousand kernel weight (TKW) of the winter wheat varied from 36.2 grams in the variant in which the land was worked for three years with the disc and one year was plowed at a depth of 30 cm, and the maximum of 41.3 grams was achieved by the variant in which the land is plowed permanently to a depth of 20 cm (Figure 4).

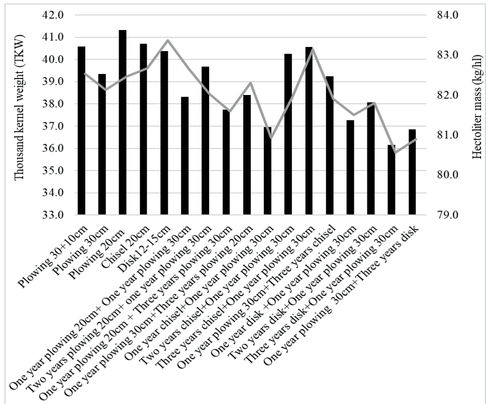

Figure 4. Thousand kernel weight (TKW) and hectoliter mass (kg/hl) at winter wheat, average 2020-2023

As for the hectoliter mass, these had close values, the minimum of 80.6 kg/hl in the variant in which the land was worked for three years with the disc and one year was plowed at a depth of 30 cm, and the maximum, of 83.4 kg/hl in the version in which the land is worked permanently with the disk at a depth of 12-15 cm (Figure 4).

In the first year of testing, the lowest wheat yield, of 6085 kg ha^{-1}, was obtained in the control variant (permanently plowed land at a depth of 20 cm), and the maximum was recorded, of 7976 kg ha^{-1} in the variant where the land is worked one year with the chisel, and one year it was plowed at a depth of 30 cm. Compared to the control variant, plowing the permanent land at a depth of 20 cm, higher yields were recorded in all the tested variants, these were statistically ensured and interpreted as significant and very significant.

The year 2021 was not a favorable year for the growth and development of the winter wheat crop, so the yields varied from 2987 kg ha^{-1}, (three years disk and one year plowing 30 cm), to 3916 kg ha^{-1} (one year plowing 30 cm and three years chisel). Compared to the control (plowed - 20 cm - 3699 kg ha^{-1}), higher yields were obtained in three variants, on the land permanently plowed at 30-10 cm (3839 kg ha^{-1}), on the land where one year it was plowed at 30 cm and three years it was worked with the chisel (3916 kg ha^{-1}), and the last variant where the land worked had been worked one year with the disk and one year it was plowed at 30 cm (3906 kg ha^{-1}), yields that were statistically ensured and interpreted as being significant and distinctly significant (Table 3).

The last agricultural year studied, recorded the lowest yields of 4349 kg ha^{-1}, in the version in which the land had been worked for three years with the disk and one year plow at 30 cm, and the highest yields, 6709 kg ha^{-1}, was recorded in the version in which the land had been worked permanently with the plow at a depth of 30-10 cm, a yield which was statistically interpreted as significant, compared to the control (plow - 20 cm).

In the three years of the study, winter wheat yields varied within very large limits, from 2987 kg ha^{-1} in the variant in which the land was worked for three years with the disk and one year plowing at 30 cm, in the year 2021-2022, one year very dry from a rainfall point of view, and the maximum of 7976 kg ha^{-1} was recorded in the year 2020-2021, in the version in which the land was worked one year with the chisel, and one year it was plowed to a depth of 30 cm, in a dry agricultural year from a rainfall point of view, but the rainfall during the flowering - grain filling period was close to the multiannual average, achieving higher yields (Table 3).

Table 3. The influence of tillage on winter wheat yield, at A.R.D.S. Secuieni, 2020-2023 period

Kind of tools	Yield obtained kg • ha^{-1} 2020/2021	2021/2022	2022/2023	Average
Plowing 30-10 cm	7259***	3839*	6709*	5936***
Plowing 30 cm	6383*	3458^{oo}	6457	5433
Plowing 20 cm	6085$^{Mt.}$	3699$^{Mt.}$	6398$^{Mt.}$	5394$^{Mt.}$
Chisel	6792***	3209^{ooo}	5230^{ooo}	5077^{oo}
Disk 12-15 cm	7584***	3730	5715^{ooo}	5676**
One year plowing 20 cm+ One year plowing 30 cm	6541***	3260^{ooo}	6184	5328
Two years plowing 20 cm+ one year plowing 30 cm	7215***	3794	5847^{ooo}	5619^{o}
One year plowing 20 cm + Three years plowing 30 cm	7071***	3514^{oo}	6083^{o}	5556
One year plowing 30 cm+ Three years plowing 20 cm	6787***	3400^{ooo}	6070^{oo}	5419
One year chisel+One year plowing 30 cm	7976***	3193^{ooo}	4825^{ooo}	5331
Two years chisel+One year plowing 30 cm	6585***	3299^{ooo}	6054^{oo}	5313
Three years chisel+One year plowing 30 cm	7241***	3651	5648^{ooo}	5513
One year plowing 30 cm+Three years chisel	7650***	3916**	6123^{o}	5896***
One year disk +One year plowing 30 cm	7238***	3906**	4475^{ooo}	5206
Two years disk+One year plowing 30 cm	7407***	3526^{o}	4915^{ooo}	5283
Three years disk+One year plowing 30 cm	7122***	2987ooo	4349^{ooo}	4819^{ooo}
One year plowing 30 cm+Three years disk	6628***	3316^{ooo}	5643^{ooo}	5196
DL 5%	239	129	236	201
DL1%	319	178	325	274
DL 0.1%	415	245	447	369

On average, over the three years, the protein content varied from 10.4% in the variant in which the land is permanently worked with plowing at 20 cm, and the maximum of 12.4% in the variant in which the land was worked for three years with the disk and one year plowing at 30 cm (Figure 5).

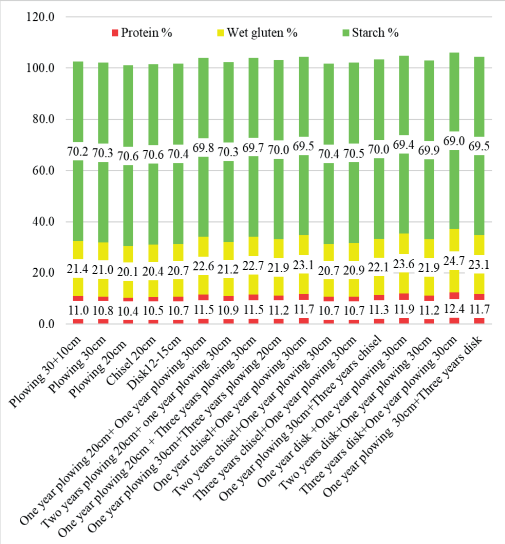

Figure 5. Winter wheat quality indices

The determinations carried out on the winter wheat seed on the wet gluten showed that the values varied quite a lot, depending on the mechanical work, from 20.1% in the plowing 20 cm variant in permanence, and the maximum of 24.7% in the variant in which the land was worked for three years with the disk and one year was plowed at 30 cm. The starch content had close values from 69% (three years disk and one year plowing 30 cm), up to 70.6% (plowing 20 cm and Chisel 20 cm in the field worked permanently) (Figure 5).

The correlation between the Zeleny index and grain hardness was direct, and the correlation coefficient (r) was statistically assured and interpreted as distinctly significant (Figure 6).

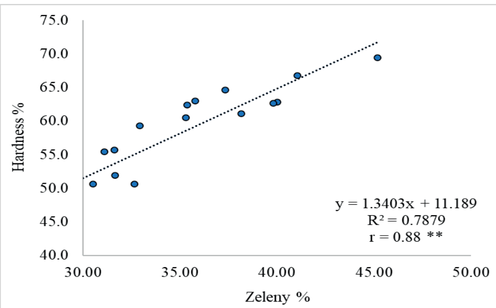

Figure 6. Correlation between the Zeleny (%) index and hardness (%) of winter wheat

CONCLUSIONS

The soil water reserve, achieved in the last year of experimentation, at the dawn of the winter wheat crop, recorded the largest water deficit of 115 mc/ha, in the 60-80 cm soil layer, where the mechanical work carried out was plowing at a depth of 20 cm, and in the soil layer 80-100 cm, a surplus of 27 mc/ha was recorded, in the version in which the land was worked with the chisel.

When harvesting the wheat crop, the soil water reserve, in 2023, achieved a deficit of 175.5 mc/ha where plowing was applied at a depth of 30-10 cm, but in the soil layer of 0-20 cm, a water surplus of 81 mc/ha was recorded, where the work carried out was to disk at 12- 15 cm, water surplus occurred as a result of the rainfall that fell before harvesting.

In the period 2020-2023, winter wheat yield varied within very large limits, from 2987 kg ha^{-1} in the variant in which the land was worked for three years with the disk and one year plowing at 30 cm, in 2021, a very dry year from rainfall point of view.

A maximum of 7976 kg ha^{-1} was recorded in the year 2020-2021, in the version in which the land was worked for one year with the chisel, and one year was plowed to a depth of 30 cm, in an agricultural year classified as very dry from a rainfall point of view, but the rainfall during the flowering - grain filling period was close to the multiannual average, achieving higher yields than in the other two years of the study, showing that the water is a primary element for agriculture, especially from rainfall, and, leads to crop yield.

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