New technologies of heavy soils tillage

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Abstract
The goal of the researches was to define the needed parameters for the construction of machines for tillage of all kinds of soils with heavy mechanical composition and, within a three year period, to develop new solutions for tillage of heavily composed soil. For example, increase of the penetration resistance, during diskng, in the right wheel's trail is the greatest at a depth of 0 to 5 cm and it reached 476.19%.

The research includes the development and verification of the effects that the new machines have on physical and water properties of the heavily composed soils, the consumption of energy and resources, the amount of returns and the development of new technologies of tillage.

With new technologies of heavy soils tillage achieved biological returns of wheat, corn and sugar beet, during conditions of dry cropping, is 12 to 21% larger in favor of the heavy mechanical class soil type (according to heavy mechanical content), for operation of subsoiling depth of 0.6 m,

Key words: heavy soils, soil compaction, tillage, arrangement of the soil’s surface and depth, new machinery.

Introduction
According to data (Vučić, 1992), in Serbia there are over 400,000 hectares of heavy soil, and nearly 1,000,000 hectares of diversely damaged soil.

The development and application of the new agriculture machinery assets (Raičević at al., 2003, 2005), requires previously defining of the technologies used for the preservation of the soil’s fertility, with taking into consideration the regional designations, intensity of the production with the prospect of greater working speeds.

The basic conventional tillage by a plough, once or twice a year, assumes that it is done through the full depth of the ploughed land (20-35 cm). This leads to a problem with the soil compaction beneath the working depth of the plough, when the two wheels of a tractor move over the furrow’s bottom (Oljača, 1993, 1994). This matter can be removed by occasional subsoiling, which improves the macrostructure of the soil, but it rarely can improve its microstructure. The tractor’s movement in the next stage of the cultivation compacts the soil further, to a certain degree. The soil compaction (Nikolić, at al., 1996), (Oljača, 1993), (Radojević at al., 2006), can effect the plant production by changing the soil’s properties, especially its cubical mass, distribution of the soil’s aggregates and the continuity of its pores.

Material and methods
Experimental researches of a tillage of one type of soil with heavy mechanical composition were carried out on the grounds of the “PKB Corporation - Belgrade”, on the “Padinska Skela” farms, on a parcel marked T-18, a 40 hectare area, type of Marsh soil.

The influence that soil tillage has on compaction, that is penetration resistance, was examined on a Marsh soil type, and Alluvium. The examined variety of the Marsh soil is with a deep humus accumulative surface, 80 cm deep. The alluvium surface with CaCO₃ at the initial process of the experiment is 100 cm deep.
The quantitative indicator of the physical, chemical, and water properties points that the examined soil falls under the heavy mechanical class soil type (heavy clay, in Ah horizon Clay content is 41.90-39.30%), meaning heavy mechanical composition.

In the aforesaid technological operations of the autumn soil cultivation, an MF-8160 tractor was used, aggregated with an MF-715 plough and an OLT Tara-36 disc harrow.

The measurement procedure, using a hand penetrometer, (Ejkelkamp Hand Penetrometer, Set A, measuring amplitude of 10 MPa), determined the penetrometric characteristics of the uncompacted and the compacted soil surfaces. These measurements were conducted in series of ten repetitions, at depths of 5 - 10 - 15 - 20 - 30 - 40 cm, on the prepared measurement sites. The penetration resistance was measured by a penetrometer on the trails of the tractor’s wheels, when they moved along the furrow or out of it, as well as beside the trails on the uncompacted soil.

**Results and discussion**

**Penetration resistance values during the ploughing operation**

The examination of the compaction of Marsh soil type, during ploughing, has been done up to a depth of 40 cm. The effects of the soil compaction were gained by comparison of the compacted and uncompacted soil, with water content up to 40 cm deep, with a water content of 24 to 20.65%. The soil compaction has stipulated changes in the values of the penetration resistance and other parameters. The uncompacted soil had average values of penetration resistance (Cone index) within an interval from 0.91 to 5.55 MPa, whereas the compacted portion of the soil is from 1.35 to 6.52, and in the trail from 1.57 to 7.33 MPa.

Table 1 shows the increase (%) of the penetration resistance behind the wheel on the field, behind the wheel in a trail and before ploughing at a depth of 15-20 cm.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Water content (%)</th>
<th>Increase Cone Index behind wheel on grass-plot (%)</th>
<th>Increase Cone Index behind wheel in furrow (%)</th>
<th>Increase Cone Index behind wheel in furrow end before tillage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>24.00</td>
<td>148.35</td>
<td>142.73</td>
<td>172.53</td>
</tr>
<tr>
<td>5-10</td>
<td>23.00</td>
<td>130.56</td>
<td>124.55</td>
<td>190.28</td>
</tr>
<tr>
<td>10-15</td>
<td>21.63</td>
<td>126.00</td>
<td>117.33</td>
<td>206.50</td>
</tr>
<tr>
<td>15-20</td>
<td>23.44</td>
<td>149.47</td>
<td>110.17</td>
<td>212.10</td>
</tr>
<tr>
<td>20-30</td>
<td>21.80</td>
<td>129.72</td>
<td>100.93</td>
<td>120.83</td>
</tr>
<tr>
<td>30-40</td>
<td>20.65</td>
<td>117.48</td>
<td>105.32</td>
<td>132.07</td>
</tr>
</tbody>
</table>

The greatest increase of the penetration resistance (Cone index), during ploughing, behind the wheels on the field was at a depth of 0-5 cm, it came to 148.35%, and at a depth of 15-20 cm, where it came up to 149.47%. The increase of the penetration resistance (%) behind the wheel in a trail was the largest at a depth of 0-5 cm, amounting 142.73%. The increase of the penetration resistance behind the wheel in a trail and before ploughing at a depth of 15-20 cm was 212.10%.

**The values of penetration resistance during the disking process**

Examining the changes of compaction values of the Marsh soil during disking was done to a depth of 40 cm. The effects of the soil compaction were gained by comparing the parameters of the compacted and uncompacted soil, with the water content from 24.54 to 21.44% up to a depth of 40 cm. The soil compaction has stipulated changes of the penetration resistance and other parameters. On the uncompacted soil, the average values of the penetration resistance were from 0.42 to 5.13 MPa, behind the left wheel the interval is from 1.70 to 5.75 MPa, and behind the right wheel from 2.00 to 5.85 MPa.

Table 2. shows the change of penetration resistance (%) during disking, behind the left and the right wheel, in relation to the soil’s condition before disking.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Water content (%)</th>
<th>Increase Cone Index behind left wheel (%)</th>
<th>Increase Cone Index behind right wheel (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>24.00</td>
<td>148.35</td>
<td>142.73</td>
</tr>
<tr>
<td>5-10</td>
<td>23.00</td>
<td>130.56</td>
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<td>10-15</td>
<td>21.63</td>
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<td>15-20</td>
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<tr>
<td>20-30</td>
<td>21.80</td>
<td>129.72</td>
<td>100.93</td>
</tr>
<tr>
<td>30-40</td>
<td>20.65</td>
<td>117.48</td>
<td>105.32</td>
</tr>
</tbody>
</table>
Table 2. The penetration resistance increase (%), during disking

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Water Content (%)</th>
<th>Cone Index before disking (MPa)</th>
<th>Cone Index in trail left wheel (MPa)</th>
<th>Increase of Cone Index left wheel (%)</th>
<th>Cone Index in trail right wheel (MPa)</th>
<th>Increase of Cone Index right wheel (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>24.54</td>
<td>0.42</td>
<td>1.70</td>
<td>404.76</td>
<td>2.00</td>
<td>476.19</td>
</tr>
<tr>
<td>5-10</td>
<td>24.22</td>
<td>0.83</td>
<td>2.64</td>
<td>318.07</td>
<td>2.68</td>
<td>322.89</td>
</tr>
<tr>
<td>10-15</td>
<td>23.05</td>
<td>1.61</td>
<td>3.00</td>
<td>186.34</td>
<td>3.03</td>
<td>188.20</td>
</tr>
<tr>
<td>15-20</td>
<td>23.00</td>
<td>1.82</td>
<td>4.00</td>
<td>219.78</td>
<td>4.00</td>
<td>219.78</td>
</tr>
<tr>
<td>20-30</td>
<td>23.00</td>
<td>3.14</td>
<td>4.40</td>
<td>140.13</td>
<td>4.40</td>
<td>140.13</td>
</tr>
<tr>
<td>30-40</td>
<td>21.44</td>
<td>5.13</td>
<td>5.75</td>
<td>112.09</td>
<td>5.85</td>
<td>114.04</td>
</tr>
</tbody>
</table>

The largest penetration resistance (Cone Index, Table 2), during disking behind the left wheel was at a depth of 5 cm and it reached 404.76%, and at a depth from 5 to 10 cm it was 318.07%. The increase of the penetration resistance in the right wheel's trail is the greatest at a depth of 0 to 5 cm and it reached 476.19%. If the increases behind the wheel and before ploughing are analyzed at a depth from 5 to 10 cm, that increase was 322.89%.

New solutions of agricultural machinery for the heavy soils tillage

The development of agricultural machinery that applies new technologies for the processes of heavy mechanical soil exploitation is given a special meaning nowadays.

For the regions with annual rainfall less than 600 mm per m², deep subsoiling tillage, with optimal agriculture machinery, can provide economically sustainable yields of basic agricultural crops: wheat, sugar beet, corn, soy and sunflower. Harmful effects of droughts in the last few years, especially in 2003, (Račević et al., 1997, 2003), are also an effect of an inadequate soil cultivation.

The goal of the research conducted by the Institute for Agriculture Engineering of the Agriculture Faculty in Belgrade (Račević et al., 1997, 2005), was to define the required parameters for the construction of all types of heavy soil arrangement and tillage machines and within a period of three years, to develop new solutions for a rational tillage of heavy soils.

According to data collected under production and experimental conditions at the parcels of the sugar refinery "Crvenka" from Crvenka, and researches (Račević et al., 1994, 2005), with a complete usage of agricultural machinery and deep subsoiling, the gained results show that the sugar beet plants advance quicker and resist the drought better. Therefore an increase in yield was noted, and an increase in gains by 14 to 20% per hectare.

A broad range of technical solutions are applied world wide for soil surface leveling, (Chen et al., 2005), (Derdack, 1989), (Nikolić et al., 1996, 2002), (Raper, 2005), subsoiling and deep soil tillage: scrape boards, special ploughs, chisel ploughs, subsoilers with stiff and vibratory working bodies, subsoilers with various add-ons, rotational machines, etc.

The Institute for Agriculture Engineering of the Agriculture Faculty in Belgrade has for a number of years worked on the development of the machines for the soil’s surface and depth arrangement: carried vibratory subsoiler VR-5 (7), (Fig.1); universal self-propelled soil arrangement machine USM-5 (Fig. 2) and drainage plough DP-4 (Fig. 3).
According to data gained during experimental measurements of the energy parameters in the course of the machines model and type testings (Fig. 1, 2, 3), it could be concluded that:

During the testing of the subsoiling tools (Račević et al., 1995, 1997), an average decrease of the tractor’s tractive power was accomplished through vibrations, of 0.80 to 0.85%.

During a working speed of 7 km/h, the tractive power was from 250 to 300 kW for a static version of the tool. Thus, for the given depth of subsoiling with the tractor usage coefficient of 80% during these working operations, a 60 kN tractive power tractor was needed.

The displayed machinery solutions are tested during conditions of different types of tillage and especially for soils with heavy mechanical composition.

Based on the test results presented in this text, it could be concluded that:

The cubic weight of the soil reaches: for plough tillage 1.40 [g/cm³], and for subsoiling (Subsoiler machine, Fig.1.) it was 1.43, at a working depth of 0.6 m,

Water permeability (the K-coefficient, by Darcy, [cm/s]), for plough tillage was (1.00 to 1.05) \(10^{-3}\), and for subsoiling the value is (1.10 to 1.30) \(10^{-3}\),

The penetration resistance of the soil (in MPa) was from 11 to 13% of the lesser values at subsoiling soils,

The achieved biological returns of wheat, corn and sugar beet, during conditions of dry cropping, is 12 to 21% larger in favor of the heavy mechanical class soil type (according to heavy mechanical content), for operation of subsoiling depth of 0.6 m,

Soil deformation, during working speeds of 0.9 to 1.33 m/s and tillage depth of 0.4 m, is significantly increased with the increment of working body’s width and increased movement speed,

Measurements have established that the lateral sides of the working body have a greater effect on soil (Fig.1.) with the vibration of the subsoiler body, compared to a stationary working body,

Testing has shown that the work with a vibratory body subsoiler (Fig.1.) have accomplished a lower traction resistance for approximately 4%, compared to a subsoiler with a stationary body,

Appliance of the vibratory subsoilers (Fig.1.) for soil tillage has saved fuel consumption compared to classic plough tillage: 16% for sugar beet, 19% for corn and 29% for soy.

**Conclusion**

By testing the changes of the more important properties of the heavy soils, it has been established that the penetration resistance has increased during all working operations and it has been especially increased during disking. Greater changes in soil compaction have been noticed in lateral areas up to 20 cm deep, which is specifically exposed to intense machine and tractor movement over the surface of the heavy soils.

Tractive resistances, during the same conditions, decrease at vibratory working bodies up to 4%, with an increase of working depth up to 6%. Application of the vibratory subsoilers in systems of a rational tillage of soils with heavy mechanical composition has led to formidable fuel savings, from 16 to 29%, depending on plant crops.

Based on new findings and new solutions of these machines world wide, it is necessary to work on perfecting the decrypted machinery solutions in this work, as well as construction of the machines that the market of agricultural and soil melioration machines in Serbia does not have and offer such improved machines to agricultural producers.

**References**


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