EFFECT OF ENVIRONMENTALLY FRIENDLY TILLAGE MACHINERY ON SOIL PROPERTIES

Egidijus Sarauskis[1], Kestutis Romaneckas[1], Edvardas Vaiciukevicius[1], Algirdas Jasinskas[1], Antanas Sakalauskas[1], Sidona Buragiene[1], Evaldas Katkevicius[1], Davut Karayel[2]
[1]Lithuanian University of Agriculture; [2]Akdeniz University, Turkey
egidijus.sarauskis@lzuu.lt, kestas.romaneckas@lzuu.lt, algirdas.jasinskas@lzuu.lt, antanas.sakalauskas@lzuu.lt, edvardas.vaiciukevicius@lzuu.lt, dkarayel@akdeniz.edu.tr

Abstract. In Lithuania environmentally friendly and energy saving agricultural technologies are integrated into manufacturing of agricultural production as the technologies giving the most innovative, economical, energetic and environmental benefits. The essence of these technologies is to limit the intensive mechanical and chemical impact on soil and vegetation, to provide the soil productivity renovation, protect the environment, rationally use the material, energetic and labour force resources, to meet strict environmental regulations, to produce wholesome food, and guarantee the economic effectiveness of manufacturing of agricultural produce. The working parts of the soil tillage machines influence the soil mechanically and change its properties. Deep loosening machines had been used to loosen deeper layers of the soil that have formed during longer periods of time. Their coulters cut the soil and make 35-40 cm depth slits but do not turn or mix it up. Air and water filtration in the soil improves because of this, therefore the plant roots develop better. On the other hand, humus and nutritious materials do not leach from the soil after heavy rain. The article presents deep tillage machines theoretical analysis, substantiation of the construction and operation technological parameters of deep tillage machinery and experimental results. The experimental scientific investigations were carried out in the period of 2009-2010 in different regions of Lithuania. The investigations basically aimed to determine positive impact of environmentally friendly tillage machinery on soil properties.

Keywords: deep tillage machines, soil properties, technological parameters.

Introduction

Soil is a very important nature object, which is one of the agricultural system basis and does make influence for all biosphere by the plants. Productive soil is the source of food. In the world every year the plots of degraded soil areas increase. The soil degradation is related to physical, chemical and biological changes of the process which influences the soil productivity based under wrong human activities [1; 2]. Globally, under human activities influenced soil degradation is a serious problem which does cover almost two billions hectares. Soil erosion is one of the main reasons which influences and affects reduction of the top layer of productive soil. Soil, the component of natural environment, is mostly affected by soil cultivation elements and machinery [3-5]. The natural soil erosion was possible to meet already before human activities. However, at that time soil erosion was not making influence into metabolism of ecosystem, because it was possible to meet the soil rarely without a vegetable layer. Under intensive human activities caused soil erosion results are much more serious. Especially a lot of soil areas are lost on cultivated plots, which are influenced by strong wind and big amount of rainfall. The longer the period is between the harvesting and seeding period, the more top layer of productivity soil is blown off or washed away. The soil compression is influenced by agriculture vehicles and their weight under the soil cultivation process, monocultural crops growing process etc. [1; 4]. It has been found in the research that conventional tillage does make influence for compacted soil layers. The top layer of the soil in the tracks of heavy agriculture vehicles is compressed till 70 cm depth. Furthermore, using conventional tillage 90-95 % of the top layer soil is compressed by tractors and wheels of other implements [2; 4; 6]. A damaging compression effect on deeper soil bed is possible to be reduced by changing the ploughing depth. However, usually it is not possible to do under the ploughing layer thickness or by a traditional ploughing process it is not possible to reach the compressed layer. To loosen the compressed soil depth tillage implements are used the main working parts of which are depth loosening tines [7; 8]. Under the tine construction the soil could be cut, loosened or mixed. To base the technological process it is needed to know the depth loosening implements working parts interface with the loosened soil layer evaluating the soil characteristics.

The density of the soil depends on the soil granule metric composition, porosity and content of humus. The sandy soil density usually is higher then loam or clay. If the loam soil density is lower than 1.0 $mg \cdot m^{-3}$, it shows that the soil is crumbly enough and it contains a lot of humus. If the soil density is from 1.1 till 1.2 $mg \cdot m^{-3}$ – the soil is considered as lain in normal conditions. If the soil density is from 1.3 till 1.8 $mg \cdot m^{-3}$, the soil is more lain as in normal conditions or it is compacted by agriculture vehicles. Sandy loam and sandy soil density varies depend on soil loosening implements or agriculture vehicles. The plants are mostly adapted to grow in the soil density is between 0.9 and 1.3 $mg \cdot m^{-3}$ [2; 9; 10].

The soil humidity has a big influence on the soil quality. Moisture soil does stick on soil cultivation working parts and does not crumble. Water destroys soil clods by changing the structure, friction and the other characteristics. The soil humidity depends on the water quantity. The optimal soil moisture in spring time is from 20 till 25 % [2; 6].

The hardness of the soil mostly depends on the soil granule metric structure and humidity. The humus and moisture reduce the hardness of the soil. If the soil granule metric structure is smooth then the measured hardness in deeper layers enlarges. The softest soil is humus. The hardness of the soil varies during the vegetation period. Too high hardness of the soil may block seed insert and plant root penetration. Especially sensitive to soil hardness are plants which are starting to germinate. Increase of the soil hardness has both positive and negative points. The positive effect is that it gets better soil drive; it is possible to go on the fields with agriculture vehicle and increase the soil resistance to compression. The negative effects are that cultivating hard soil increases energy costs and it is harder to penetrate the plant root deeper into the soil. Scientists divide the soil under its hardness into these groups: very hard homogenous >10 MPa, very hard – 5-10 MPa, hard – 3 5 MPa, partly hard – 2-3 MPa, partly loose – 1-2 MPa, loose – <1 MPa [11].

The aim of the research is to explore an environmental friendly deep soil tillage technological process and to determinate the influence of soil characteristics in different Lithuania locations.

Theoretical analysis

Under the deep soil tillage technological process the loosened soil layer resists to tine movement, soil resistance to the cutting force F appears, the direction of which is opposite to the direction of the machine movement. These forces have the biggest influence on the soil layer physical- mechanical characteristics including the implement tine parameters. Vagin (Вагин) has determined that the soil moisture content of the normal force F is parallel to the soil cultivation implement speed vector direction [12]. However, on high density or dry soil conditions in relation of humidity and external friction force F the direction is changing. The direction change variation limit of these forces is defined by the angle φ, it allows to determinate the soil physical- mechanical characteristics changes.

To avoid the deposit of soil in front of working tine surface, the soil resistance to the compression tension should be higher or equal to the soil resistance of the cutting force F and layer of loosened soil plot relation. Working with deep loosening implements it is desirable not to mix between the top and deeper layers, because on the top surface nutriment matter and humus layer would be inserted into deeper bed and it would be hard to reach them by the plants.

The deep loosening implement tine position and loosening depth have the influence on the soil loosening quality, plant residue and blockage in front of the tine. Deep loosening tines cut the soil layer and at the same time compress it perpendicular to the tine movement direction. According to the tines position on the machine frame the soil is loosened in stripes. On the tine working zone the soil cracks, interstices appear. In agro-technical requirements it is not determined which soil layer area could not be loosened working with depth loosening soil cultivation implements. There is often the loosened soil degree considered as the uplift soil layer comparing to not loosen soil parameters. However, in this case it is not possible to evaluate the loosened soil plot area.

Considering the soil looseness, a very important factor is movement of the soil layers which is determined by the angle ψ. Researchers carried out the case studies and found the ψ dependence of the soil cultivation depth and deep soil loosening machinery construction parts and technological parameters [13]:

$$\psi = 100\left(1 - \frac{(n-1)\left(\frac{(L-b)^2}{4} ctg \frac{\lambda}{2} + (L-b)h\right)}{((n-1)L+b)a}\right) \tag{1}$$

where n – tine quantity units;
L – lengh between tines on perpendicular direction, m;
b – tine width, m;
λ – angle, appreciative soil deformation in both sides of the tines;
a – working depth, m;
h – hight of the tine point, m.

Assuming that on the soil cultivation implement 6 deep loosening tines are mounted the width of which are 0.1 m, height of the point 0.12 m, angle λ=90º, working depth 0.4 m, it is possible to calculate the dependence between the intensity of loosening soil and the length between the tines. The relation between the cultivated and uncultivated soil plot areas should be no less than 60 % [14]. That soil would be calculated in this proportion distance between the tines and then it should be less (Fig. 1).

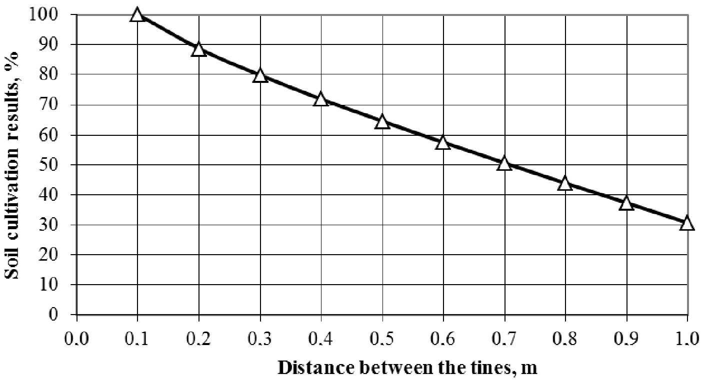


Fig. 1 **Tines spacing influence for soil cultivation results** (n=6, b=0.1 m, λ=90º, h=0.12 m, a=0.4 m)

Reducing the spacing between the tines is increasing the cultivated soil area. Reducing the space between the tines till 0.1 m the whole soil area is cultivated.

The cultivated soil part depends on the working depth also. Increasing the working depth it loosens all soil layers; more cracks and splits appear on the soil. Therefore, the cultivated soil area is increased. The deep loosening soil cultivation implement working depth is mostly from 0.3 till 0.4 m. Accepting that the distance between the tines is 0.6 m and calculating under 1 formula, it is determined that under this working depth cultivated, the loosened soil segment is from 45 till 58 %. Therefore, reaching that 60 % and even more of the soil area would be cultivated, it is needed to increase the working depth (Fig. 2).

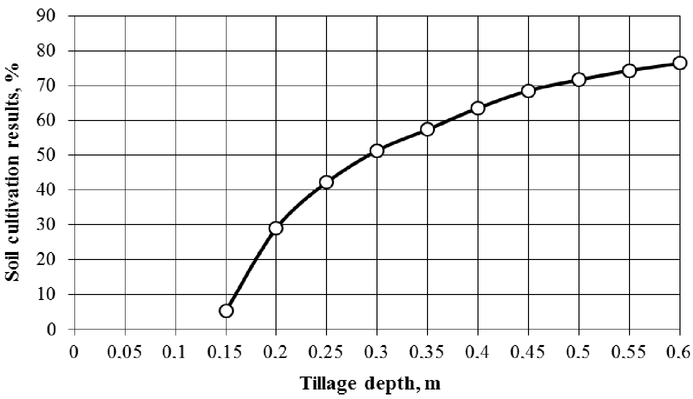


Fig. 2. **Soil cultivation implement working depth influence on soil cultivation results** (n=6, b=0.1 m, λ=90º, h=0.12 m, L=0.6 m)

The cultivated soil part also depends on the deep soil cultivation implement tines width, point height. Increasing the tine width a bigger part of the soil is cultivated, too. Increasing the tine point height- the soil layers are lifted higher, better soil layer movement is reached and the soil cracks faster.

Materials and methods

The research in the influence of deep soil cultivation implements on the soil characteristics was performed in three regions: Vilkaviškio, Pakruojo and Klaipėdos. In Vilkaviškio and Pakruojo areas the soil was light clay. In Klaipėdos region – heavy clay loam. The research was done during 2009 and 2010 in spring time after the soil cultivation process. For the research the "Agrisem" company deep soil loosening implement "Combiplow" with 6 tines, the tine distance 0.5 m, was used. The working depth was approx. 0.35-0.40 m. Under the experimental studies the soil structure and durability, soil humidity, density and hardness were determined. To test the soil structure and durability 5 examples where taken in different places on the soil layer depth 0-0.25. The analysis was done by the N. Savinovo method under dray and moisture soil sieve way.

The soil humidity and density were determined by the cylinder method. The cylinder capacity – 200 cm^3. The samples where taken by the Nekrasovo auger from 0-0.1 m depth soil layer no less than in 10 trail places. The samples were drayed in 105 ºC temperature till consistent bulk. According to the humidity and dray mass differences the humidity and calculated density were determined. The soil density is natural light dry soil mass per unit volume.

The soil hardness was determined by an electronic hardness measuring unit (penetrologger "Eijkelkamp"). Examination of soil hardness was done in 5 measurements in 1.0 m^2 soil plot. Pressing the conical hardness measuring unit point into the soil the soil hardness till 0.8 m depth was measured. Connecting the soil humidity measuring unit at the same time the soil moisture on the top soil layer in 0-0.05 m depth was determined. The measurement data were saved in the measuring unit memory and were transferred to the attached computer. The research was done 5 times. The received data were processed by mathematical statistical methods using "Anova"data proceeding program.

Results and discussion

According to the soil structure test results it was determined, that the soil structure was good enough in all research areas (Table 1). On the soil top layer (1.8-3.2 %) very fine soil aggregates were found, under this reason compacted soil formation on the soil top surface is rather minimal. As the result of the deep soil cultivation process the erosion risk is quite low. If the optimal soil structure stability is reached, then the soil aggregates influenced by water, do not crumble 50 % and more. The experimental studies have shown that under deep soil cultivation rather high resistant soil structure to water influence is reached. In all research areas it was higher then 50 %. That means that the deep soil cultivation process allows saving high soil structure stability to water influence. Therefore, there is less probability that soil will be affected by water erosion. Soil will stand better on higher loads.

Table 1

Soil characteristics influenced by deep soil cultivation process in different Lithuania areas

Research area	**Soil structure %**			**Soil durability %**	**Humidity**		**Density 0-0.1 $mg \cdot m^{-3}$**
	mega > 10 mm	makro 1-10 mm	mikro 0-1 mm		0-0.05 %	0-0.1 %	
Vilkaviškis	33.4±2.4	64.1±5.3	2.5±0.2	54.3±3.3	25.5±0.2	17.4±0.1	1.47±0.2
Pakruojis	43.6±3.1	53.2±2.8	3.2±0.4	65.8±3.8	30.0±0.2	20.3±0.1	1.18±0.1
Klaipėda	52.3±3.4	45.9±3.2	1.8±0.3	51.4±2.9	31.0±0.3	22.5±0.2	1.38±0.1

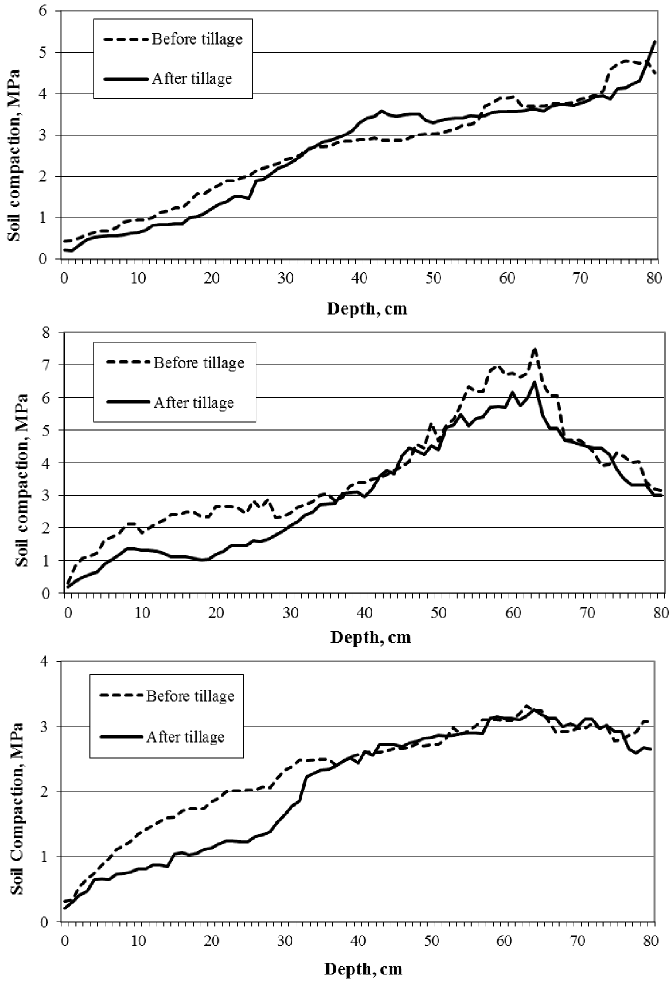
Measuring the soil density it was determined that in all research areas the soil density has met the requirements from 1.0 till 1.8 $mg \cdot m^{-3}$. In Pakruojo region a little bit lower soil density was stated comparing to the other regions. It could be explained by the main reason that in these areas for few years the deep soil cultivation technology was used and plants were grown in non tillage soil conditions. As the soil density is related to the soil humidity, it is observed that in Pakruojo region the soil humidity is rather high (approx. 30 %). The soil structure durability in this area was determined also the highest.

Estimating the soil humidity on the top layer it was found that in all research areas the humidity was adequate, in Pakruojo and Klaipėdos regions even too high. However, in the soil, influenced by deep soil cultivation tines, humidity is distributed till deeper soil layers. The conditions for seed germination and growth were fine.

The soil hardness parameters are measured before the soil cultivation process and immediately after it. After the hardness test in Vilkaviškio region light clay loam soil (Fig. 3 a), it was determined that deep soil cultivation has reduced the soil hardness on the top soil layer. At 0.35-0.4 m depth the soil layer hardness becomes equal to the former conditions.

Measuring the soil hardness in heavy clay loam in Pakruojo region, it was determined that the deep soil cultivation process has reduced the soil hardness till 0.3-0.35 m different comparing to Vilkaviškio region results (Fig. 3 b). In the soil depth from 0.1 till 0.25 m the soil hardness has reduced more than two times. In deeper then 0.4 m soil layers the soil hardness has stayed similar comparing to results before soil cultivation.

Similar results were obtained in light clay loam soil, Klaipėdos region (Fig. 3 c). After the soil cultivation process including deep soil loosening tines on the soil layer till 0.35-04 m depth, the reached soil hardness was much lower then before this soil cultivation process.



a) b) c)

Fig. 3. **Soil compaction before and after tillage:**
a – District Vilkaviškis; b – District Pakruojis; c – District Klaipeda

The experimental trails under Lithuania conditions showed a similar tendency as in other authors' research in other soil conditions. Deep loosening soil cultivation does not damage the soil structure; it improves the soil moisture, avoids soil layer compression, reduces soil hardness on the top layers and solid soil layer after the plough, and protects the soil from the influence of wind and water erosion.

Conclusions

1. Deep loosening soil cultivation depends on the implement design and technological parameters: number of tines, their width and height, distance between the tines, working depth and other parameters.
2. The cultivated soil part will be 60 % higher if the distance between the tines will be less than 0.6 m, the tine width will be equal or even bigger than 0.1 m, the working depth higher than 0.4 m.
3. Loosening the soil with a deep tine cultivator the soil layers are mot mixed, better soil airing is reached, and the soil structure durability for water (>50 %) is saved. The soil density (1.18-1.47 $mg\cdot m^{-3}$) in all research places corresponds to agro-technical requirements (1.1-1.8 $mg\cdot m^{-3}$).
4. With deep loosening soil cultivation implements it is possible to reduce the soil hardness, to remove soil layers compression till the tines working depth. In deeper soil layers the tines influence on soil compaction was not determined.

References

1. Arvidsson J. Effects of cultivation depth in reduced tillage on soil physical properties, crop yield and plant pathogens. European Journal of Agronomy, 9, 1998, pp. 79-85.
2. Heuer H., Tomanova O., Koch H.J., Mäländer B. Subsoil properties and cereal growth as affected by a single pass of heavy machinery and two tillage systems on a Luvisol. Journal of Plant Nutrition and Soil Science, 171, 2008, pp. 580-590.
3. Batey T. Soil compaction and soil management – a review. Soil Use and Management, 25, 2009, pp. 335-345.
4. Hobbs P.R., Sayre K., Gupta R. The role of conservation agriculture in sustainable agriculture. Philosophical Transactions of the Royal Society B, 363, 2008, pp. 543-555.
5. Jabro J.D., Stekens W.B., Iversen W.M., Evans R.G. Tillage depth effects on soil physical properties, sugarbeet yield, and sugarbeet quality. Communications in Soil Science and Plant Anglysis, 41, 2010, pp. 908–916.
6. Romaneckas K., Pilipavičius V., Šarauskis E. Impact of seedbed density on sugar beet (Beta vulgaris L.) seed germination, yield and quality of roots. Journal of Food, Agriculture & Environment, 8 (2), 2010, pp. 599-601.
7. Romaneckas K., Šarauskis E., Pilipavičius V., Adamavičienė A., Avižienytė D. Impact of primary soil tillage intensity on maize (Zea mays L.) seedbed formation and productivity parameters. Journal of Food, Agriculture & Environment. Vol. 8 (3&4), 2010, pp. 679-682.
8. Šarauskis E, Romaneckas K., Buragienė S. Impact of conventional and sustainable soil tillage and sowing technologies on physical-mechanical soil properties. Environmental Research, Engineering and Management. ISSN1392-1649. 2009, Nr.3 (49), pp. 36-43.
9. Šarauskis E., Vaiciukevicius E., Romaneckas K., Sakalauskas A., Baranauskaite R. Economic and energetic evaluation of sustainable tillage and cereal sowing technologies in Lithuania. Rural Development 2009, Proceedings, 4 (1), 2009, pp. 280-285.
10. Šarauskis E., Godlinski F., Sakalauskas A., Schlegel M., Kanswohl N., Romaneckas K., Jasinskas A., Pilipavičius V. Effects of soil tillage and sowing systems on sugar beet production under the climatic conditions of Lithuania. Landbauforschung, 2 (60), 2010, pp. 101-110.
11. Dospechov B. A., Vasiljev I. P., Tulikov A. M. Practicum of agriculture. 1997, 367 p. (In Russian)
12. Širov I. N., Parchomenko I. N., Parchomenko G. G. Substantiation of the parameters of new generation soil tillage combined unit for deep soil subsurface layering. 1983, 11 p. (In Russian). [online] [08.03.2011]. Available at: http://www.kgau.ru/img/konferenc/49.doc.
13. Vagin A. T. On the question of justification of the parameters of the working bodies for primary tillage. Proceedings UNIIMESH of the non-mould zone of the USSR. T.16, 1967, pp. 57-98. (In Russian)
14. Dzambov V. Research on the operation of the reduced deep machines. Agricultural machinery, 4, 1979. pp. 3-9. (In Bulgarian)