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INFLUENCE OF AUTO-EJECTED BLADES WHEELS ON SOIL COMPACTION

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Introduction. Testing of the new construction types of agricultural tractor still increases because these machines directly influence on results of agricultural production [2–5]. The first possibility how to reduce the negative effects of the soil compaction by tractor passing is to increase its ground speed by reducing the slippage of the driving wheels, thus it reduces the time of impact of the wheel to land. The knowledge of soil compaction has increased substantially in the past two decades, especially after results of an international project of more than 20 soil compaction experiments in North America and Europe which were published. Based on this work, researchers had discovered that [1]: (1) compaction in the topsoil is related only to the ground contact pressure, (2) compaction in the upper part of the subsoil is related to both ground contact pressure and axle loading, and (3) compaction in the lower subsoil is related only to axle loading, as seen in Fig 1.

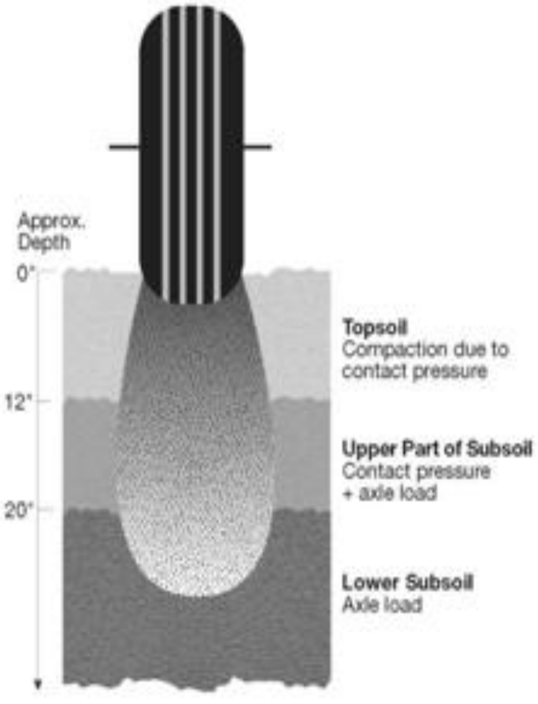

Fig. 1. Soil compaction caused by ground contact pressure and axle loading [1].

Consequential to international soil compaction project, it shows that 10…12 tons compaction due to contact pressure is reduced approximately 15% in the first year and decreasing about 3…5% in the next 10 years after compaction. Researchers suggested that 10% of the yield loss in the first year was due to compaction in the topsoil and upper part of the subsoil. Fertility of the topsoil and upper subsoil due to compaction was decreased in the next 5…10 years, as seen in Fig. 2. These losses of soil fertility were caused due to deep subsoil compaction, which did not disappear during the period in which these measurements were taken (12 years for the longest experiments). The conclusion of this research is that lower subsoil compaction is permanent and should not therefore be avoided by all means, whereas the topsoil compaction and upper subsoil compaction are temporary and should be limited as much as possible.

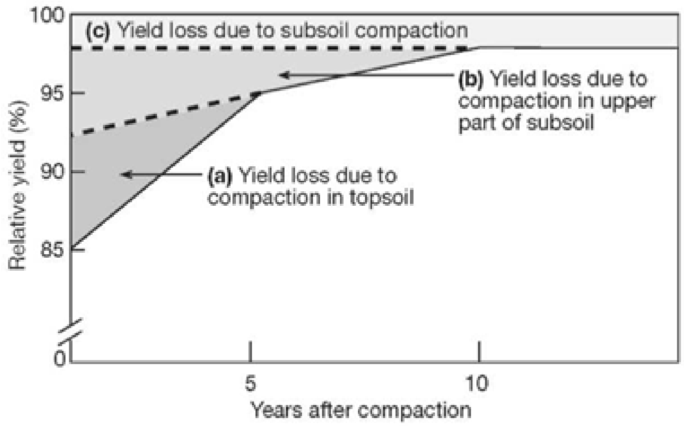

Fig. 2 Compaction of the topsoil (a), upper part of the subsoil (b) and deep subsoil (c).

Material and methods. Measurements were carried out on the land area of Botanical Garden in Slovak University of Agriculture. Auto-ejected blade wheels were mounted on tractor`s type MINI 070. Tractor was loaded by constant tensile force on the 1st gear by braking car. The car weighing 1100 kg was used as constant loading and it was breaking by parking brake in the same position for all measurements. Individual measurements of soil compaction were made by device type Penetrologgerom Eijkelkamp. It was realized three times along the same track and in both versions of the driving wheels. Penetrometer resistance measurements were performed to the depth of 40 cm. Results of penetrometer resistance were recorded every 1 cm of measured depth. Individual measurements were repeated three times, with regard to the same measurement values [7] and then averaged for each passage.

Auto-ejected blades wheels. Auto-ejected blades wheels have been developed at the Department of Transport and Handling for the rear driving wheels of tractor type MINI 070. Automatically ejected blades wheels were designed according to the works published [9, 5]. Advantage of these wheels is that they do not have to be removed from the tractor when passing on the road and also they are automatically ejected if the tractor`s driving wheels will be slipping. Repeated taking down of driving blades occurs by reverse movement of the tractor. The tractor does not have to be equipped with additional loading weights, because they are replaced by auto-ejected blades wheels. Auto-ejected wheels are mounted to the wheel disc and it consists of the parts as follows Fig. 3.

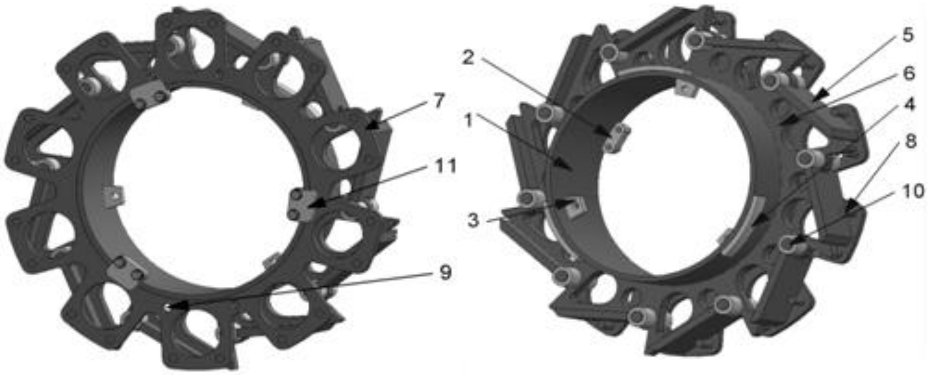

Fig. 3. Auto-ejected blades wheels: 1 – bearing tube; 2 – locking handle; 3 – bracket fastening the device to the disc of wheel; 4 – spacer plates; 5 – blades; 6 – carrier wheel; 7 – controlling disc of blades; 8 – guide pin, 9 – locking hole; 10 – pin of vanes; 11 – buffer plate.

Bearing tube (1) is a basic part of the entire unit. By using of bearing tube, remaining equipments are attached to each other. On the bearing tube, there are welded three parts of locking handles (2) and three handles (3) by which all the equipment is connected to the tractor wheel. Furthermore, there is on the bearing tube strongly welded a carrier wheel (6) through which ten pins are pivotally mounted to blades (5). On the bearing tube, there are also welded spacer plates (4) which use to set the device to the centre of the driving disc. Behind the carrier wheel (6), there is placed freely rotating controlling disc of blades (7) on the bearing tube. Into rotor of controlling disc of blades, there are fixed twenty guide pins (8) around, by which the blades are ejected and inserted. On the other side of controlling disc of blades, there are four locking holes (9) which use to fix the position of the blades in inserted position. Three buffer plates (11), which are mounted by six screws on the locking handles (2), fix the controlling disc of blades on the bearing tube.

Loading of the tractor during measurements. Tensil force of the tractor Mini 070 was recorded using a force transducer which was connected between the constant breaking car braked by hand brake and measured tractor MINI 070 through the chain. Measurements of penetrometer resistance were carried out on a track of tractor in the same place with the area of 0.5 m^2. The plot was set out in two sections in 5 m distance apart[6]. One section was set on the passage of the tractor only with the tires and the other with the passage with auto-ejected blade wheels. Thus were obtained comparable conditions to the initial. Connection of tractor MINI 070 to the car was done by chains. Use of breaking car was necessary because of the higher wheel track of car thus minimize affection of the results of soil compaction by tractor wheels[8].

Table 1.

Technical parameters of tractor MINI 070

Year of construction	1989	
Kerb weight	310 kg	
Driving speed at rated engine speed 3600 rpm	1^{st} gear	1.53 km/h
	2^{nd} gear	2.72 km/h
	3^{rd} gear	4.96 km/h

	4^{th} gear	14.40 km/h
Clutch	Dry, single plate with direct mechanical shutdown.	
Engine	Gasoline four-stroke air-cooled Briggs & Stratton.	
	Number of cylinders	1
	Displacement	400 ccm
	Max. performance/rotation speed	8 kW/3600 rpm
Tires	Barum TS 790 – 6.15/155-14-4PR	

a *b*

Fig. 5. Passages of tractor: *a* – with tires; *b* – with auto-ejected blade wheels.

Penetrometer resistance and bulk density of soil. Penetrometer resistance was measured by using Penetrologgera Eijkelkamp, seen in Fig. 6. This device records penetrometer resistance of each cm up to maximum depth of 80 cm. To measure penetrometer resistance, it was chosen the method of three repetitions of the same measurement up to the depth of 40 cm. Averaged values are reported in Table 2. The average penetrometer resistance of individual passages were calculated according to Eq. (1):

$$P_p = \frac{\sum_{i=1}^{n} Qi}{N}, \quad \text{MPa}. \qquad (1)$$

If Qi – i – the value of penetrometer resistance at specific depth, MPa; N – number of measured depths.

Unreduced bulk density of soil was determined according to standard STN 72

Fig. 6. Penetrologger Eijkelkamp.

1010 [11] – Method of Kopecky rollers. The values on Table 2 were calculated according to equation (2):

$$\rho_w = \frac{m_1 - m_2}{V_s}, \ \ \text{g} \cdot \text{cm}^{-3}. \qquad (2)$$

If m_1 – weight of wet soil with Kopecky roller, g; m_2 – weight of empty Kopecky roller, g; V_s – capacity of Kopecky roller, cm^3.

Soil moisture was determined according to standard STN 46 5321 [10] after drying of Kopecky roller with soil at 105°C according to equation (3):

$$w = \frac{m_1 - m_3}{m_3 - m_2} \cdot 100, \ \%. \qquad (3)$$

If m_3 – weight of dry soil with Kopecky roller, g.

The land, on which the measurements were made, is situated in the area of [7] Botanical Garden in Nitra approximately 2000 m^2. Measurements were carried out in October on mould soil type with the average soil moisture w = 10.2%, calculated according to equation (3). The average bulk density of soil ρ_w = 1.51 g.cm^{-3} was calculated according to equation (2).

Results and discussion. Results of penetrometer resistance to the depth of 40 cm were obtained at tensile force 2200 N. This is equivalent to half value of maximum tensile force of tractor without using of auto-ejected blade wheels – as seen on Table 2. Tensile force was measured by analogue tensile force meter. Constant tensile force was provided by breaking car. The handbrake of this car has always been at the same position. At the beginning of measurement, it was set the braking effect to corresponding position. Penetrometer`s measurements were performed by the same person. This minimized effect of differences in speed of pushing cone penetrometer into the soil.

Table 2.

Values of penetrometer resistance and bulk density of soil

Tires	**PENETROMETER RESISTANCE, MPa**														
	Depth, cm	Natural state	1. crossing		2. crossing		3. crossing		**Auto-eject blades wheels**	Natural state	1. crossing		2. crossing		3. crossing	
			Track A	Track B	Track A	Track B	Track A	Track B			Track A	Track B	Track A	Track B	Track A	Track B
	1	0.15	0.25	0.20	0.30	0.24	0.30	0.29		0.15	0.23	0.20	0.29	0.33	0.39	0.40
	2	0.22	0.30	0.31	0.40	0.38	0.32	0.30		0.33	0.27	0.24	0.32	0.34	0.38	0.43
	3	0.21	0.50	0.38	0.42	0.44	0.35	0.22		0.35	0.34	0.30	0.34	0.40	0.45	0.56
	4	0.19	0.39	0.45	0.55	0.38	0.44	0.44		0.43	0.37	0.43	0.37	0.43	0.47	0.67
	5	0.28	0.54	0.55	0.50	0.42	0.48	0.37		0.34	0.46	0.44	0.54	0.45	0.76	0.69
	6	0.40	0.70	0.70	0.95	0.45	0.85	0.55		0.56	0.47	0.45	0.56	0.65	0.70	0.89
	7	0.34	0.56	1.09	1.23	0.68	0.88	0.50		0.45	0.67	0.50	0.46	0.76	0.86	1.13

	8	0.30	0.67	1.35	1.13	1.02	0.98	0.61		0.46	0.56	0.67	0.50	0.78	0.58	1.40
	9	0.54	0.59	1.50	1.16	1.38	1.32	0.93		0.48	0.68	0.78	0.67	0.76	0.68	1.36
	10	0.60	0.75	0.90	1.15	1.33	1.59	1.20		0.67	0.78	0.75	0.78	0.88	0.69	1.40
	11	0.67	0.76	0.85	1.16	1.45	1.23	1.50		0.89	0.96	0.78	0.67	0.97	0.80	1.45
	12	0.70	0.90	0.63	1.14	1.23	1.32	1.59		0.68	0.87	0.68	0.76	1.04	0.98	1.56
	13	0.84	0.85	0.42	1.20	1.30	1.30	1.34		0.65	1.40	1.20	0.90	1.12	1.07	1.76
	14	0.82	1.10	1.20	1.23	1.34	1.32	1.31		0.89	1.24	1.00	1.18	1.19	1.20	1.65
	15	0.90	0.90	1.14	1.18	1.27	1.43	1.80		1.30	1.46	1.12	1.34	1.45	1.33	1.70
	16	0.94	1.05	1.19	1.24	1.33	1.39	1.58		1.26	1.47	1.24	1.27	1.56	1.45	1.90
	17	1.05	1.10	1.24	1.30	1.35	1.40	1.30		1.43	1.58	1.22	1.50	1.43	1.43	1.89
	18	1.00	1.15	1.24	1.37	1.35	1.42	1.37		1.65	1.37	1.23	1.56	1.35	1.45	1.54
	19	1.30	1.20	1.27	1.22	1.30	1.56	1.60		1.55	1.67	1.34	1.57	1.56	1.59	1.67
	20	1.33	1.25	1.31	1.34	1.39	1.36	1.90		1.43	1.87	1.45	1.46	1.67	1.49	2.00
	21	1.43	1.29	1.34	1.50	1.45	1.45	1.80		1.54	1.68	1.46	1.54	1.56	1.90	2.14
	22	1.20	1.34	1.35	1.43	1.48	1.39	1.69		1.57	1.87	1.50	1.45	1.60	2.15	2.46
	23	1.43	1.39	1.35	1.51	1.55	1.46	1.98		1.67	1.68	1.56	1.60	1.76	1.70	2.30
	24	1.40	1.44	1.38	1.56	1.48	1.47	1.56		1.68	1.76	1.57	1.80	1.80	1.90	2.37

Continuation of Table 2

Tires	25	1.50	1.49	1.42	1.60	1.58	1.68	1.67	**Auto-eject blades wheels**	1.37	1.87	1.70	1.78	1.98	2.15	2.45
	26	1.28	1.45	1.42	1.60	1.43	1.70	1.65		1.87	1.79	1.67	1.90	2.00	2.23	2.30
	27	1.36	1.59	1.54	1.57	1.56	1.59	1.78		1.65	1.99	1.87	1.78	2.12	2.34	2.17
	28	1.34	1.64	1.48	1.64	1.65	1.99	2.14		1.76	1.78	1.92	1.67	1.89	2.43	2.40
	29	1.48	1.85	1.57	1.68	1.67	1.98	2.10		1.87	1.69	1.90	1.98	1.97	2.12	2.43
	30	1.36	1.74	1.65	1.80	1.76	2.30	2.10		1.65	1.89	1.87	1.78	2.13	2.70	2.54
	31	1.40	1.79	1.67	1.75	1.78	2.12	2.02		1.89	2.11	1.99	1.89	2.17	2.76	2.65
	32	1.54	1.80	1.70	1.72	1.90	2.35	2.40		1.98	1.97	2.12	2.23	2.65	2.54	2.76
	33	1.69	1.88	1.72	1.79	1.76	2.38	2.49		2.30	2.14	2.32	2.34	2.68	2.65	2.87
	34	1.89	1.75	1.80	1.86	1.89	2.40	2.50		2.24	2.36	2.21	2.43	2.43	2.60	2.76
	35	1.98	1.98	1.80	1.97	1.98	2.30	2.56		2.60	2.22	2.33	2.34	2.54	2.80	2.70
	36	1.80	2.03	1.86	1.99	2.40	2.39	2.40		2.32	2.26	2.43	2.22	2.65	2.78	2.75
	37	2.15	2.01	1.85	2.14	2.14	2.27	2.29		2.45	2.43	2.35	2.50	2.54	2.83	2.68
	38	2.07	2.13	1.90	2.25	2.35	2.44	2.45		2.65	2.54	2.70	2.54	2.65	2.34	2.78
	39	2.35	2.31	2.00	2.35	2.40	2.47	2.56		2.76	2.76	2.85	2.60	2.58	2.43	2.79
	40	2.30	2.32	2.40	2.49	2.50	2.59	2.56		2.70	2.57	2.60	2.67	2.80	2.49	3.00
Average resist in depth 40 cm		1.17	1.27	1.28	1.41	1.42	1.55	1.59		1.41	1.50	1.42	1.45	1.59	1.66	1.93
Bulk density,g/cm^3		1.50	1.57		1.59		1.63			1.52	1.55		1.58		1.60	
Average resist in depth 20 cm		0.66	0.77	0.90	1.01	1.00	1.06	1.04		0.80	0.94	0.80	0.85	0.96	0.94	1.30
Soil moisture,%		10.2														

Although in Figure 7, there is not observed the lower soil compaction with auto-ejected blades wheels, it has to be taken into account the higher value of penetrometer resistance in natural state. The higher value was caused by higher bulk density of the soil in the surface layer of soil in the natural state, as shown in Figure 7.

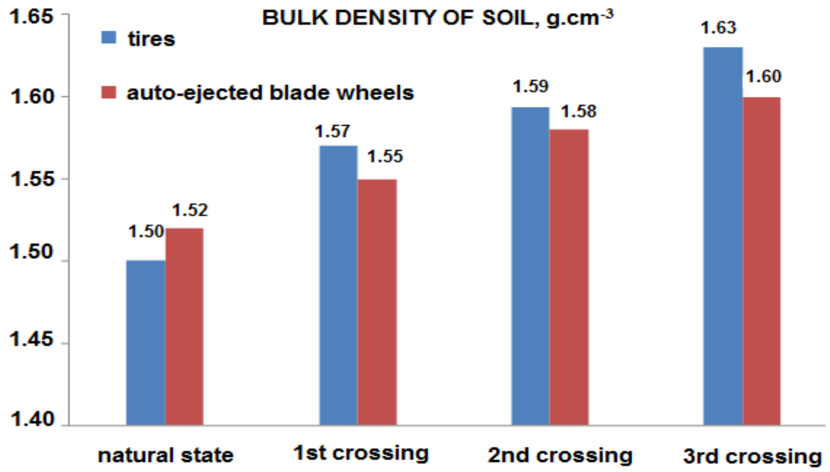

Fig. 7. Bulk density of soil after each passage.

Results in Figures 9 and 10 clearly show that even at relatively low soil moisture (10.2%), less slippage of driving wheels to reduce soil penetrometer resistance in the track left and right wheel tractor occurs, due to the rapid movement of the tractor. However, if consider the values of penetrometer resistance for individual passages tractor only to the depth of 20 cm and not 40 cm, the results of penetrometer resistance in Figure 8 are much favourable for auto-ejected blade wheels.

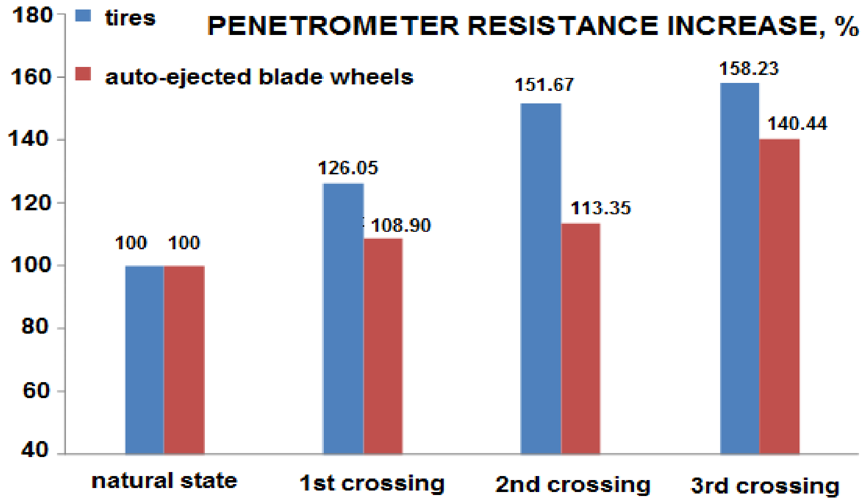

Fig. 8. Penetrometer resistance increase in surface layer to the depth of 20 cm after each passage.

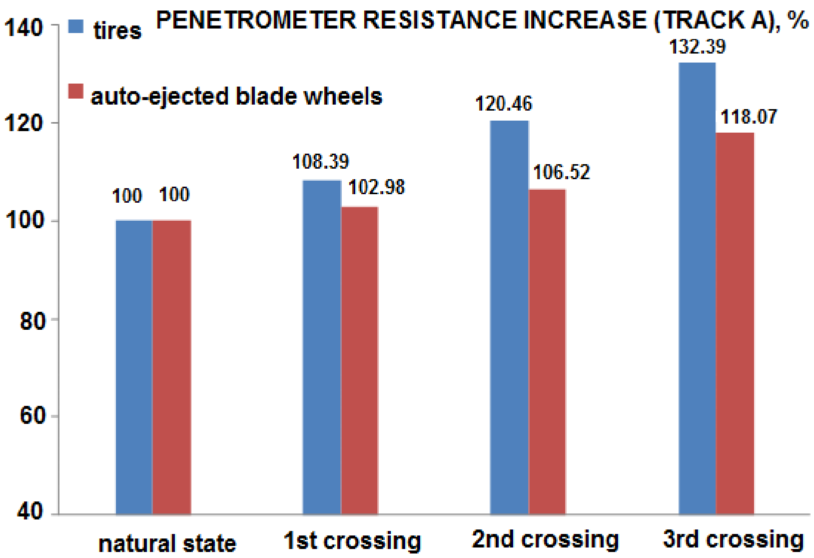

Fig. 9. Penetrometer resistance increase under the left track (A) of the tractor after each passage.

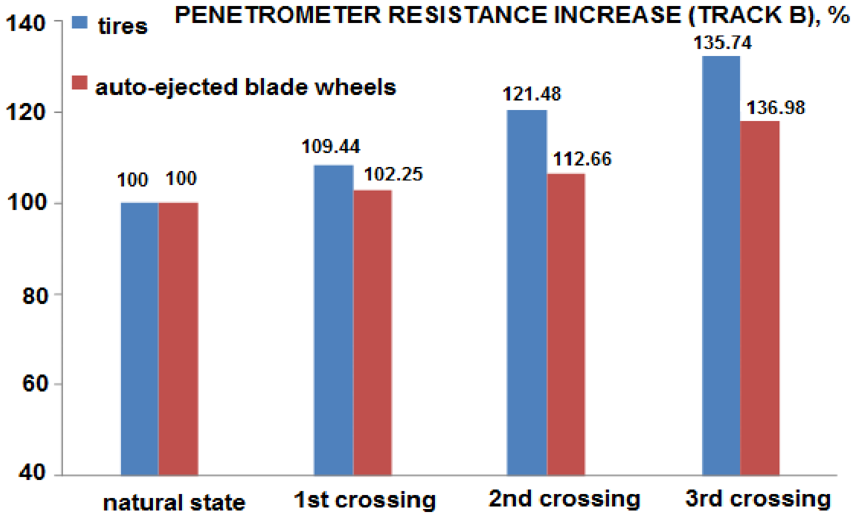

Fig. 10. Penetrometer resistance increase under the right track (B) of the tractor after each passage.

Conclusion. Measurements were carried out in October when the average soil moisture reached 10.2% on mouldy soil type, with an average density about 1.51 g·cm^{-3}. The soil was after harvesting of wheat as stubble land. Measurements of tensile force were realized by analogue tensile force meter. Tractor Mini 070 was braked by the car with handbrake at the same position for all measurements. Auto-ejected blade wheels can also be used for heavier tractors. Wheel paddles as they are moving in one direction and are self-cleaning, they can be folded easily by riding backwards. After work they must be thoroughly cleaned, preferably by water pressure, because the drying clay prevents tipping of blades. Automatically retractable paddle wheels can be made for different types of wheels tractors. Results clearly declare reduction of soil compaction due to increased movement speed and smaller slipping of tractor by generating of constant tensile force.

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Р. Абрахам, Р. Майдан, М. Мойзіс, Ф. Варга, Д. Ухрінова, Т. Щур. Вплив автоматично-викинутих лопатей колеса на ущільнення ґрунту.

Стаття спрямована на можливості зниження негативного ущільнення грунту трактором. Також, було приведено порівняння ущільнення грунту. Трактор з авто-викидаючими лопатями коліс досяг в середньому на 8% менше ущільнення грунту по всьому профілю. Порівнюючи з шинами, він досяг близько 24% зниження ущільнення грунту на глибину 20 сантиметрів.

Ключові слова: шини, опір грунту, вологість грунту, межа міцності при розтягуванні.

R. Abrahám, R. Majdan, M. Mojžiš, F. Varga, D. Uhrinová, T. Shchur. Influence of auto-ejected blades wheels on soil compaction.

The paper is focused on the possibility of reducing of negative soil compaction by agricultural tractor. It was compared the soil compaction by passing tractor evolving a constant tensile force on the tires with the auto-ejected blades wheels. The tractor with auto-ejected blades wheels reached an average of 8% below the value of the soil compaction over the whole profile. It reached about 24% lower the value of the soil compaction into the depth of 20 cm compared to tires.

Keywords: tires, resistance of the soil, soil moisture, tensile strength of tractor.

Р. Абрахам, Р. Майдан, М. Мойзис, Ф. Варга, Д. Угринова, Т. Щур. Влияние авто-выброшених лопатей колес на уплотнение почвы.

Статья направлена на возможности снижения негативного уплотнения почвы трактором. Было сравнено уплотнение почвы. Трактор с авто-выбрасывающимися лопатями колес снизил в среднем на 8% уплотнения почвы по всему профилю.Если сравнивать с шинами, то он достиг около 24% снижения уплотнения почвы на глубину 20 сантиметров.

Ключевые слова: шины, сопротивление почвы, влажность почвы, прочность на растяжение.