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Effects of soil tillage system on yield and weeding level in wheat crop

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SUMMARY

This paper presents the yield and evolution of weeding level in wheat crop, as part of a three-year soybean-winter wheat-corn rotation, with the implementation of minimum soil tillage variants with: rotary harrow, paraplow and chisel plough. The experiment has been conducted on a Phaeozem argic soil type in Transylvania Plain, with conventional and four minimum tillage systems of soil cultivation. The level of weeding was influenced by the soil tillage system in the phase of springing up to the harvest of the wheat crop. At crop springing, the total number of weeds was 31.8 weeds/m² in the variant with plough + rotary harrow and between 31.6-34.7 weeds/m² in minimum tillage variants. A greater number of perennial dicotyledonous weeds can be recorded in the minimum tillage variant (between 1.2-1.6 weeds/m²), when compared with plough + rotary harrow variant (0.9 weeds/m²). At the crop harvest stage, the number of weeds was 8.2-50.6% higher in the variants with minimum tillage system, when compared to the conventional tillage system. A decrease in the percent of annual dicotyledonous weeds is evident, from 85.9% in the variant with plough, to 71.5-78.9% in the variants with minimum tillage systems, with an increase in perennial dicotyledonous (from 7.9% to 8.4-13.8%) and monocotyledonous weeds (from 6.2 to 11.6-20%). The changes in the floristic content of weeding level indicates the need for changing the strategies of weed control in winter wheat crop in the variants with minimum soil tillage systems. Increasing the percent of perennial dicotyledonous weeds by 59% (from 7.9% to 13.8%) makes the wheat cultivation in crop rotation with leguminous necessary, completed with the use of specific herbicide methods, in previous crop and wheat

crop. The presence of monocotyledonous weeds of about 11.6% to 20.0% completes the necessity for the application of different strategies of control and correlation, for the weeding level as well as the type of weed, including their annual or perennial character. Yields obtained by applying minimum tillage were 97.8-98.2%, when paraplow and chisel are compared to plough and were significantly lower in the rotary harrow variant, while weeding level was the highest.

Keywords: soil tillage systems, minimum tillage, crop rotation, weeding level.

INTRODUCTION

The minimum soil tillage system has spread continuously in Romania, being considered a component of conservative agriculture (Rusu et al., 2015a,b). The purpose of applying minimum soil tillage is to preserve the soil and water (Cociu and Cizmas, 2013), to increase the soil organic matter (Moraru and Rusu, 2013), to prevent degrading phenomena (Domuta et al., 2012) and to grow the economic and energy efficiency of agricultural technologies (Lazureanu et al., 2011; Dzigurski et al., 2012; Marin et al., 2015).

The extension of minimum soil tillage has agrotechnical, organization and economic advantages, but putting them into practice requires changes of certain concepts, such as fertilization, weeds and disease control (Marin et al., 2015). The application of minimum tillage increases weeding level by 20-43%, which consequently leads to an increase of herbicide consumption with up to 30-35% or complete replacement of the current herbicide range with new ones (Chetan et al., 2015). There are no bad weeds for an agricultural crop, only their effects vary, in response to numerous pedo-climate, biological and technological parameters. The impact of weeds on any agricultural system is synthesized through the following aspects: the decrease of the quality and quantity of the crop; costs of weed control in any technological system; changes imposed in the system of cultivation due to certain weeds; external costs, caused by the spread of weeds.

Weeds reduce the efficiency of certain agricultural tillage, such as fertilizers application, irrigation and soil tillage (Romanekas et al., 2009). Validation of these inputs by the cultivated plant has usually been done at small parameters; their efficiency is not found in the obtained yields. Thus, plowing of weeded soils is difficult, a depth uniformity is poor as well as the burial of vegetable scraps; the correct cutting of the soil is not possible, etc. In the case of minimum tillage of the weeded soils, the suitable depth, uniformity, leveling and cutting of soil is also not done correctly. Due to this, neither the sowing can be done with the established quality parameters, nor the mechanical maintenance of tillage during vegetation. Soil tillage is one of the oldest

methods for weed control, but it is also very important nowadays (Lyon and Young, 2015).

The effect of soil tillage on weed control efficacy depends on the type of tillage, its execution period and the quality of the soil, the organized crop rotation and the plant cultivated (Lal et al., 1994). Sowing has a strong impact on weed control (Gus et al., 2004): the seeds from the superficial layer are introduced deeper from where they hardly arise or they don't arise at all; almost all annual and biennial weeds in vegetation are cut, incorporated into the soil and destroyed.

A minimum tillage system partially destroys weeds and the soil is less mobilized (Shahzad et al., 2016). The efficiency of minimum tillage in weed control is better when they arise or when they are in the stage of plantula. When using the rotary harrow, most young weeds are destroyed and a good condition of soil is maintained. Reducing the number of soil tillage in order to preserve the soil resources (minimum tillage, direct sowing) must be associated with compensation measures for weed control: the organization of adequate rotations, preventive measures and diversifying integrated weed management measures, focusing mostly on the biological measures (Vrbničanin et al., 2004; Rusu et al., 2006).

The failure of many attempts to apply the minimum tillage system in Romania is based on the unsuitable weed control. In the case of minimum tillage, weeds are concentrated in the first 10 cm, they germinate explosively in the first year of application, leading to excessive weediness and after five years the weediness decreases again. The influence of the tillage system is found in the total number of weeds (the level of weeding), but also in their floristic composition (Bogdan, 1997). The influence of the soil tillage system is completed with the climate particularities over the years, thus, regardless of the tillage system, weeding is low during the drought years and is maximum during the rainy years (Rusu et al., 2015a,b; Chetan et al., 2016).

Alternating disc plowing with chisel plowing for one or several years has determined a reduction of the level of weeding, more emphasized in the case of alternating disc plowing and proportional to the number of disking applied. The number of weeds was even more reduced as the soil tillage was made deeper. As the superficial disc tillage or without turning the soil with the chisel went on, the number of weeds is almost doubled (Zahan and Bandici, 1995). The minimum tillage changes the floristic composition of weeds in time, by increasing the percentage of monocotyledonous weeds and decreasing the dicotyledonous, with a noticeably increased growth of weeding in the first years after its application.

The purpose of the paper is to research the effect of minimum tillage systems applied to a Phaeozom argic soil from the Transylvanian Plain, in winter wheat crop. The research is made inside a three crop rotation, common for the mentioned production area: soybean-winter wheat-maize. The paper presents the evolution of weeding

level at wheat crop with the implementation of minimum soil tillage with: rotary harrow, paraplow and chisel, compared with conventional system (with plough).

MATERIAL AND METHODS

The field experiment was conducted in the Transylvanian Plain, area characterized with a multiannual average of precipitation of approximately 500 mm and a temperature multiannual average of 9.2°C. The air temperature is closely related to the geographical position of the Transylvanian Plain, compared to the big morphological units nearby. The soil from the experimental field is a Phaeozom argic type (SRTS, 2012), with a clayey-loamy texture (clay between 42-43%) and a high content of humus (4.5-4.7%), pH 6.02 (Am)-7.88 (B/C).

The chosen experimental variants were:

A. Conventional system (CS): V1 – reversible plough (22-25 cm)+ rotary harrow (8-10 cm);

B. Minimum tillage systems (MT): V2 – rotary harrow (10-12 cm); V3 – chisel (18-22 cm) + rotary harrow (8-10 cm); V4 – paraplow (18-22 cm) + rotary harrow (8-10 cm).

The experimental design was a split-plot design with three replications. In one variant, the area of a plot was 450 m². The experimental variants were studied in the 3 years of crop rotation: soybean (*Glycine hispida* L. Merr.) - winter wheat (*Triticum aestivum* L.) - maize (*Zea mays* L.). Except for the soil tillage, all the other technological sequences of sowing and fertilizing were identical in all the variants. Weed control in the winter wheat crop was done with Granstar 50 SC herbicide (25% thifensulfuron methyl + 25% tribenuron methyl), 40g/ha + Trend 250 ml/ha.

The level of weeding of the winter wheat crop in relation to the applied soil tillage systems was determined with 0.25 m² quadrants placed in the middle of each plot in different stages of the vegetation growth of the crop plants and weeds: upon the crop emergence, before herbicide application, upon the crop harvest. The results were analyzed especially among the groups of weeds. The vegetation upon density parameters were determined with 0.25 m² quadrants placed in 10 points on the diagonal test plot.

Determination of the weed seeds reserve was done by collecting samples of soil (on the depth of 0-5, 5-10, 10-20, 20-30 cm), washing on the sieve with mesh of 0.25 mm, separating the seeds with potassium carbonate 53% (1.56 g/cm³). Identification of seeds was done following the methodology indicated by Rusu et al. (2012).

The productivity of winter wheat was determined in each experimental plot by weighting the biomass and grain yield and the data were statistically assessed by the analysis of variance (ANOVA).

RESULTS AND DISCUSSION

The effect of soil tillage systems on weed control has become evident after specific technological operations: weeds cutting in vegetation; fragmentation of rhizomes and vegetative propagation; incorporation of weed seeds into the soil or, on the contrary, bringing weed seeds on the soil surface; mobilization and aeration of soil, determination of weed seeds, germination etc. In the case of wheat crop, the influence of the soil tillage systems on weeding was done in the period of the crop emergence (Table 1) and up to its harvesting (Table 2).

Upon the emergence of the crop, the total number of weeds was 31.8 weeds/m² in the plough variant and between 31.6-34.7 weeds/m² in the minimum tillage variants. The higher number of perennial dicotyledonous weeds was recorded in the minimum tillage variants (between 1.2-1.6 weeds/m²), compared to the plough variant (0.9 weeds /m²).

At the crop harvest, the number of weeds was 8.2-50.6% higher in the minimum tillage variants, when compared to the plough variant. A reduction of the annual dicotyledonous weed species was detected from 85.9% in the variant with ploughing, to 71.5-78.9% in the minimum tillage variants (Table 3; Figure 1) and a growth of the perennial dicotyledonous (from 7.9% in the variant with ploughing, to 8.4-13.8% in the minimum tillage variants) and of monocotyledonous (from 6.2 in the variant with ploughing, to 11.6-20% in the minimum tillage variants).

Table 1. The influence of soil tillage systems on the winter wheat weediness before herbicide application (10 April 2015)

Nr.crt.	Species	Plough	Rotary harrow	Chisel	Paraplow
		Average number of weeds/m ²			
1	<i>Chenopodium album</i>	3.3	2.6	3.6	6.3
2	<i>Galeopsis tetrahit</i>	2.0	1.6	7.6	1.0
3	<i>Galium aparine</i>	0.3	1.0	0.3	-
4	<i>Lapsana communis</i>	0.6	0.6	3.0	0.6
5	<i>Polygonum aviculare</i>	5.6	5.6	2.0	4.3
6	<i>Polygonum convolvulus</i>	9.6	8.0	3.0	6.6
7	<i>Polygonum lapathifolium</i>	5.6	2.3	4.3	3.6
8	<i>Sinapis arvensis</i>	0.1	1.3	-	-
9	<i>Stelaria media</i>	0.3	6.3	0.3	0.3
10	<i>Viola arvensis</i>	1.0	-	6.0	2.3
Annual dicotyledonous		28.0	29.3	30.1	25.0
11	<i>Cirsium arvense</i>	0.3	-	0.3	0.3
12	<i>Convolvulus arvensis</i>	0.3	1.0	0.3	0.6
13	<i>Symphytum officinale</i>	0.1	-	-	-
14	<i>Taraxacum officinale</i>	0.6	0.6	0.6	0.3
Perennial dicotyledonous		0.9	1.6	1.2	1.2
Other species		2.1	3.8	1.9	5.4
Total weeds		31.8	34.7	33.2	31.6

Table 2. The influence of soil tillage systems on the winter wheat weediness before harvest (7 August 2015)

Nr.crt	Species	Average number of weeds/m ²			
		Plough	Rotary harrow	Chisel	Paraplow
1	<i>Agrostis tenuis</i>	1.0	0.3	4.2	0.4
2	<i>Avena fatua</i>	0.3	1.3	0.6	0.3
3	<i>Setaria sp.</i>	0.2	2.6	1.3	2.6
Annual Monocotyledonous		1.5	4.2	6.1	3.3
5	<i>Amaranthus retroflexus</i>	2.5	1.9	0.3	1.9
6	<i>Chenopodium album</i>	1.9	4.9	3.5	3.9
7	<i>Galeopsis tetrahit</i>	0.6	4.3	4.3	3.3
8	<i>Galinsoga parviflora</i>	1.3	3.5	2.0	2.0
9	<i>Galium aparine</i>	0.9	0.3	0.6	0.3
10	<i>Lapsana communis</i>	1.3	4.0	-	3.0
11	<i>Polygonum sp.</i>	7.7	2.8	7.5	1.8
12	<i>Sinapis arvensis</i>	1.3	1.8	0.6	1.3
13	<i>Stelaria media</i>	1.6	3.6	-	3.1
14	<i>Viola arvensis</i>	1.6	-	3.0	-
Annual Dicotyledonous		20.7	27.1	21.8	20.6
15	<i>Cirsium arvense</i>	0.8	0.6	1.3	0.5
16	<i>Convolvulus arvensis</i>	0.5	2.0	-	1.0
17	<i>Rubus caesius</i>	-	0.9	-	-
18	<i>Symphytum officinale</i>	-	0.3	-	0.3
19	<i>Taraxacum officinale</i>	0.6	1.2	1.3	0.4
Perennial Dicotyledonous		1.9	5.0	2.6	2.2
Total weeds		24.1	36.3	30.5	26.1

The changes in the floristic composition indicate the necessity of changing the strategy of weed control in the autumn wheat crop in the minimum tillage variants. The increase in the percent of perennial dicotyledonous weeds by 59% (from 7.9% to 13.8%) indicates the need for the wheat rotation cultivating, with hoeing and leguminous plants, supplemented by the use of integrated methods of using specific herbicides, both at the preliminary plant and the wheat crop. The increase of monocotyledonous weeds from 11.6% to 20.0% completes the need to differentiate the control and correlation strategies, both in the level of weeding and in the type of weeding, including their annual or perennial character. Thus, the control of perennial weeds on the stubble by using herbicides with total action is mandatory.

Table 3. The influence of soil tillage systems on the presence of weed groups in winter wheat

Weed group	Average number of weeds/m ² , at harvesting			
	Plough	Rotary harrow	Chisel	Paraplow
Monocotyledonous	1.5/6.2	4.2/11.6	6.1/20	3.3/12.7
Annual Dicotyledonous	2.7/85.9	27.1/74.6	21.8/71.5	20.6/78.9
Perennial Dicotyledonous	1.9/7.9	5.0/13.8	2.6/8.5	2.2/8.4
Total no./m ²	24.1/100	36.3/100	30.5/100	26.1/100
%	100 (witness)	150.6	126.5	108.2

The research of the weed seedbank and reserve of weed seeds in the soil at the end of the rotation, showed an increase by 12% in the total number of weed seeds at the depth of 0-30 cm, from 19311 weed seeds/m² in the conventional variant, to 21979

weed seeds/m² in the rotary harrow variant (Table 4). Then, it is evident that 92% of the weed seeds from the rotary harrow variant are located at 0-10 cm depth, compared with the plow variant, where 70% of the weed seeds at this depth can be found.

Figure 1. The influence of soil tillage systems on the winter wheat weediness

Different weed growth can be explained by the influence of tillage system on winter wheat density (Table 5). The number of plants is between 490-510/m². The greatest density was recorded in plough version, 510 plants/m², while the lowest values were recorded in variants worked with rotary harrow (490 plants/m²), followed by chisel and paraplow (500 plants/m² in both variants).

Table 4. Soil infestation with weed seeds influenced by soil tillage systems (seeds/m²)

Variant	Plough					Rotary harrow				
Depth, cm	0-5	5-10	10-20	20-30	Total	0-5	5-10	10-20	20-30	Total
Monocotyledonous	2880	2812	1136	684	7512	6012	5758	600	99	12469
Dicotyledonous	3621	4222	3277	679	11799	3652	4685	825	348	9510
TOTAL	6501	7034	4413	1363	19311	9664	10443	1425	447	21979
Distribution, %	34	36	23	7	100	44	48	6	2	100

Table 5. Influence of soil tillage systems on some productivity elements of winter wheat crop during the vegetation (18 April 2015)

Variant / characteristic	Plants number / m ²	Plants with one brother / m ²	Plants with two brothers / m ²	Offshooting plants, %	Medium length of the roots, cm	Medium length of the sistems, cm
Plough	510	357	31	76	11.6	13.7
Rotary harrow	490	372	21	80	9.2	12.2
Chisel	500	368	16	77	11.0	12.4
Paraplow	500	367	18	77	11.1	12.5

Yields obtained by applying minimum tillage are similar to those obtained in the variant with conventional system, accounting for 97.8-98.2% when paraplow and chisel are compared to the plough (Table 6). Yield was significantly lower in the rotary harrow variant, while weeding level was the highest.

Table 6. Influence of soil tillage system on average production of winter wheat crop

Soil tillage system	Production kg/ha	Production %	Difference ±	Differences significance
Reversible plough + rotary harrow	4263	100	w	w
Rotary harrow	4050	95.0	- 213	0
Chisel + rotary harrow	4189	98.2	- 74	-
Paraplow + rotary harrow	4170	97.8	- 93	-

DL (p 5%) = 208 kg/ha; DL (p 1%) = 264 kg/ha; DL (p 0.1%) = 363 kg/ha, w-witness.

CONCLUSIONS

In spring, prior to the herbicide treatment, the weeding level of winter wheat is different depending on the soil tillage system. Total number of weeds was 31.8 weeds/m² for plough and 31.6 to 34.7 weeds/m² for minimum tillage. We record a higher number of perennial weeds in minimum tillage (between 1.2-1.6 weeds/m²), compared to plough alternative (0.9 weeds/m²).

At harvest, the 24.1 weeds/m² were recorded in plough variant and 26.1 to 36.3 weeds/m² in minimum tillage. At the crop harvest, the number of weeds is 8.2-50.6% higher at variants with minimum tillage of soil, compared to the conventional tillage system. At this stage of the winter wheat growth cycle we have recorded a reduction of annual dicotyledonous weeds from 85.9% in the plough variant to 71.5-78.9% in the minimum tillage; an increase in perennial dicotyledonous species, from 7.9% in the plough, to 8.4-13.8% in the minimum tillage variant; an increase in monocotyledonous species from 6.2% in the plough variant, to 11.6-20% in the minimum tillage.

The increase in the proportion of dicotyledonous and monocotyledonous weeds was obtained in the minimum tillage variant, indicating wheat cultivation in rotation with legumes, supplemented by integrated methods for weed control, both in the winter wheat and previous crops.

The influence of tillage systems becomes evident primarily in the level of weed infestation of crop and through its development and productivity parameters.

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Uticaj sistema obrade zemljišta na prinos i stepen zakorovljenosti useva pšenice

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REZIME

Rad predstavlja rezultate prinosa i promene nivoa zakorovljenosti u usevu pšenice, kao deo trogodišnje rotacije soja- ozima pšenica-kukuruz, sa uvođenjem varijanti minimalne obrade zemljišta sa: rotacionom drljačom, plugom podrivačem i kosim plugom. Eksperimenti su sprovedeni na Phaeozem poljoprivrednom tipu zemljišta u transilvanijskoj ravnici, sa konvencionalnim i četiri sistema minimalne obrade zemljišta. Na nivo zakorovljenosti uticao je tip sistema obrade zemljišta, u periodu od faze klijanja do žetve useva pšenice. U fazi klijanja useva, ukupan broj korova iznosio je 31,8 korova/m² u varijanti sa oranjem+obrada rotacionom drljačom i između 31,6-34,7 korova/m² u varijanti minimalna obrada zemljišta. Povećan broj višegodišnjih dikotiledonih korova može biti registrovan u varijanti minimalna obrada zemljišta (između 1,2-1,6 korova/m²), u poređenju sa varijantom oranje+obrada ro-

tacionom drljačom (0,9 korova/m²). U stadijumu žetve useva, broj korova bio je 8,2-50,6% viši u varijantama sa minimalnom obradom zemljišta, u poređenju sa kovencionalnim sistemom obrade. Smanjenje procenta jednogodišnjih dikotiledonih korova očigledan je, 85,9% u varijanti sa plugom, i 71,5-78,9% u varijanti minimalnaobrada zemljišta, sa povećanjem kod višegodišnjih dikotiledonih korova (sa 7,9% na 8,4-13,8%) i monokotiledonih korova (sa 6,2 na 11,6-20%). Promene u florističkom sastavu ukazuju na potrebu za promenom strategije kontrole korova u usevu ozime pšenice, u varijantama minimalne obrade zemljišta. Povećanje procenta višegodišnjih dikotiledonih korova za 59% (sa 7,9% na 13,8%) dovodi do neophodnosti za uzgojem ozime pšenice u rotaciji useva sa leguminozama, uz primenu specifičnih herbicida, u prethodnim usevima i usevu pšenice. Zastupljenost monokotiledonih korova od 11,6% do 20,0% naglašava neophodnost za primenom različitih strategija kontrole i korelacije, za nivo zakorovljenosti kao i tip korova, uključujući tu i njihov jednogodišnji ili višegodišnji karakter. Prinosi koji su ostvareni primenom sistema minimalne obrade zemljišta kretali su se oko 97,8-98,2%, kada se obrada kosim plugom i plugom podrivačem porede sa oranjem i bili su značajno niži u varijanti obrade rotacionom drljačom, dok je u tom slučaju nivo zakorovljenosti bio najviši.

Ključne reči: sistemi obrade zemljišta, minimalna obrada, rotacija useva, zakorovljenost