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SPECIAL TILLAGE MACHINERY FOR SOILS WITH INCREASED CLAYEY TYPE MECHANICAL COMPOSITION -MARSH SOIL CASE

SUMMARY

Today in Serbia there are over 0.40 million hectares of soil with increased of clayey mechanical type composition and over one million ha of diversely damaged soil. These kinds of soils are possibly fertile by their characteristics, they have good chemical properties and very bad physical and mechanical properties and they present a specific problem during exploitation.

Soils with clayey mechanical composition require a special tillage system which guarantees preservation of natural potentials and fertile resources, and prevents degradation processes of the soil, exceptionally with an optimal consumption of energy and labor.

Agricultural machinery for tillage of the soils with clay mechanical composition should fulfill the basic demands: arrangement of the soil's surface and depth, preservation of the soil's biological system, regulation of the water and air system, thus enabling an efficient irrigation, conservation of the natural humidity, insurance of a rational energy, labor and resource consumption for the defined structure and production level.

To ensure a quality and steady returns of plants, it is necessary to ensure an optimal air and water system for the soil. That means the soil's surface and depth has to be arranged, thereby creating conditions for the conservation and rational usage of the natural humidity from the cultivated layers and from the deeper layers of the soil.

The goal of the researches conducted by the Institute for Agricultural Engineering of the Agricultural Faculty of Belgrade, R. Serbia, was to define the needed parameters for the construction of machines for tillage of soils with clayey type of mechanical composition and, develop new solutions for tillage of composed soil with clay mechanical type of composition. 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.

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The primary goal of applying the new machinery is to verify the important parameters for the construction of the machines, defying of the parameters with positive effects on the soil with a clear goal of perfecting the technologies for the exploitation of potential fertility of the soil, under the conditions of irrigation for two harvests.

Key words: Marsh soils, special tillage machinery, clayey type mechanical composition

INTRODUCTION

According to data (Pavićević, N. et al., 1973), (Vučić, N., 1992) in Serbia there are over 0.40 million ha of soil with clay type mechanical composition and nearly one million ha of diversely damaged soil. These kinds of soils are possibly fertile by their characteristics, they have good chemical properties and very bad physical and mechanical properties, and they present a specific problem during exploitation.

Soils with clay mechanical composition require (Vučić, N., 1992, Oljača, V. M., 1992) a tillage system which guarantees preservation of the soil's natural potentials and fertile resources, and prevents degradation processes of the soil, exceptionally with an optimal consumption of energy, water and labor.

Agricultural machinery for the tillage of soils with clay mechanical composition should fulfill the basic demands: arrangement of the soil's surface and depth, preservation of the soil's biological system, regulation of the water and air system, enabling an efficient irrigation, conservation of the natural humidity, insuring a rational energy, labor and resource consumption for the defined structure and production level.

Inadequate soil tillage presents a large problem in Serbia, especially for soils with clay mechanical composition, in the last 15 years. This was a consequence of general economic circumstances in the country, which are fore mostly noticed by absence of adequate agricultural mechanization. This has brought to two major negative consequences: decrease of yields, and increase of energy consumption, primarily because of the lack of modern agricultural machinery for this purpose, because the consequences of compaction and inadequate cultivation have led to enormous agricultural damages, which is especially distinctive in very dry or very humid years.

The application of optimal technical and technologic systems of tillage depends on the available agricultural machinery which is suitable for the exploitation of clay and other types of soil. Quality tillage of the soil is directly dependent on the applied machinery (Raičević et al, 1989). Tough economic circumstances in Republic of Serbia have disturbed the economic environment of the primary agricultural production and the optimal husbandry of the land.

In addition to the negative effects, there are some disagreements between the relevant fields of expertise (Raičević et al, 1994) that are dealing with soil problems from different points of view, which additionally interferes with the ascertainment of rational methods and resources from the standpoint of expected results and application of the agricultural machinery and the consequences that may occur in dry or humid periods.

The results of developing the technical and technological solutions of agricultural machinery (Raičević et al, 1997), (Raičević et al, 1992), and the accompanying elements of computer technology (for instance, control of the work quality, or the tillage process) present an opportunity to define the adequate tillage methods for all types of soil, including clay soils, for the given conditions with a minimum amount of harmful effects (Raičević et al, 2005). Adequate arrangement and tillage are the basic demands of rational soil exploitation, especially of clay types of soil.

Degradation of the soil is the impairment of it's abilities to fulfill it's purpose, as an environment for plant breeding, as a regulator of the water system and as a significant filter for the preservation of the environment.

The degradation process of all types of soils, especially of the clay soils (high clay particle content in it's mechanical composition), starts with the degradation of the structure, which causes disabling of the soil's pores to transport and keep water when the creating of the crust on the soil's surface begins, which also follows the process of soil compaction. Aside from all these processes, the negative characteristics are also contributed by very intense or very weak drainage, then lack of humidity, emergence of rapid erosion of the soil and similar processes.

The phenomenon of soil particle compacting and packing is primarily important because of compaction and over-hydrating, which have for an aftermath:

- Reduced fertility and increased consumption of labor and energy for the cultivation of these types of Marsh soils.
- The mechanization, combined with tractors, effect the soil by trampling it, and the negative effects are tended to be removed on various ways, fore mostly by a specific tillage manner, which frequently is not adapted for the intensity of the soil exploitation and it's watering system.
- Earlier researches (Raičević, D., 1983), had a task to instate the basic principles to form a technological and technical system and technical solutions for the machinery by the name of "Joint Engineering" for the arrangement and tillage of the clay soils, especially in the region of south Banat (Vojvodina), which gave results and constructive solutions for the new machines. Further development was delayed due to an economy crisis and the breakdown of the domestic agricultural machinery industry.

Because of the aforementioned facts, the basic criteria for appliance of the new technologies of soil cultivation and arrangement should be stated (Raičević D. et al, 1994, Ohtomo, K., Tan, C.C.A., 2010), ensuing ways of exploiting the soil of clay mechanical composition and the development of the assets of agricultural engineering:

- Fulfillment of the requirements set by the consistent agricultural production of the agro system,
- The mechanization is the bearer of the consistent agriculture technologies,
- Preservation of the soil as a complex biological system,
- Preservation of the soil's fertility,
- Arrangement of the soil's depth and surface,
- A water system – soil compaction,
- Conservation of the natural humidity,
- Prospects of intense irrigation,
- Rational consumption of labor, energy and other resources, per hectare,
- Erosion processes and soil degradation on flat and sloped terrain.

Different technical solutions are being applied in practice, with different results for all kinds of tillage of clay types of soil. In the last 15 years, the appropriate technical solutions have not been applied for the processes of soil exploitation and maintenance because of the limited material resources for the development and acquisition of agricultural machines for this purpose, which led to harmful effects from excess watering, compaction, reduction of the yields and large expenditures of labor and energy.

The development and application of the new agriculture machinery assets (Raičević et al, 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 changes of agricultural machinery have been intense in the last decades of the 20th century. The intensity of the tillage was increased or decreased depending on the circumstances, but there was a constant trend of increasing the tractor engine power and the axle work load of the machines. The increase of the work load causes damage to the soil's structure, which further increases risk of soil erosion and increases the energy requirements for the tillage. Modern agricultural machines enable the reduction of the work expenditures and quality execution of the working operations and in a timely manner.

As a countermeasure to increasing of the machines weight, the low-pressurized pneumatics has been developed, which allow constant pressure to be sustained on the surface of the soil.

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, M., 1993, Keller T., Arvidsson J., 2004). This matter can be removed by occasional subsoiling, which improves the macrostructure of the soil, but it rarely can improve it's microstructure. The tractor's movement in the next stage of the cultivation compacts the soil further, to a certain degree. The soil compaction (Nikolić et al, 1996), (Oljača, M., 1992), (Raper, R.L., 2005), 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. These changes effect the filtration, drainage, water accessibility, airing, the root's expansion, and nutrients reception from the soil (Mulqueen et al, 1977), (Nikolić et al, 1996).

For an adequate analysis of the effects the tillage and compaction of the soil with clay composition have on plant products, it is necessary to describe the changes in the soil caused by movement of the agricultural machinery.

MATERIAL AND METHODS

Experimental researches of a tillage soil with clayey mechanical type composition were carried out on the grounds of the PKB Corporation – Belgrade, on the Padinska Skela farms, (position 44° 56′ N, and 20° 26′ E), on a parcel marked T-18, a 40 ha area, type of Marsh soil.

Figure 1: Appearance of the surface of the Marsh soil, location Padinska Skela

Basic physical properties of the soil were determined by method JDPZ, 1971. The mechanical composition of the soil was determined by the pipette method, and the samples were prepared using sodium pyrophosphate, was determined by method JDPZ, 1971.

Basic chemical properties of the soil were determined by method JDPZ, 1971: The soil reaction (pH in H_2O and nKCl) was determined with a potentiometer. The total carbonates were determined by the volumetric Scheibler method. The content of the total humus was determined by the Kotzman method. Easily accessible phosphorous and potassium were determined by the Al-method and the adsorptive complex (y1, S, T, V) was determined by the Kappen method.

Basic properties of Marsh soils

The influence that soil tillage has on compaction, that is penetration resistance, was examined on a Marsh soil type (Pavićević, N. et al.,1973). The examined variety of the Marsh soil is with a deep humus accumulative surface, 80 cm deep.

Table 1., shows the mechanical composition, basic soil physical properties, and basic soil chemical properties (Radojević R., Raičević D., Oljača M., Gligorević K., Pajić M.,2006), of the examined soil.

Table 1. Basic properties of Marsh Soil

Mechanical composition and texture class of the soil						
Soil horizon	Depth (cm)	Fine send 0,2-0,02 (mm)	Silt 0,02-0,002 (mm)	Clay <0,002 (mm)	Silt+Clay <0,02 (mm)	Texture class of Soil
A_h	0-20	24.90	33.20	41.90	75.10	Clay
A_h	30-50	25.30	35.40	39.30	74.70	Clay
GB_{Ca}	80-100	23.10	38.60	38.60	77.20	Clay
CG	100-140	32.90	32.90	32.20	65.10	Clay-loam

Basic physical properties of the soil							
Soil horizon	Depth (cm)	Specific mass Mgm^{-3}	Soil bulk density Mgm^{-3}	Total porosity % vol	Reten. capacity % vol	Current moisture % vol	Psysiol. moist. % vol
A_h	0-20	2.68	1.315	51.12	42.70	21.75	20.95
A_h	30-50	2.68	1.315	51.12	42.20	21.92	20.91
GB_{Ca}	80-100	2.70	1.339	50.74	42.80	22.01	20.79
CG	100-140	2.70	1.339	50.74	41.40	21.25	20.15

Basic chemical properties of the soil								
Soil horizon	Depth (cm)	$CaCO_3$ %	pH in H_2O	Humus %	Adsorptive complex			
					Y_1 ccm	S m.ekv.	T m.ekv.	V %
A_h	0-20	0.00	7.60	5.40	3.49	39.91	42.17	94.64
A_h	30-50	0.00	7.20	5.10	2.05	33.30	34.63	96.15
GB_{Ca}	80-100	0.00	7.20	-	1.71	30.00	31.71	94.60
CG	100-140	4.98	7.80	-	-	-	-	-

The quantitative indicator of the physical, chemical, and aquatic properties points that the examined soil falls under the clayey mehanical class soil type.

Used agricultural mechanization

In the afformentioned 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 basic technical and working characteristics of the machines are shown in tables.

Table 2. Basic technical and working characteristics of the examined tractor MF-8160

Type / Category of tractor (kN)	Effective power (kW)	Mass of tractor without ballast (kg)			Mass of tractor with ballast (kg)			T i r e s
		Forward weels	Rearward weels	Total	Forward weels	Rearward weels	Total	Forward/ Rearward
4x4 S / 40 kN	147	3580	4340	7920	4000	7200	11200	480/70-30 / 620/70-42

Table 3. Basic technical and working characteristics of the connecting implements

Type of machines	Category of tractor (kN)	Mass (kg)	Number of work body	Working scale (m)
Plough MF – 715	40	1430	4/5	1.5-2
Disk harow OLT - Tara 36	40	1430	36	4.5

Examining methods

The applyed field examining methods are devided into two phases:

- The first phase includes methods for basic data gathering about the most important general distinctions of the specyfied location's soil.
- The second phase includes the methods which register the changes of physical and mechanical compositions, ensued by the passage of the running system of a tractor over the soil's surface. During the examing, aside from other parameters, a penetration resistance was determined, depending on soil humidity and depth.

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 measurings were conducted in series of ten repetitions, at depths of 5 – 10 – 15 – 20 – 30 – 40 cm, on the prepared measurment sites.

During the examination, the technological process of tillage of Marsh soil types was watched, meaning the cosenqences of movement of the running system of a tractor with connecting implements and machines for execution of the autumn soil tillage. The changes of soil properties by compaction were followed through the analysis of the parameters before and after the carried out operations. 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.

Table 4 shows the working operations with the scope of works, types of drive mechanization and the connecting elements, and the job time limit.

Table 4. Working operations during the autumn cultivation of the Marsh soil

	Tillage or Working operations	Area (ha) or quantity (kg /ha)	Power machines	Supply machinery	Time limit
1.	Exfoliation stubble	40 ha	MF - 8160	Disk harow Tara – 36	06.-12.Aug.
2.	Manure distributor	5410kg / 40 ha	Landini - Ghibli	ZMAJ	12.Aug-29.Sept.
3.	Ploughing depth 30-35 cm	40 ha	MF - 8160	Plough MF – 715	14.Aug.-10.Oct.
4.	Discing	20ha + 20 ha	MF - 8160	Disk harow Tara – 36	29.Sept -16.Nov.
5.	Soil levelling	40 ha	MF - 8160	Soil grader protype RA-540	27- 28.Oct.
6.	Mole drainage	40 ha	MF - 8160	Draining plough DP-4	01.Nov.
7.	Granule spreader	6360 kg / 40 ha	Landini Ghibli	RVC	17.Nov.
8.	Ploughing depth - 40 cm	40 ha	Legend Same Titan	Kuhn 121	06.- 09.Dec.

RESULT AND DISCUSSIONS

Penetration resistance values during the ploughing operation

Table 5., shows the average values of the characteristics of the uncompacted soil with clay mechanical composition, before ploughing with a tractor and a machine aggregate: MF-8160 and plough MF-715.

Table 5. Average values of the uncompacted soil's characteristics, before ploughing

Depth (cm)	Water con. (%)	Soil bulk density Mgm^{-3}	Total porosity (%)	Cone Index (MPa)
0-5	24.00	1.317	50.48	0.91
5-10	23.00	1.327	50.11	1.44
10-15	21.63	1.343	49.51	2.00
15-20	23.44	1.366	48.64	2.81
20-30	21.80	1.399	47.40	3.60
30-40	20.65	1.414	46.23	5.55

The average values of the compaction parameters on the MF-8160 tractor's wheels trail, during ploughing at a depth of 35 cm are shown within the Table 6.

Table 6. Average values of the penetration values during ploughing (tractor MF-8160)

Depth (cm)	Water content (%)	Soil bulk density (Mgm^{-3})	Cone Index (MPa)	Cone Index behind wheel on grass-plot (MPa)	Cone Index -in furrow (MPa)	Cone Index behind wheel in furrow (MPa)
0-5	24.00	1.317	0.91	1.35	1.10	1.57
5-10	23.00	1.327	1.44	1.88	2.20	2.74
10-15	21.63	1.343	2.00	2.52	3.52	4.13
15-20	23.44	1.366	2.81	4.20	5.41	5.96
20-30	21.80	1.399	3.60	4.67	4.31	4.35
30-40	20.65	1.414	5.55	6.52	6.96	7.33

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- 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 0.91-5.55 MPa, whereas the uncompacted portion of the soil is 1.35- 6.52, and in the trail 1.57 - 7.33 MPa.

Table 7. The increase (%) of the penetration resistance(Cone Index) during ploughing

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

Table 7 shows the increase (%) of the penetration resistance behind the wheel on the field, behind the wheel in a trail and behind the wheel in a trail compared to the condition of the soil before ploughing.

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

Table 8 shows the average characteristics values of the uncompacted soil before disking with a tractor and machine aggregate consisting of: tractor MF-8160 and disc harrow OLT Tara-36.

Table 8. Average parameter values of the uncompacted soil, before disking

Depth (cm)	Water content (%)	Soil bulk density (Mgm^{-3})	Total porosity (%)	Cone Index (MPa)
0-5	24.54	1.291	51.41	0.42
5-10	24.22	1.295	51.31	0.83
10-15	23.05	1.299	51.16	1.61
15-20	23.00	1.302	51.05	1.82
20-30	23.00	1.313	50.63	3.14
30-40	21.44	1.414	46.23	5.13

The average values of the parameters of compaction on an uncompacted soil and on the trails of an MF-8160 during disking are shown in Table 9.

Table 9. The penetration resistance of the soil during disking (tractor MF-8160)

Depth (cm)	Water content (%)	Soil bulk density (Mgm^{-3})	Cone Index before disking (MPa)	Cone Index in trail left wheel (MPa)	Cone Index in trail right wheel (MPa)
0-5	24.54	1.398	0.42	1.70	2.00
5-10	24.22	1.405	0.83	2.64	2.68
10-15	23.05	1.421	1.61	3.00	3.03
15-20	23.00	1.508	1.82	4.00	4.00
20-30	23.00	1.554	3.14	4.40	4.40
30-40	21.44	1.579	5.13	5.75	5.85

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 24.54- 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 0.42 -5.13 MPa, behind the left wheel the interval is 1.70-5.75 MPa, and behind the right wheel 2.00 - 5.85MPa.

Table 10. 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 10. The penetration resistance increase (%), during disking

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

The largest penetration resistance (Cone Index, Table10.) , during disking behind the left wheel was at a depth of 5 cm and it reached 404.76%. At a depth 5-10 cm it was 318.07%. The increase of the penetration resistance in the right wheel's trail is the greatest at a depth 0-5 cm and it reached 476.19%. If the increases behind the wheel and before ploughing are analyzed at a depth 5-10 cm, that increase was 322.89%.

How to repair and remove consequences of compaction during exploitation of the soils with clay mechanical composition?

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

Because of this, Department of Agriculture Engineering of the Faculty of Agriculture in Belgrade has researched, tested and developed:

1.New technologies and machines for preparation condition of crops growing with a reduced number of work operations and passages, and with a considerable reduction of driving energy consumption.

2.Adjustment of the production structure – selection of the crops that can be grown on surfaces with a clay mechanical composition.

3.Selection of the tillage methods that sustain the fertility of the soil and the reduction of the degradation processes with agriculture machinery for the soil's depth and surface arrangement.

To ensure a quality and stable plant yields, it is necessary to ensure an optimal water and air system in the soil. That means that the soil needs to be arranged by it's depth and it's surface, thus creating conditions for conservation and rational usage of natural moisture from the cultivated layers and from the layers on a greater depth. For the regions with annual rainfall less than 600 mm, 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: (Raičević et al, 1997; Raičević et al, 2005; Raper, R.L., 2005; Soane B D, van Ouwerkerk C,1994; Chancellor, J.W. 1976; Hamza M.A., Anderson W.K., 2005) are also an effect of an inadequate soil cultivation, with a high frequency of soil compaction by the mechanization, a bad disposition of rainfall during winter and without rainfall during spring, which is why the winter moisture conservation was left out.

The goal of the research conducted by the Institute for Agriculture Engineering of the Agriculture Faculty in Belgrade (Raičević, 1983), (Raičević et al, 2005), (Akker, J.J.H., Canarache, A., 2001), was to define the required parameters for the construction of all types of clay soil arrangement and tillage machines and within a period of three years, to develop new solutions for a rational tillage of clay soils.

The research includes the development and crosschecking of the effects the new machinery solutions have on physical and aquatic properties of clay soils, energy and resource consumption, yields and the development of new technologies of tillage.

The basic goal of the applyment of the new machinery solutions is to crosscheck the relevant parameters for the construction of the machines, to determine the positive effects these parameters have on the soil, with a clear goal of technology advancement for the exploitation of the potential soil fertility, with the condition of two harvest irrigation. Today, the most common basic soil tillage is with ploughs and an additional tillage with different types of seedbed preparation machines. During plough tillage, a flat and compacted furrow bottom is left behind. After many years of plough tillage and numerous passages of the mechanization over the soil's surface, the compaction of the furrow's bottom is progressively increased and a hard, water-resistant layer of the soil is formed.

This newly created soil surface has double negative properties:

- It does not transmit the surface water to the lower layers of the soil, which leads to inaptly conditions for plant development, thus not enabling moisture conservation during dry periods.
- It does not allow water movement from the lower layers of the soil towards the surface layers, which could be used by the plant during shortcomings of moisture in the surface layer.

The mentioned problem is especially of significance when rainfall is insufficient – drought periods during vegetative period, which are more and more present in our area. The plant has no moisture from the rainfall, but they also can't use the moisture from the deeper layers of the soil, because that moisture can't reach them.

Numerous experiments conducted world wide and in our country have pointed out a need to tillage the soil's surface as well as it's deeper layers by subsoiling and alike, to ensure a favorable air and aquatic conditions within the soil, that is to improve the capacity of moisture accumulation and conservation and it's movement towards the plant's root system, which significantly moderates the rainfall shortcomings during the vegetational periods.

The science and expertise in our country has intensively pointed out this problem more than 20 years ago, and deep subsoiling was very much accepted. But as energy is consumed by this process, this system of tillage was almost completely abandoned in Serbia, in order to save energy.

And after perennial basic tillage by using ploughs, most of our soils are well enough disabled to ensure an optimal air and water system for plant growth and development, which is especially displayed during dry periods. According to data (Raičević, D. 1983), (Raičević D., Ercegović Đ., Oljača M.V., Pajić M., 2003), collected under production and experimental conditions at the parcels of the sugar refinery from Crvenka (45° 39′ N, 19° 27′ E), and researches (Raičević et al, 1994; Raičević et al, 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 14-20% per hectare. In this manner, it was confirmed that deep subsoiling presents one of special pedo-meliorations measures and a permanent solution to fight droughts and to gain steady yields.

A broad range of technical solutions are applied world wide for soil surface leveling, (Chen et al, 2005; Antončić, 1987; Keller T., Arvidsson J., 2004; Soane and Ouwerkerk, 1994), 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.

Perennial results of researches concerning subsoiling tools and machines applyment, have shown significant advantages compared to conventional methods of tillage of soils with clay mechanical composition. Significant improvement of some of the parameters were achieved: porosity, air and water system, a better development of the root system, a better and favorable moisture conservation, a positive reaction to an irrigation (rational water consumption) and normal maintenance of the soil's biological system.

Three groups of positive changes can be separated during the work with subsoiling tools and machines:

- Positive changes of the mechanical, physical properties of the soil,
- Symmetrical work of the power unit with a reduction of the propulsive unit's wheel sliding,
- Favorable energy expenditure.

The Institute for Agriculture Engineering of the Agriculture Faculty in Belgrade has for a number of years worked on the development (Raičević et al, 1991; Raičević, 1983, Raičević et al, 2006) of the machines for the soil's surface and depth arrangement.

Discovery of a rational machinery solution for soil tillage in order to gain stable and economical yields has stipulated the research, development and appliance of different kinds of working bodies and ways of oscillations, vibration or rotation of the subsoiling machine's working bodies.

Experimental and commercial models of the machinery and tools solutions have been created:

- Carried vibratory subsoiler VR-5 (7), (Figure 2);
- Universal self-propelled soil arrangement machine USM-5 (Figure 3);
- Drainage plough DP-4 (Figure 4).

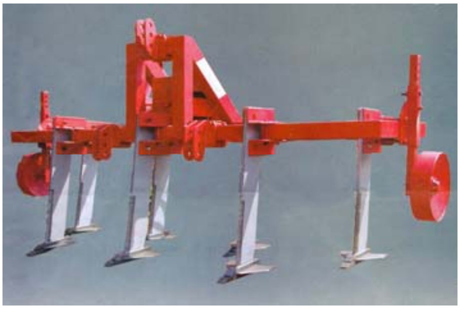

Figure 2. Carried vibratory subsoiler VS-5/7

Figure 3. Universal self-propelled soil arrangement machine USPM-5

Figure 4. Drainage plough DP-4

According to data gained during experimental measurements of the energy parameters in the course of the machines model and type testings (Figures 2, 3, 4), it could be concluded that:

- During the testing of the subsoiling tools (Raičević et al, 1995; Raičević et al, 1997), an average decrease of the tractor's tractive power was accomplished through vibrations, 0.80- 0.85 %,
- During a working speed of 7 kmh, the tractive power was 250-300 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 clay 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 Mgm^{-3}, and for subsoiling (Subsoiler machine , Figure 2.) it was 1.43 Mgm^{-3}, at a working depth of 0.6 m, according (Chen et al, 2005);
- Water permeability (the K-coefficient, by Darcy, in cm/s), for plough tillage was $(1.00 \text{ to } 1.05) \cdot 10^{-3}$, and for subsoiling the value is $(1.10\text{-}1.30) \cdot 10^{-3}$;
- The penetration resistance of the soil (in MPa) was 11-13% of the lesser values at uncohesive soils, according (Raper, R.L., 2005);
- The achieved biological returns of wheat, corn and sugar beet, during conditions of dry cropping, is 12-21% larger in favor of the clay mehanical class soil type (according to clay mechanical content), for operatin of subsoiling depth of 0.6 m;
- Soil deformation, during working speeds 0.9-1.33 m/s and tillage depth of 0.4 m, is significantly increased with the increment of working body's width and increased movement speed, according (Nikolic et al, 2001);
- Measurements have established that the lateral sides of the working body have a greater effect on soil (Figure 2.) with the vibration of the subsoiler body, compared to a stationary working body, according (Ohtomo, K., Tan, C.C.A., 2010);
- Testing has shown that the work with a vibratory body subsoiler (Figure 2.) have accomplished a lower traction resistance for approximately 4%, compared to a subsoiler with a stationary body, according (O'Sullivan et al,1999);
- Appliance of the vibratory subsoilers (Figure 2.) for soil tillage has saved fuel consumption compared to classic plough tillage 16% - 29% for different plant crops production.

CONCLUSIONS

By testing the changes of the more important properties of the soils with clay mechanical composition, 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 clay soils.

Reduction of the tractor's axle load, usage of radial pneumatics with a certain pressure and usage of paired pneumatics, can reduce the degenerative changes of the soil's physical and chemical properties.

When the penetration resistance measuring determines the negative effect of the tractor's and machine's movement over the parcel, the applyment of subsoiling can repair the compacted layer's properties.

Tillage of soils with clay mechanical composition requires a leveling of the surface layer, and initiation of deep suboiling tillage, to create favorable soil conditions for agricultural production. At subsoilers with a vibratory body, the deformation angle of the soil's landscape increases with the increment of the working speed and the width of the working body, compared to a stationary subsoiler. Tractive resistances, during the same conditions, decrease at vibratory working bodies up to 4%, with an increase of working depth up to 6%.

Vibrations of the subsoiling working organs affect the decrement of the tractive power, witch justifies further research and appliance.

Vibrations of the subsoiling working bodies has a marked effect on soil's trituration and rastresanje, which insures a good water permeability, better development of the root system and better yields. Applyment of the vibratory subsoilers in systems of a rational tillage of soils with clay mechanical composition has led to formidable fuel savings, 16-29%, depending on plant crops. Battle against drought aftermaths is possible, not only by implementing expensive irrigation systems and their complicated and expensive maintenance, but also by arrangement of the soil's surface and depth, as well as by applying a rational tillage, that is by applying a subsoiler for deep subsoiling and subsoiling.

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

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SPECIJALNE MAŠINE U OBRADI ZEMLJIŠTA SA IZRAŽENIM GLINOVITIM MEHANIČKIM SASTAVOM -PRIMER RITSKE CRNICE

SAŽETAK

Danas u Srbiji, ima preko 0,40 miliona ha zemljišta sa mehaničkim sastavom sa povećanim udelom gline, i preko jedan milion ha, na različite načine oštećenih zemljišta. Ovakva zemljišta, prema svojim karakteristikama, su potencijalno plodna, imaju dobre hemijske osobine, i veoma loše fizičko-mehaničke osobine, i predstavljaju poseban problem tokom obrade i korišćenja.

Zemljišta sa izraženim glinovitim mehaničkim sastavom zahtevaju poseban sistem obrade koji obezbeđuje očuvanje prirodnih potencijala i resursa plodnosti, koji sprečava degradacione procese u zemljištu, a posebno sa optimalnim utroškom energije i rada.

Poljoprivredna tehnika za izvođenje obrade teških tipova zemljšta, treba da ispuni osnovne zahteve: uređenje zemljišta po površini i dubini, očuvanje biosistema zemljišta, regulisanje vodnog i vazdušnog režima, omogućavanje efikasnog navodnjavanja, konzerviranje prirodne vlage, obezbeđenje racionalne potrošnje energije, potrošnje rada i resursa za definisanu strukturu i nivo proizvodnje.

Za obezbeđenje kvalitetnih i stabilnih prinosa biljaka neophodno je obezbediti optimalni vodni i vazdušni režim u zemljištu. To znači da je zemljište potrebno urediti po površini i dubini i stvoriti uslove za konzervaciju i racionalno korišćenje prirodne vlage iz obrađenih slojeva i iz slojeva na većoj dubini zemljišta.

Cilj istraživanja u Institutu za poljoprivrednu tehniku Poljoprivrednog fakulteta u Beogradu, R. Srbija, je definisanje potrebnih parametra za konstrukciju mašina za uređenje i obradu svih tipova glinovitih zemljišta, i razviju nova rešenja mašina za racionalnu obradu zemljišta sa izraženim glinovitim mehaničkim sastavom.

Istraživanje obuhvata razvoj i proveru uticaja novih rešenja mašina na fizičke i vodne osobine teških zemljišta, potrošnju energije, potrošnju resursa, prinose i razvoj novih tehnologija obrade.

Osnovni zadatak primene novih rešenja mašina je provera relevantnih parametara za konstrukciju mašina, određivanje parametara pozitivnih efekata na zemljište sa jasnim ciljem usavršavanja tehnologija za iskorišćenje potencijalne plodnosti zemljišta u uslovima navodnjavanja za dve žetve.

Ključne reči: Zemljišta ritova, specijalne mašine za obradu glinovitih zemljišta, glinoviti mehanički sastav.