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STUDIES ON THE ESTABLISHMENT OF CONSERVATION TECHNOLOGIES OF TILLAGE MECHANIZATION IN GRAIN MAIZE CROP, UNDER SOIL SPECIFIC CONDITIONS FROM N-E ROMANIA

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ABSTRACT - For establishing the best conservation technologies of tillage mechanization from NE Romania in grain maize crop, six technology variants were tested in the spring of year 2007. In each technology variant, we have determined the qualitative indices for every work equipment and the energetic and exploitation indices for each farm equipment. After crop sowing, we have determined for each variant, soil resistance to penetration, mean weighted diameter of soil structural elements and water stability of these elements. At the same time, we have determined the fuel consumption per hectare, for mechanized tillage and sowing. We have also found that when selecting the mechanization technologies of soil tillage, we should take into account the obtained seed yields. After the analysis of the obtained results, we have established the best mechanization technologies that ensured soil conservation conditions for maize crop.

Key words: technologies, mechanization, soil tillage, conservation, soil penetration, soil structure, fuel consumption

REZUMAT - Cercetări privind stabilirea tehnologiilor conservative de mecanizare a lucrărilor solului la porumbul pentru boabe, pentru condițiile de sol specifice zonei de N-E a României. Pentru stabilirea celor mai bune tehnologii conservative de mecanizare a lucrărilor solului în zona de N-E a României, la cultura de porumb pentru boabe, în primăvara anului 2007, s-au experimentat şase variante de tehnologii. În cadrul încercărilor efectuate, la fiecare variantă de tehnologii s-au determinat indicii calitativi, pentru fiecare utilaj de lucru, dar şi indicii energetici şi de exploatare, la fiecare agregat agricol. La o anumită perioadă de timp de la însămânțarea culturii s-au determinat, la fiecare variantă, rezistența solului la penetrare, diametrul mediu ponderat al elementelor de structură ale solului şi stabilitatea hidrică a acestor elemente. Totodată, s-a determinat, la

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fiecare variantă de tehnologii, consumul de combustibil la hectar pentru efectuarea mecanizată a lucrărilor solului şi semănatului. De asemenea, s-a considerat că la selectarea tehnologiilor de mecanizare a lucrărilor solului trebuie să se țină seama şi de producțiile de semințe obținute. În urma analizei rezultatelor obținute la încercările efectuate, s-au stabilit cele mai bune tehnologii de mecanizare a lucrărilor, care asigură condiții de conservare a solului, la cultura de porumb.

Cuvinte-cheie: tehnologii, mecanizare, lucrări sol, conservare, penetrare sol, structură sol, consum de combustibil

INTRODUCTION

For establishing the conservation technologies in grain maize crop, for the mechanization of soil tillage and of machine systems, used in sustainable agriculture, experimental investigations are required. It is necessary that the mechanization technologies and the proposed equipments (designed by the research team or already found in production) should be tested under laboratory and production conditions, in order to establish if they correspond to the required demands (Badea, 1980; Canarache, 1986; Canarache, 1990, Jităreanu, 1995; Stănilă et al., 2003,*).

For solving these problems, the research team proposed more variants of technologies for soil tillage mechanization and sowing in grain maize crop. These technologies were tested in order to establish which of them were proper to the highest degree to the concept of sustainable agriculture and ensure protection, conservation and improvement of agricultural fields. Each variant of mechanization technologies, which includes unconventional soil tillage, done with adequate equipments, will be compared with the control variant, where the classical conventional technology of soil tillage is applied, but the comparison will be also made with the other technologies. Each variant of mechanization technology includes soil tillage systems in maize growing and the equipments, which are involved in this activity. Here are included basic soil tillage, superficial tillage of land maintenance and seedbed preparation (Florescu and Zelingher, 1957; Vlădiceanu, 1998).

Because, some of the tested technologies include combined, complex equipment units, which also have sowing equipments in their structure, we established that sowing should be present in all the technologies, so these could be compared between them.

MATERIALS AND METHODS

The trials on the establishment of conservation technologies for the mechanization of soil tillage in maize crop were carried out in 2007. We must also mention that, at the end of 2006 and in 2007, there were two drought periods during September-December 2006 and April-July 2007. The rainfall amounts

* **Cojocaru I., 1999** – *Cercetări privind tehnologia de lucrare a solului fără răsturnarea brazdei, cu cizelul, la înființarea culturilor de cereal (Investigations on soil tillage technology without furrow revert, with chisel, at cereal crop setting up).* PhD Thesis, U.S.A.M.V. Iaşi

were lower than the multiannual monthly means.

Soil on which tests were conducted is Meso-Calcaric Cambic Chernozem to Baticalcaric, with a clayey-loam texture and mean values of the apparent density and moisture. The mean longitudinal field slope is of 2 degrees. The predecessor plant is sunflower.

In all the technology variants for the mechanization of soil tillage and sowing, applied in grain maize, the vegetal mass was chopped with a SR 250 machine; therefore, the normal conditions for soil tillage and sowing have been created.

We have tested six variants of technologies for the mechanization of soil tillage and sowing (*Table 1*).

Table 1 – Variants of technologies for the mechanization of soil tillage and sowing in grain maize

Used equipments	Variants of technologies
• Valtra T-190 tractor + Opal 140 reversible mouldboard plough (used in autumn) • U-650 tractor + GD-3.2 light disk harrow + 2 GCR-1.7 tooth harrow (2 passages, in spring) • U-650 tractor + SUP-8 precise sowing machine for hoed plants	V_1 (control)
• U-650 tractor + PC-7 chisel (used in autumn) • U-650 tractor + GD-3.2 disk harrow + 2 GCR-1.7 tooth harrow (in spring) • U-650 tractor + Vibromixt VM–251 (in spring) • U-650 tractor + SUP-8 precise sowing machine (in spring) • U-650 tractor + CPU–8 hoe cultivator (2 times hoeing)	V_2
• U-650 tractor + PC-7 chisel (used in autumn) • U-650 tractor + GD-3.2 disk harrow + 2 GCR-1.7 tooth harrow (in spring) • Valtra T-190 tractor + BS 400 A (kompaktor) (in spring) • U-650 tractor + SUP-8 precise sowing machine (in spring) • U-650 tractor + CPU–8 hoe cultivator (2 times hoeing)	V_3
• U-650 tractor + PC-7 chisel • U-650 tractor + complex unit (FPL-4 rotary hoe for legume hoeing + SPC-4 precise sowing machine), in spring • U-650 tractor + CPU–8 hoe cultivator (2 times hoeing)	V_4
• Valtra T-190 tractor + GDG-4.2 heavy harrow (used in autumn) • U-650 tractor + GD-3.2 disk harrow + 2 GCR-1.7 tooth harrow (in spring) • U-650 tractor + Vibromixt VM–251 (in spring) • U-650 tractor + SUP-8 precise sowing machine (in spring) • U-650 tractor + CPU–8 hoe cultivator (2 times hoeing)	V_5
• Valtra T-190 tractor + GDG-4.2 heavy harrow (used in autumn) • U-650 tractor + complex unit (FPL-4 rotary hoe for legume hoeing + SPC-4 precise sowing machine), in spring • U-650 tractor + CPU–8 hoe cultivator (2 times hoeing)	V_6

V_1 is the control variant, because it represents the technology for the mechanization of soil tillage and sowing, which is generally applied under field conditions; this is the classical conventional technology of soil tillage.

In each variant of the technology for the mechanization of soil tillage and for each working unit (machine or tool), we have determined the quality indices of the done work. The energetic and exploitation indices were determined for each unit. The obtained results were compared to the limits established by the agrotechnical demands, to see if the results were proper. Based on the values of these indices, each technology was compared to the control technology and to the other ones, for establishing which is the best.

For selecting the technologies for the mechanization of soil tillage, we have determined for each of them, after maize sowing, soil resistance to penetration and stability of soil structural elements. We consider that these indices, soil resistance to penetration and, especially, stability of soil structural elements (expressed by mean weighted diameter of soil structural elements and water stability) are very important, because, on their basis, we could establish how much each technology for the mechanization of soil tillage contributes to its degradation.

For choosing the best technologies for tillage mechanization, we have calculated the fuel consumption per hectare in each technology, for mechanized soil tillage and sowing. We also considered that when selecting the technologies for the mechanization of soil tillage, we must also take into account the obtained seed yields.

RESULTS AND DISCUSSION

When choosing the technologies for the mechanization of soil tillage, which are recommended to be applied in production, we will take into account the degree of soil breaking up at seedbed preparation, soil resistance to penetration, mean weighted diameter of soil structural elements, water stability, fuel consumption per hectare for soil tillage, sowing and seed yield per hectare.

We established that among the qualitative working indices, the most important one is the degree of soil breaking up. The problems we faced at seedbed preparation were related to improper soil crumbling. The diminution of the degree of soil breaking up at lower values, found below the minimum limits imposed by agrotechnical demands, could appear especially at seedbed preparation for the crops, which are sown in autumn.

Among all the energetic and exploitation indices of the agricultural equipments, the most important one is fuel consumption per area unit.

The degree of soil breaking up at seedbed preparation had very close values in all the six variants of technologies for tillage mechanization, which varied from 96% to 100%, according to the applied technology (*Table 2*).

Table 2 – Degree of soil breaking up at seedbed preparation (grain maize)

Variant of technology	Degree of soil breaking up, %
V_1 (control)	96
V_2	98
V_3	99
V_4	100
V_5	98
V_6	100

The agrotechnical demands required that at seedbed germination, the degree of soil breaking up should be at least of 90% (even 95%) (Jităreanu, 1995). Analysing the obtained results, we found that the degree of soil breaking up was very good in all the variants, but the differences between variants were very small, even insignificant. However, we found that in V_4, V_6 and V_3 variants, the obtained results were not as good as in case of others variants.

Soil resistance to penetration was determined after four days since maize sowing. In *Table 3* are shown the obtained results regarding soil resistance to penetration for different applied technologies.

Table 3 - Soil resistance to penetration, obtained at different technologies for mechanization of soil tillage and sowing (grain maize)

Variants of technology	Depth (cm)					
	5	10	15	20	25	30
	Soil resistance to penetration, daN/cm^2					
V_1 (control)	4.2	4.8	4.5	7.6	5.9	6.9
V_2	0.7	0.9	2.2	2.7	1.6	2.0
V_3	4.0	5.2	3.3	4.1	3.9	9.8
V_4	0.6	0.8	2.1	2.5	3.2	3.8
V_5	0.8	1.0	2.4	2.8	2.1	2.6
V_6	0.8	0.9	2.8	2.6	3.0	3.7

The agrotechnical demands have established more value classes for soil resistance to penetration: very low = below 11 daN/cm^2, low = 11 – 25 daN/cm^2, medium = 26 – 50 daN/cm^2, etc. (Canarache, 1990). By comparing these requirements to the obtained results, we found that soil resistance to penetration was "very low" in all variants and at all depths. Therefore, soil resistance to penetration was very good in all variants.

At the 0 – 20 cm depth, the lowest values of soil resistance to penetration were recorded in V_4 and the highest ones, in V_1 (control). Higher values of this index were also obtained in V_3. A higher soil resistance to penetration was obtained in V_3, because the three rollers of the BS 400 A kompaktor achieved a certain degree of soil compaction.

We appreciate that the very low values of soil resistance to penetration are caused by the fact that soil was loosened at surface, after the hoeing was done in the predecessor crop (sunflower) and the determination of this index was done very early, the next day after sowing.

The agrotechnical demands have established that at soil resistance to penetration up to 25 daN/cm^2, the plant roots grew normally. If we compare these demands to the obtained results, we could find that in all variants and for all depths, there were conditions for a normal growth of maize roots.

The mean weighted diameter of soil structural elements was determined after four months since maize sowing, for three depths: 0 – 10 cm, 10 – 20 cm and 20 – 30 cm. In *Table 4* are shown the obtained results on the mean weighted diameter of soil structural elements for different applied technologies and depths.

Table 4 - Mean weighted diameter of soil structural elements for different applied technologies (grain maize)

Variants of technology	Depth (cm)			
	0 – 10	10 – 20	20 - 30	Mean
	Mean weighted diameter of soil structural elements, mm			
V_1 (control)	3.23	3.74	5.49	4.15
V_2	2.96	4.31	7.22	4.83
V_3	2.65	5.76	7.20	5.20
V_4	3.17	4.58	5.82	4.52
V_5	2.69	4.18	5.11	3.99
V_6	3.01	4.95	5.42	4.46

In case of mean weighted diameter of soil structural elements, the interest focused on the structural elements with a 2 – 5 mm diameter (even over 5 mm). By comparing these demands to the obtained results, we found that the mean weighted diameter of soil structural elements was proper in all variants and depths*.

At 0 – 10 cm soil depth, the best results (the highest values) were obtained in V_1, followed by V_4 and V_6 variants. In case of V_3, the mean weighted diameter of soil structural elements was the lowest (at 0 – 10 cm soil depth).

At 10 – 20 cm depth, soil was tilled only one time by the equipment that carried out the basic work: mouldboard plough, chisel or heavy disk harrow. Because soil was tilled only one time, the structural elements were less fragmented, so that the mean weighted diameter of soil structural elements was higher than at depth of 0 – 10 cm.

At 20 - 30 cm depth, soil was not tilled by agricultural equipments. Therefore, the mean weighted diameter of soil structural elements was higher.

* **Răus L., 2007** – *Influenţa diferitelor sisteme de lucrare asupra proprietăţilor fizice, chimice şi biologice ale solului şi producţiei principalelor culturi (Influence of different tillage systems on physical, chemical and biological characteristics of soil and yield in main crops).* PhD Thesis, Universitatea de Ştiinţe Agricole şi Medicină Veterinară, Iaşi

At 0-10 cm depth, soil was 4-6 times tilled, so the fragmentation process of soil structural elements was greater than at deeper layers. Therefore, at 0-10 cm soil depth, the mean weighted diameter of soil structural elements was the lowest.

Water stability of soil structural elements was also determined after four months since maize sowing, for three depths: 0 – 10 cm, 10 – 20 cm and 20 – 30 cm. In *Table 5* are shown the obtained results on water stability of soil structural elements for different technologies and depths.

Table 5 – Water stability of soil structural elements for different applied technologies (grain maize)

Variants of technology	Depth (cm)			
	0 – 10	10 – 20	20 - 30	Mean
	Water stability of soil structural elements, %			
V_1 (control)	59.02	65.01	66.92	63.65
V_2	70.05	66.28	69.78	68.70
V_3	57.62	60.04	71.54	63.07
V_4	67.30	71.72	73.15	70.72
V_5	65.16	68.38	69.95	67.83
V_6	65.12	72.25	72.70	70.02

The agrotechnical norms have established that if water stability of soil structural elements was 40 – 60%, this index could be framed within the "very high" class; when the index exceeds 60 %, it is framed within the "extremely high" class. By comparing the obtained results to these agrotechnical demands, we found that water stability of soil structural elements was very high (very good) in all variants and depths.

The best results (the highest values) were obtained in V_4, followed by V_6; on the last two places, there were V_1 and V_3 (the lowest values of the index were obtained in V_3). The highest value of water stability of soil structural elements, obtained in V_4 and V_6, could be explained by the fact that soil was less mobilized, so the fragmentation of structural elements was reduced.

At 20 – 30 cm depth of soil, which was not tilled by agricultural equipments, water stability of soil structural elements was higher in all the technological variants. At 10 – 20 cm soil layer, which was tilled only one time, water stability of soil structural elements was lower, because some elements were affected by fragmentation. At 0 – 10 cm depth, where soil was 4-6 times tilled, the value of the index was the lowest, because repeated tillage led to the increase in the fragmentation process of structural elements.

Fuel consumption per hectare. We appreciate that this index was very important in selecting the technological variants and establishing those to be applied. The index was obtained by summing up the diesel quantities consumed for the mechanization of soil tillage and sowing per hectare, therefore the works requested for each technological variant. In *Table 6* are shown the fuel consumptions per hectare for all the six technological variants.

Table 6 - Fuel consumption per hectare for soil tillage and sowing (grain maize)

Variants of technology	Fuel consumption per hectare for soil tillage and sowing, l/ha
V_1 (control)	34.568
V_2	27.061
V_3	28.245
V_4	21.046
V_5	24.677
V_6	18.622

We found that in the tested technological variants, the fuel consumption per hectare for soil tillage, before sowing and hoeing, was proper. The lowest fuel consumption was recorded in V_6 (18.662 l/ha) and V_4 (21.046 l/ha). On the third place, it was found V_5, with a fuel consumption of 24.677 l/ha. In V_1 (control), the fuel consumption per hectare was the highest (34.568 l/ha).

The low fuel consumption per hectare for soil tillage (including hoeing) and sowing, recorded in V_6 and V_4, could be explained by the fact that soil was tilled by four passages of the agricultural equipments. In the other technological variants, soil was tilled by six passages of the agricultural equipments, leading to an increase in fuel consumption. In addition, in V_6 and V_4, the combined equipment was used for seedbed preparation and sowing and soil was tilled in strips, but not on the entire area. The lowest fuel consumption in case of V_6, compared to the one of V_4, could be explained by the fact that in V_6, working depth was smaller than in V_4 (working depth of the equipment, which did the basic work). At the same time, in case of V_6, the heavy disk harrow has active organs with a free rotation movement, due to the contact with soil, while in V_4, the active organs have a linear translation movement, opposing a greater resistance.

Obtained seed yields. We must mention that the seed yield depends on many factors, one of them being soil tillage. In *Table 7* are shown the results regarding the seed yield obtained in different variants of technologies for the mechanization of soil tillage and sowing.

The seed yield has varied, according to the applied variant of technology, from 2750 kg/ha (V_1) to 3520 kg/ha (V_4). We must also mention that in all technological variants, maize seed yields were low. This was caused by the fact that, during September-December 2006 and April-June 2007, the rainfall amounts were lower than the multiannual monthly means.

The highest maize seed yield was obtained in V_4 = 3520 kg/ha (soil tilled in autumn with chisel; in spring, seedbed preparation in strips and sowing with the complex equipment: FPL-4 rotary hoe + SPC-4 sowing machine). On the second place, there was V_6 = 3430 kg/ha and on the third place, V_3 = 3280 kg/ha. In V_1 (control) (in autumn, mouldboard ploughing and in spring, seedbed preparation was done with two passages of GD-3.2 disk harrow + 2 GCR-1.7 tooth harrow, then sowing was done with SPC-8), the lowest yield per square unit = 2750 kg/ha was recorded.

Table 7 - Obtained maize seed yield in different variants of technologies

Variants of technology	Seed yields	
	kg/ha	Compared to the control (classical) variant, %
V_1 (control)	2750	100.00
V_2	3030	110.18
V_3	3280	119.27
V_4	3520	128.00
V_5	2910	105.82
V_6	3430	124.73

For pointing out the differences of $V_2…V_6$ to V_1 (control), regarding the seed yields, the yields of variants were shown as percentage, considering that the yield of V_1 was 100 %. Therefore, we found that in V_5, maize seed yield increased by 5.82 %, compared to the control variant. In V_2, seed yield increased by 10.18 %, compared to V_1. In case of V_3, we found that seed yield increased by 19.27 %, compared to the yield of V_1. A significant increase of 24.73 % was recorded in V_6, compared to the control. In V_4, maize seed yield increased by 28 %., compared to the yield increase obtained in V_1 Variant.

Variants of applied technologies. The six variants of technologies for the mechanization of soil tillage were studied separately, for each index. For establishing the technologies to be applied and their order, we had in view more indices: soil crumbling degree at seedbed preparation, soil resistance to penetration, mean weighted diameter of soil structural elements, water stability of these elements and fuel consumption per hectare for soil tillage before sowing, sowing and hoeing and seed yield per hectare.

For each index, we have established which are the variants to be applied, variants with lower results, the order of variants starting with the best one. We had to establish the variants to be applied, their order and the variants that are not recommended to be used, taking into account all the above-mentioned indices.

It is necessary to use, as much as possible, unconventional conservation tillage, without turning upside-down the mobilized soil layer (they should avoid the usage of mouldboard plough). When there are favourable conditions for unconventional conservation tillage, without using mouldboard plough, we consider that the variants to be applied, starting with the best one, are V_6, V_4 and V_5. If V_6 could not be used for various reasons, V_4 will be used instead; if neither V_4 could be used, V_5 will be applied. When establishing the variants that could be applied and their order, we must take into account the fuel consumption per hectare, soil crumbling degree, soil resistance to penetration and stability of soil structural elements.

If there are no conditions of applying unconventional tillage, ploughing should be done by turning upside-down the mobilized soil layer (when the usage of mouldboard plough is a must) and the modified V_6 (or V_4) will be applied: basic tillage will be done in autumn with the Opal-140 reversible mouldboard plough (GDG-4.2 heavy disk harrow or PC-7 chisel should not be used). V_1 (control) is not recommended to be applied in this case, because the fuel consumption per hectare for soil tillage and sowing is too high, while the others indices are low, compared to those from variants V_6 and V_4.

CONCLUSIONS

The degree of soil breaking up at seedbed preparation had very close values in all the six variants of technologies for the mechanization of soil tillage. This index is very good in all variants.

Soil resistance to penetration, determined after four days since maize sowing, is “very low” (very good) in all variants of technologies. For 0 – 20 cm soil layer, the lowest values of soil resistance to penetration were recorded in V_4, and the highest ones in V_1 (control). We found that in all technological variants, there were conditions for a normal growth of maize roots.

The mean weighted diameter of soil structural elements was proper in all the six tested variants of technologies. In the 0 – 10 cm soil layer, the best results (the highest values) were recorded in V_1, followed by variants V_4 and V_6; in case of V_3, the mean weighted diameter of soil structural elements was the lowest.

Water stability of soil structural elements was very high (very good) in all technological variants and depths. The best results (the highest values) were recorded in V_4, followed by V_3 and the last two places were occupied by variants V_1 and V_3 (the lowest values were recorded in V_3).

Fuel consumption per hectare for soil tillage and sowing, determined in the six experimental variants of technologies for grain maize, was adequate. The lowest fuel consumption was recorded in V_6, followed by V_4. On the third place, there is V_5. In V_1 (control), the fuel consumption per hectare was the highest.

The highest maize seed yield per hectare was obtained in V_4, on the second place being found V_6 and on the third place, V_3. In V_1 (control), the lowest seed yield per area unit was obtained. The maize seed yields recorded in variants V_3, V_6 and V_4 were by 19.27 % - 28 % higher that the yield obtained in V_1 Variant.

If there are favourable conditions for conservation tillage (without using mouldboard plough), the variants recommended to be applied, starting with the best one, are V_6, V_4 and V_4. If it is not possible to use V_6 for various reasons, V_4 will be used; if neither V_4 could be used, V_5 will be applied.

If there are no conditions of applying unconventional tillage or when mouldboard plough must be used, the modified V_6 (or V_4) will be used: soil basic tillage will be done in autumn with the Opal-140 reversible mouldboard plough (GDG-4.2 heavy disk harrow or PC-7 chisel will not be used at basic tillage). In this case, it is not recommended to use V_1 (control), because fuel consumption per hectare is too high, and the others indices are lower than those from variants V_6 and V_4.

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