THE INFLUENCE OF MINIMUM TILLAGE SYSTEMS UPON THE SOIL PROPERTIES, YIELD AND ENERGY EFFICIENCY IN SOME ARABLE CROPS

INFLUENȚA SISTEMULUI MINIM DE LUCRARE ASUPRA PROPRIETĂȚILOR SOLULUI, PRODUCȚIEI ŞI EFICIENȚEI ENERGETICE LA UNELE CULTURI AGRICOLE

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ABSTRACT

The paper presents the influence of the conventional ploughing tillage technology in comparison with the minimum tillage, upon the soil properties, weed control, yield and energy efficiency in the case of maize (Zea mays L.), soyabean (Glycine hispida L.) and winter wheat (Triticum aestivum L.) in a three years crop rotation. For all cultures within the crop rotation, the weed encroachment is maximum for the disc harrow and rotary harrow soil tillage, followed by the chisel and paraplow. The weed encroachment is minimum for the conventional ploughing tillage technology. The results of investigations showed that the yield is a conclusion soil tillage systems influence on soil properties, plant density assurance and on weed control.

KEY WORDS: minimum tillage, yield, energy efficiency

REZUMAT

Lucrarea prezintă influența sistemului convențional de lucrare, cu plugul, în comparație cu sistemul minim de lucrare a solului, asupra proprietăților solului, îmburuienării, producției şi eficienței energetice la culturile de porumb, soia şi grâu de toamnă încadrate într-un asolament de trei ani. Pentru toate culturile din rotație îmburuienarea este maximă în variantele lucrate cu discul şi grapa rotativă, urmate de cizel şi paraplow. Îmburuienarea este minimă în variantele lucrate după sistemul convențional cu plug. Din cercetările efectuate se constată că producția culturilor din asolament este o rezultantă a influenței sistemului de lucrare asupra proprietăților solului, asigurarea densității plantelor şi îmburuienarea culturilor.

CUVINTE CHEIE: lucrări minime, producție, eficiență energetică

INTRODUCTION

The classic system of soil tillage practised even since the 11-th century, that predominantly in usage today is definitely characterized by classical ploughing (with the use of which the soil is turned) and the preparation of the germinal layer. The necessity of the decreasing the number of tillage and also the elaboration of soil tillage system has appeared ever since the 50's and the 60's. Thus new systems of soil tillage have developed (unconventional ones, alternative systems, system of preserving the soil) with several options: working with disc harrow, rotary harrow, chisel and paraplow, the system of working with protecting layer, the system of working with strips, direct sowing etc.

The cultures respond to the system of soil tillage in a way that is hard to predict. The results depend on one hand on the soil characteristics and microclimate and on the other hand, on the association of different practices, such as: the rank of soil preparation, the sowing dates, the equipment used, the cultures rotation, the species or the hybrid used, the way in which it is fertilized (the time and the way it is applied), the weed control etc. The relation between the production – its profit and the systems of soil tillage is mostly influenced by the previous management of the soil and by the weather. Consequently, the applying of the new systems of soil tillage must be done together with the managerial input, with the results acquired by research and the creation of new species and hybrids.

The alternative systems look for the sustainability of the agricultural system, to increase the actual soil fertility and ensure – as research proves - productions close in number to those obtained by classical ploughing. Another fact that must be specified is that the equal productions or the reductions up to 90 – 95% in the case of unconventional systems of soil tillage in opposition to the classic systems, are considered more profitable. This is explained by the reduction of the expenditures when eliminating the ploughing in case of new systems of soil tillage and by the increasing of optimum tilled and traffic ability as result of the improving the soil characteristics.

The production differences between the alternative systems and the classic one can be the result of a variant choice that can be used in certain pedoclimate conditions (Dick and the collab., 1994; Guş and the collab., 1995, 1997; Rusu and the collab., 1999; Horn and the collab., 2000; Moroizumi and Horino, 2002). The efficiency of the alternative systems is ensured only in the case of a crop rotation, case in which cultures rotation alternates with the systems of tillage.

MATERIAL AND METHOD

The tests were organized during 1999-2001 at the Didactic Department of the University of Agricultural Sciences and Veterinary Medicine of Cluj Napoca, Romania, on a moderately inclined northern slope, on haplic luvisol, with medium fertility, content of 2.7-3.29% humus, slightly-moderate acid reaction (pH = 5.17-6.06), clay texture (40-42% clay in Ap), medium content of nitrogen and potassium, small content of phosphorus. These areas were was our research presents a medium multi annual temperature of 8.2^{0}C medium of multi annual rain drowns: 613 mm (table 1).

The soil profile is the following: Ap–A/Bw-Btyw-Bty-B/C-C, the 3rd quality class with 47 points of fertility potential of using arable.

Stationary testing with 6 variants:

a. The classic systems:

V_1 –classic plough + disc –2x

V_2 – reversible plough + rotary harrow

b. Minimum tillage:

Table 1 The climatic situation

Year	Month												Media
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Temperature, ^{0}C													
1999	-0.9	1.2	1.1	10.6	13.4	18.9	19.6	12.2	13.8	10	2.3	-5.6	8.6
2000	-2.3	-0.8	4.8	10.8	14.3	19.6	21	19.1	13.2	9.2	2.1	-1.7	9.1
2001	-6.0	0.3	3.9	12.6	17.4	19.2	19.5	20.8	13.8	10.1	6.3	0.6	9.8
1901-1990	-4.4	-2.3	3.2	9	14.1	17.2	18.9	18.2	14.2	8.8	3.1	-1.6	8.2
Precipitation, mm													
1999	39.4	12.5	35.8	50.7	68.6	192.6	52.6	35.8	84.7	54.7	43	4.6	675
2000	14	40	8.8	76.4	88.4	138.4	170.6	62	56.3	32.4	24.1	40.6	752
2001	26.6	12.6	37.6	25.0	35.5	49.7	76.7	18.2	60.3	1.3	3.5	22.2	369.2
1901-1990	27	26.2	27	51	74.5	99	81.4	77.3	50	43.3	28.6	27.5	613

V_3 – disc + rotary harrow
V_4 – rotary harrow –2x
V_5 – paraplow + rotary harrow
V_6 – chisel + rotary harrow

The several variants were tested three times in a row. In one variant the area of a land was 300 m^2. The cultures resulted from rotation were: maize (1999), soya-bean (2000), and winter-wheat (2001). The biological material was represented by the 200 Turda – hybrid maize, S2254RR – a variety of bean-bean resistant to Roundup Ready and the Ariesan – species for the winter-wheat. Except for the soil tillage, all the other technological sequences of sowing, fertilizing, weed control, are identical in all the variants. The weed control for maize was accomplished by a preemergent – ppi (pre planting incorporated) treatment with the Guardian CE herbicide (acetochlor 820-860 g/l + antidote) 2.5 l/ha; 2 treatments postemergent – on vegetation with Roundup Ready (glifosat acid 360 g/l) 2.5-2 l/ha for soya-bean; a postemergent treatment with Icedin Super (dicamba 100 g/l + 2.4D 280g/l) 1.0 l/ha for winter-wheat.

RESULTS AND DISCUSSIONS

The influence of soil tillage system upon the yield in the case of maize, soya-bean and winter-wheat. The soil tillage system influences the productivity elements of cultivated species and finally the productions thus obtained. Two elements are considered worthy being analyzed taking into account the influence they have on production: plants density and weeding rate.

The results show in all years of experimentation the change of culture density when applying the minimum system (table 2). When this applied on such type of soil it is imperious to differentiate the conventional system considering the aspect of optimum density by the quantity of seed that is used.

Taking into consideration the aspect of weeding, one con register different ranks of weeding influenced by yield and soil tillage system. Maximum weeding is when rotary harrow-2x is used, followed by disc harrow, chisel and paraplow. Weeding is minimum for conventional tillage technology with ploughing.

The different soil tillage systems influence the productions obtained. One thing that con be noticed is that when using the ploughing + rotary harrow for the preparation of the germinal layer (for all the three rotating cultures) the greatest yield was obtained. The productions are lower at maize yield in opposition to the classic soil tillage systems with significant differences, in all variants worked by the minimum tillage system. The soya-bean culture reacts surprisingly well when the minimum tillage systems are applied, the productions obtained being even greater, with disting positive significance when working

Table 2 The influence of different soil tillage systems upon the plants density, weeding and yield in the case of maize, soya-bean and winter-wheat crops cultivated on haplic luvisol

Table 2 Influența sistemului de lucrare a solului brun argiloiluvial asupra densității plantelor, îmburuienării şi a producțiilor obținute la porumb, soia şi grâu de toamnă

Variant / Characteristic		Plough + disc – 2x	Plough + rotary harrow	Disc + rotary harrow	Rotary harrow - 2x	Paraplow + rotary harrow	Chisel + rotary harrow
Plants/m^2	M	3.5	3.8	3.3	3.3	3.5	3.5
Plants/m^2	S	24.3	24.7	18.5	19.4	17.8	16.4
Plants/m^2	W	480	500	460	475	465	440
Weeding	M[1]	65.9	54.4	86.2	110.2	78.3	85.3
Weeds/m^2	S[2]	63.8	62.6	87.9	92.2	88.1	87.7
	S[1]	2.3	1.7	1.7	2.1	1.8	2.0
	W[1]	24.1	18.7	27.7	36.3	26.1	30.5
Production	M	4860(Mt)	5849(***)	4314($_{000}$)	4583($_{000}$)	4730($_0$)	4710($_0$)
kg/ha	S	3025(Mt)	3546(***)	3146(-)	3313(**)	3385(**)	3113(-)
	W	3730(Mt)	3986(*)	3683(-)	3612(-)	3615(-)	3486($_0$)

M - maize, S - Soya-bean, W - winter-wheat,
[1]Determination acquired when yielding, [2] Determination acquired before the first treatment.

Table 3: The influence of soil tillage system in a haplic luvisol upon the efficiency of the energy utilization at maize, winter-wheat and soya-bean

Table 3: Influenţa sistemului de lucrare a solului brun argiloiluvial asupra eficienţei energetice, la cultura de porumb, grâu de toamnă şi soia

Variant / Characteristic		Plough + disc -2x	Plough + rotary harrow	Disc + rotary harrow	Rotary harrow –2x	Paraplow + rotary harrow	Chisel + rotary harrow
Soil tillage	MJ/ha	1956.9	1672.26	1138.56	1352.04	1494.36	1423.2
	%	100	85.4	58.2	69.1	76.4	72.7
Power balance efficiency, %	M	100.0	102.0	99.3	99.5	100.3	100.2
	S	100.0	103.7	101.6	102.5	102.9	101.1
	W	100.0	101.6	100.5	99.9	99.7	99.0
Energy utilization, MJ	M	9.54	11.54	9.01	9.17	9.83	9.76
	S	5.23	6.02	5.69	5.53	5.50	5.32
	W	5.56	6.21	5.63	5.88	5.97	5.51

M - maize, S - Soya-bean, W - winter-wheat,

with paraplow + rotary harrow and rotary harrow –2x. The winter-wheat culture, the productions obtained at the minimum tillage systems are without statistic differences, except when using chisel + rotary harrow, case in which the production differences are significantly negative.

One thing that weeds to be mentioned is that when applying the minimum tillage systems of working the land the results are both in immediate effects, satisfactory productions and also the preserving and the increasing of soil fertility which has profitable effects in time. The applying of any variant can be taken into consideration, regarding culture, climate conditions, available agricultural equipment and the measures of protecting the plants (especially the weed control).

The influence of soil tillage system upon efficiency and gasoline consuming. The necessary power quantified for accomplishing the basic tillage and the preparation of seeds layer is different for each soil tillage system. In what concerns the classic plough and disc-2x for the preparation of seeds layer is of 30.9-41.8% energy input reduction and disc + rotary harrow, rotary harrow-2x and of 23.6-27.3%, to paraplow + rotary harrow and chisel + rotary harrow (table 3).

The power balance shows us that the decreasing of energy input with soil tillage with conservative purpose, does not diminish the efficiency of energy used. When the variants with minimum tillage are used, the indicator shows us that the best values for maize yield when the paraplow + rotary harrow are used and chisel + rotary harrow, for winter-wheat when worked with the disc + rotary harrow, and all variants for the soya-bean culture.

The efficiency of the energy utilization shows, us firstly, that starting from a power consuming on a total culture, in general, alt all 3 cultures of 22000-24000 MJ/ha, the energy resulted at 1 MJ/ha invested is almost double at maize, apposed to soya-bean and winter-wheat. Starting from the fact that in all variants worked by the minimum tillage system the productions were smaller at maize culture, as apposed to the variants where the plough is applied; we can safely say that when - by the yield potential - the best results on this type of soil are acquired by the intensely processed mobilization. We can notice that the efficiency of the energy utilization is practically very close or even equal at maize, and equal or even greater at winter-wheat and soya-bean when related to the classic plough + disc.

The gasoline consuming. It is known the fact that on of the technological operations with the highest rate of gasoline consuming is classical ploughing with the use of which the soil is turned. This that the soils are of medium smoath or smoath texture and the processed is done deeper. Its replacement, at least partial, is a solution to decrease the fuel consumption especially if the productions are not significantly reduced. The replacement of ploughing and the preparation of germinal layer by disc-2x with tillage paraplow + rotary harrow or chisel + rotary harrow accomplisher an economy of fuel of 12.4-15.2 l/ha, and in the case of processing only with the help of the disc + rotary harrow or rotary harrow-2x the decrease is of 19.3-25.3 l/ha.

The evolution of agrophysical properties on haplic luvisol depending on the soil tillage system. The effect of soil tillage systems' action over the structure provokes a special theoretical and practical interest. Hydro stability of structural aggregates (H.S.) determined at every yield show firstly for the minimum tillage systems a growth in stability in the soil's surface towards its depth. At the end of the 3 rd year of tests the results acquired set the

Table 4 The evolution of stability rate (H.S.,%) on a haplic luvisol depending on the soil tillage system
Table 4 Evoluția gradului de stabilitate (H.S.,%) a solului brun argiloiluvial în funcție de sistemul de lucrare al solului

Rotation	Depth cm	Soil tillage system					
		Plough + disc-2x	Plough + rotary harrow	Disc + rotary harrow	Rotary harrow 2 x	Paraplow + rotary harrow	Chisel + rotary harrow
Maize	0-10	58.2	59.1	58.7	59.4	59.6	59.0
	10-20	60.2	65.0	61.5	69.2	69.0	69.5
	20-30	61.6	64.2	62.4	68.5	69.4	69.6
Soya-bean	0-10	63.8	64.1	65.3	66.8	67.4	67.4
	10-20	64.4	65.3	68.2	70.4	70.6	70.6
	20-30	65.5	66.4	70.4	73.5	71.5	72.4
Winter-wheat	0-10	62.4	63.0	64.5	68.0	67.5	64.0
	10-20	66.0	66.8	67.2	73.5	68.0	67.1
	20-30	63.5	70.0	71.5	74.5	69.2	68.5

stability rate in a variation domains of 62.4-74.5% hydro stabile macro-aggregates. As opposed to the witness classic plough + disc-2x variation of the stability rate was higher within the minimum systems: 1.6-5.6%, on 0-10 cm depth, 1.1-7.5% on 10-20 cm depth and 5-11% on 20-30 cm depth (Table 4).

The state of physical settlement of the soil expressed through the apparent density (A.D.) calculated annually as an average of the determinations on phenophase shows that in all years of experimenting a better mellow on the 0-20 cm depth at variants were the plough is used (A.D. = 1.0 – 1.38 g/cm3). Beneath the depth of 20 cm the soil remains slightly ram with medium values (A.D. = 1.4 – 1.45 g/cm3). Thus it is shown a stratification on the soil's profile from the point of view of settlement state, through the existence of a layer that can be ploughed (trough the energetic tillage). The tillage without turning off the soil with paraplow and chisel respectively leads to a apparent density value raising and slightly decreasing in underploughing level. But the values remain on a variation domain slightly mellow-ram, and respectively medium-low on the layers of haplic luvisol one can practically differentiate the following (table 5):

- 0-10 cm depth, there are no differences as opposed to the ploughing variation, the soil being slightly mellow with low values for this type of soil (texture) under 1.31 g/cm3 at A.D.;
- 10-20 cm depth, the soil remains more ram in comparison to the variant where it was ploughed (A.D. in general 1.33-1.36 g/cm3);
- 20-30 cm depth the soil is slightly ram and much more in the ploughing variant (A.D. = 1.4 – 1.45 g/cm3) and more reduced for chisel and paraplow (A.D. = 1.35 – 1.41 g/cm3) thus being much more closer to the specific values of this type of soil, for this depth;
- 30-40 cm depth and respectively 40-50 cm there are no differences between variants, the values determined being in general medium among and tendency to improve.

Our tests confirm that the haplic luvisol has the tendency to return to its initial setting state that is specific to be stable of relatively balance with the environment, a state given by the relation: pedogenetic factors – environment – properties and soil characteristics if the degrading factor is discarded and the phenomenon does not exceed bearable limits.

The annual soil tillage system with disc and rotary harrow without further deep mellows leads to registering some A.D. values practically equal to the other values of other variants on 0-10 cm depth. Beneath this depth, 10-20 cm for these variants, we have the highest values of apparent density: A.D. = 1.38 – 1.4 g/cm^3.

The water supply (W, m^3/ha) of the soil calculated annually and a 0-50 cm depth as an average of the phenophase determinations is greater in the ploughing variants in all years of experimenting. As opposed to the witness variant – classic plough + disc-2x the value are more reduced for the minimum tillage variants with 20-86 m^3 /ha for maize, with 23 m^3 /ha for soya-bean, with 10-61 m^3 /ha for winter-wheat (figure 1).

After three years of applying the same soil tillage system, one can notice with the help of determinations that the soil's capacity to retain water is better when working with rotary harrow-2x and chisel + rotary harrow variant,

Table 5: The evolution of apparent density (A.D., g/cm^3) on haplic luvisol depending on soil tillage

Table 5: Evoluția densității aparente (D.a., g/cm^3) a solului brun argiloiluvial în funcție de sistemul de lucrare al solului

Rotation	Depth -cm-	Soil tillage system					
		Plough +disc- 2x	Plough+ rotary harrow	Disc + rotary harrow	Rotary harrow - 2 x	Paraplow + rotary harrow	Chisel + rotary harrow
Maize	0-10	1.30	1.14	1.30	1.24	1.22	1.27
	10-20	1.38	1.21	1.38	1.40	1.36	1.34
	20-30	1.45	1.41	1.39	1.39	1.41	1.41
	30-40	1.45	1.38	1.40	1.38	1.41	1.41
	40-50	1.47	1.47	1.46	1.45	1.46	1.46
Soya-bean	0-10	1.17	1.00	1.18	1.10	1.11	1.12
	10-20	1.27	1.18	1.33	1.35	1.26	1.32
	20-30	1.40	1.40	1.39	1.38	1.36	1.35
	30-40	1.40	1.40	1.40	1.39	1.39	1.39
	40-50	1.47	1.47	1.46	1.46	1.46	1.46
Winter wheat	0-10	1.20	1.13	1.11	1.08	1.18	1.18
	10-20	1.26	1.23	1.38	1.36	1.35	1.33
	20-30	1.40	1.40	1.42	1.40	1.39	1.39
	30-40	1.41	1.40	1.41	1.40	1.39	1.41
	40-50	1.43	1.43	1.45	1.44	1.44	1.44

the values being 5.54 and respectively 5.08 l/m^2/min. For witness classic plough + disc-2x the water quantity tickled in was of 4.25 l/m^2/min. The lowest amount was registered for rotary harrow – 2x variant with 3.21 l/m^2/min.

The evolution of agrochemical properties on haplic luvisol depending on the soil tillage system. The soil's content of humus depending on the variant used of tillage has at the end of three years of experimenting limits that very between 2.28-3.29% and the depth 0-20 cm with obvious tendency to grow if the minimum system with paraplow + rotary harrow and chisel + rotary harrow is used (table 6). The increasing of organic matter and even of humus is due to the vegetal remainders partially incorporated and to an adequate biological activity.

The soil's content of phosphorus and mobile potassium change significantly under the influence of soil tillage system in the way that the administered fertilizers are located at different depots. Thus working with disc harrow or rotary harrow locates large quantities of mobile phosphorus in the first 10 cm of tillage soil. The paraplow and chisel do the exact same thing but we have to mention that phosphorus reaches 10-20 cm deep in practically equal quantities with the classic tillage system that involves ploughing. The intensity of aeration and the thickness of plants motivate the lower contents of mobile phosphorus in the variant where the classic ploughing is used.

The soil's reaction and the rate of saturation in bases, remain practically unchanged regardless of the way in which the soil was tillage except for the variants where the paraplow and chisel were used and pH (H_2O) tendencies is to drop and the soil to acidify as a result of hydrogen status growing and base status dropping.

CONCLUSIONS

The soil tillage system influences the productivity elements that derive from the different thickness of plants and the influence of weed upon the vegetation factors, mostly upon water and nourishing substances.

By applying the unconventional soil tillage systems one can obtain productions comparable to the classical variant with ploaghing as for the maize, soya-bean and winter-wheat yield. The productions are equal or even greater for the minimum soil tillage system in the case of soya-bean crop and for the disc + rotary harrow, rotary harrow-2x and paraplow + rotary harrow variants for the winter-wheat crop.

The fuel consumption is reduced to 12.4-25.3 liters of gasoline / ha by applying the minimum soil tillage systems of haplic luvisol and also by reducing the power input to

Table 6 The influence of soil tillage system upon certain agrochemical properties of haplic luvisol
Table 6 Influența sistemelor de lucrare a solului asupra unor însuşiri agrochimice ale solului brun argiloiluvial

Soil tillage system	Depth, cm	$pH_{(H2O)}$	Humus %	N total %	P mobil ppm	K mobil ppm	V %
Plough+ disc-2x	0-10	6.06	2.55	0.220	12	155	79
	10-20	6.08	2.28	0.217	15	134	80
	20-30	6.30	2.70	0.242	4	117	83
Disc+ rotary harrow	0-10	5.90	2.72	0.195	34	211	78
	10-20	5.79	2.68	0.217	12	122	79
	20-30	6.13	2.11	0.200	7	125	84
Rotary harrow -2x	0-10	5.81	2.70	0.226	33	196	79
	10-20	6.03	2.59	0.241	9	131	80
	20-30	5.95	2.32	0.235	3	125	79
Paraplow + rotary harrow	0-10	5.62	3.00	0.252	25	158	74
	10-20	5.72	3.06	0.239	10	117	74
	20-30	5.80	2.53	0.224	8	128	75
Chisel+ rotary harrow	0-10	5.77	3.29	0.280	27	207	75
	10-20	5.73	3.16	0.263	12	151	73
	20-30	5.80	2.62	0.240	7	122	79

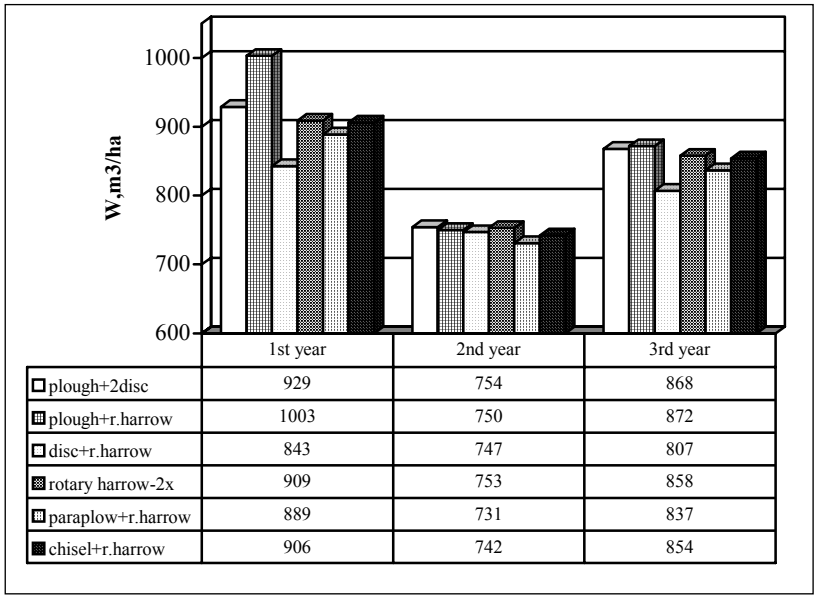

Figure 1 The water suppy of the haplic luvisol, and a 0-50 cm depth, depending on soil tillage sistem
Figure 1 Rezerva de apa a solului brun argiloiluvial, pe adancimea 0-50 cm, in functie de sistemul de lucrare al solului

23.6-42.8%. The power efficiency is greater in the case of minimum soil tillage variants when the production differences are not significaly negative as apposed to classical soil tillage systems.

The use of minimum soil tillage systems within a three years rotation: maize, soya-bean, wheat favorites the rise of the aggregates hydro stability with 5.6-7.5% on a 0-20 cm depth and 5-11% on 20-30 cm depth.

Under the influence of tillage system the main thing that is modified is the accumulation of phosphorus and potassium in the soil. Tillage with disc harrow or rotary harrow locates large quantities of phosphorus in the first 10 cm beneath the soil. The paraplow and the chisel do the same thing but we have to mention the phosphorus can go beneath 10-20 cm deep.

The soil's reaction and the saturation rate of base status remain practically unchanged, no matter how the soil was tillage. What is registered is the soil reaction in water (pH) tendency to drop and a slight acidify of the soil for the paraplow and chisel variants.

The water supply accumulated in the soil correlates with the tillage system and is maximum for the ploughing variant. The speed at which the water infiltrates in the superior side of the soil's profile is maximum for the paraplow and chisel tillage variants.

The advantages of unconventional soil tillage systems can be turned into account as improving methods in weak productive soils with reduced structure stability on slope fields and as measures of preserving the soils on the rest of the surfaces.

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