EVOLUTION OF SOIL COMPACTION IN A HIGH DENSITY APPLE ORCHARD UNDER THE INFLUENCE OF SOIL EROSION CONTROL TREATMENTS AND TECHNOLOGICAL TRAFFIC

EVOLUTIA COMPACTĂRII SOLULUI ÎNTR-O PLANTAȚIE INTENSIVĂ DE MĂR SUB INFLUENȚA SISTEMULUI DE AMENAJARE ANTIEROZIONALĂ ŞI A TRAFICULUI TEHNOLOGIC

IANCU M., TEBEICA A.
Research Institute for Fruit Growing Pitesti, Romania

Abstract. *The investigations were carried out in an orchard established in 1984 on a hillside with a 6-12 % slope. The following factors were experimented: A Factor - the performing year of determinations, with 2 graduations; B Factor - the soil, with 3 graduations and C Factor - erosion control system with 2 graduations. On average on the three soil types and two soil erosion control systems, in the forth year versus twentieth year after tree planting the used compacted soil indices showed a reducing of soil compaction on the 0-20 cm soil depth. On average on two time periods and three soil types, inside of contour line soil erosion control system versus the alley cropping system (ACS) on the four analyzed soil depths, the compaction indices 1 (CI_1) was significantly higher by 9- 12,7% and the compaction indices 3 (CI_3) by 112-174%.*

Key words: soil erosion control treatments: apple orchard

Rezumat. *Cercetările s-au efectuat într-o plantație înființată în anul 1984 situată pe un versant cu o pantă de 6-12%. S-au experimentat factorii: Factorul A - Perioada de timp de la plantarea pomilor la care s-au efectuat determinările, cu 2 graduări. Factorul B - Solul, cu 3 graduări şi Factorul C - Sistemul de amenajare antierozională cu 2 graduări. În medie pe cele 3 tipuri de sol şi cele 2 sisteme de amenajare antierozională a terenului, în perioada de timp situată la 4 ani față de cea situată la 20 de ani de la plantarea pomilor, indicii intensității de compactare utilizați au arătat o reducere a procesului de compactare în special pe stratul de sol de 0-20 cm. În medie pe cele 2 perioade de timp şi în cadrul sistemului de amenajare antierozională CL față de sistemul STTL, pe cele 4 adâncimi de sol analizate, IC_1 a fost semnificativ mai ridicat cu 9-12,7%, iar IC_3 cu 112-174%.*

Cuvinte cheie: sisteme de amenajare antierozională; livadă de măr

INTRODUCTION

In high density apple orchards located on sloping lands, soil erosion control systems have a great importance in defining the degree of soil compaction. To reduce the intensity of this process, Isac and Iancu (1982) introduced a new tree cropping system by planting the trees in bands separated by technological traffic lanes (the alley cropping system). The study of soil physical properties values within this new tree cropping system has shown its superiority versus the classical tree cropping system on contour line (Iancu, 2001, Iancu et al., 1997). The purpose of this paper was to highlight the differentiation of technological traffic effects on the degree of soil

compaction in two - soil erosion control systems - after a relatively long period of time since trees planting (20 years). In this sense, within the Research Institute for Fruit Growing Pitesti - Maracineni some investigations were conducted.

MATERIAL AND METHOD

The researches were carried out in a high density apple orchard established in 1984 on a hillside with a length of 200 m and a slope of 6-12% in the studied area. It was organized the following experimental scheme: A factor: period (years) after trees planting, with graduations: a1 = 4 (1978), a2 = 20 (2004). Factor B: soil type, with the following graduations: b_1 = eutricombosol with colluvic character (ECC), b2 = slightly eroded eutricombosol (SEE) b3 = typical eutricombosol (TE). Factor C: soil erosion control system, with graduations: c_1 = cropping system with tree rows oriented along the general direction of the contour lines (CL), c_2 = alley cropping system (ACS). In the CL system, the distance between trees rows was 3.6 m and along the row was 1.5 m. For this tree cropping system, technological traffic was done on each interval between 2 tree rows. Within the alley cropping system (ACS) 10.5 m wide tree bands were performed in which the planted trees were separated by 3,6 m alleys designed for the technological traffic. Within tree bands, trees were planted in rows oriented up-down the hill. The rows were 2 m, spaced, while trees were 1.2 m spaced along the row. For both cropping systems the intervals between tree rows were kept sodded. On the tree row direction, along a 0.8 – 1.0 m wide band in case of CL and 0.6 m in case of ACS, the soil was maintained as cultivated through mechanical works in case of CL and only through manual works in case of ACS. Soil samples were taken in 4 replications from zones located on the trees row axis and at mid interval between rows, for both cropping systems. Samples were collected on depths 5-10 cm, 15-20 cm, 35-40 cm, 55-60 cm. It was determined the bulk density (BD), the saturated hydraulic conductivity (Ksat) and resistance to penetration (RP).

RESULTS AND DISCUSSIONS

A. Influence of the period after tree planting and the soil erosion control system on the compaction intensity on three soil types

On average, for experimental factors B and C, in the 4th year after trees planting versus 20th year, compaction index characterized by bulk density (CI_1) was significantly higher by 3.1 to 8.6% in the first two soil depths investigated and significantly reduced by 4.9% in the 55-60 cm depth. In the same conditions, the compaction index characterized by saturated hydraulic conductivity (CI_2) did not significantly differentiate between the two periods after trees planting at any of the four soil depths investigated. Compaction index characterized by resistance to penetration (CI_3), in the 4th year after trees planting, versus 20th year, was significantly higher by 39% only on the first depth studied (5-10 cm). On average, on the experimental factors A and C, on ECC and SEE, versus TE, CI_1 was significantly higher by 5.6 -6.7% only on 35-40 cm depth. In the same conditions, on TE, versus SEE, the CI_2 was significantly higher by 115% in 5-10 cm depth. Instead, on the depth of 35-40 cm, the same index on ECC presented a significantly higher value by 60%, compared to SEE and 70% versus TE. On average, on the same experimental factors A and C, CI_3 did not significantly differentiated on the three soil types on any of the four soil depths studied. On average, on the experimental factors A and B, in

the CL system versus ACS one, in the four soil depths studied, CI_1 was significantly higher by 9-12.7% and CI3 by 112-174%. In the same conditions, the CI_2 significantly differentiated the two soil erosion control systems in the same sense as CI_1 and CI_3, but only on 5-10 cm and 55-60 cm depths (table 1).

Table 1

Evolution of soil compaction intensity in a high density apple orchard under the influence of soil erosion control treatments and technological traffic

Soil depth (cm)	Compaction index (CI)	A factor graduations			B factor graduations				C factor graduations		
		a_1	a_2	LSD 5%	b_1	b_2	b_3	LSD 5%	c_1	c_2	LSD 5%
5-10	1	1.15	1,06	0,05	1,10	1.11	1,11	N.S	1,15	1,06	0,06
	2	1,30	1.42	N S	1,40	0.85	1.82	0 84	0,89	1,91	0,70
	3	2,11	1.52	0,28	2.22	1,63	1.59	N.S	2,61	1,01	0,67
15-20	1	1.05	- 02	0,02	1.03	1.04	1,02	N.S	1.08	0,98	0,04
	2	1,58	2 88	N.S	2,72	1.18	2,78	N.S	2,14	2,32	NS
	3	1,47	1,49	N S	1,73	1,26	1,46	N S	2,10	0,86	0,52
35-40	1	1,00	1,05	N S	1,05	1,04	0,98	0.06	1 08	0,96	0,05
	2	1,02	1.11	N.S	1,44	0,85	0,90	0 39	1.03	1,09	NS
	3	1,20	1,56	N.S	1,56	1,25	1,31	N S	1.87	0,88	0,40
55-60	1	1,01	1.06	0,04	1,04	1.06	1,02	N.S	1,10	0,98	0,05
	2	4,66	2.00	N.S	3,28	2 07	4,63	N S	2,24	4, 42	2,17
	3	1,16	1.72	N S	1,89	1.18	1.25	N S	2.11	0.77	0,80

Compaction index (CI) = ratio of medium compacted zone located in mid-interval between trees rows and weakly compacted zone situated on the tree row axis for**:** CI_1 = bulk density; CI_2 = hydraulic conductivity; CI_3 = resistance to penetration**.** The significance for graduations of experimental factors A, B, C was presented in the text at chapter "Material and Method"; NS = nonsignificant at 5% significance threshold.

B. Influence of the erosion control system on soil compaction intensity during the investigation periods (interaction of experimental factors A, C)

At 4 years from trees planting (a_1), in case of CL system, versus ACS, on the four soil depths investigated, CI1 recorded significantly higher values by 2-13% and at 20 years from trees planting (a_2) by 7-22%. In the same conditions, the CI2 was significantly higher by 40-219% and 97-356% respectively. A significant difference, but only at 5-10 cm depth, in the same sense as in CI3, was also recorded in the case of CI2. In case of the same interaction of experimental factors A, C, it is interesting to follow the compaction index values for each of two soil erosion control systems (CL and ACS) at the two moments of making observations (a_1 and a_2). Thus, for CL system, in situation a_2 versus a_1, CI_1 values have increased by 11-14% within first two depths and decreased by 5-10% for 35-40 and 55-60 cm depths. Instead, for ACS system, in situation a_2 versus a_1, the CI_1 value decreased by 1-6%. A more obvious difference between the two moments of determinations, for each soil erosion control

system was recorded in case of CI3, both in terms of its values and the distribution of these values on the four depths (Table 2).

Table 2

Influence of the erosion control system on the soil compaction during the two to investigation periods

Soil depth (cm)	Compaction index (CI)	*a1*		*a₂*		LSD %	
		c_1	c_2	c_1	c_2	e	f
5-10	1	1,02	1,00	1,17	0,96	0,07	0,05
	2	0 83	1,76	0,79	2,06	1,00	N.S
	3	3,21	1,00	2,01	1.02	0,95	0,40
15-20	1	1,03	0,96	1,14	0.96	0,07	N.S
	2	0,99	2,18	3,30	2,45	N.S	N.S
	3	2,06	0,88	2,14	0,85	0,73	N.S
35-40	1	1,11	0,99	1,06	0,97	0,06	0,03
	2	0,85	1,18	1,21	1,00	N.S	N.S
	3	1,4	1,00	2,34	0,76	0,57	0.65
55-60	1	1,21	1,09	1.10	1,02	0,08	0.07
	2	3,57	5 74	0.90	3,10	N.S	N S
	3	1,39	0,92	2,82	0,62	1,03	1,10

Compaction index CI 1, CI 2, CI 3 the same significance like in table 1; LSD = 5%; e = constant a, c different, f = constant c, a different. The significance of graduations of a_1, a_2, c_1, c_2 was presented in the text at chapter "Material and Method"; NS = nonsignificant at 5% significance threshold

C. Influence of the soil erosion control system (c_1, c_2) on the compaction intensity on three soil types (b_1, b_2, b_3) (interaction of experimental factors B, C)

Over each of the three soils studied, in case of CL planting system, compared with ACS system, the CI_1 value was significantly higher in nearly all the soil depths studied. The differences were more obvious by SEE, followed by TE and on the last place was ECC. Also, for each of the three soils studied, the two soil erosion control systems were differentiated in the same direction but with a greater intensity by CI_3 than that by CI_1. In this case, of all the three soils studied the most obvious differentiation was recorded on TE. Similarly as in the case of CI_1 and CI_3, also CI_2 differentiated clearly much higher degree of compaction in the mid-interval between trees rows versus the zone located on the tree row axis, in the CL system compared with ACS system (table 3).

D. Influence of experimental factors on the nature and intensity of correlations between the three compaction intensity indices (CI_1, CI_2 and CI_3).

The number and intensity of correlations between indicators used to estimate the degree of compaction was essentially similar to a_1 and a_2. These characteristics were also similar in the two soil erosion control systems (CL and ACS). Of the three soil types on which it was worked, the highest number of significant correlations and a higher degree of their intensity was recorded on TE versus the other two soils.

Analyzing the number of significant correlations for each soil erosion control system within the two investigations periods it is found that the highest number was

recorded in the determinations made at 20 years from trees planting in ACS system (interaction of a_2c_2).

Table 3

Influence of soil erosion control system (c_1, c_2) on the process of compaction on three soil types (b_1, b_2, b_3)

Soil depth (cm)	Compaction index (CI)	b1		b2		b3		LSD 5%	
		C1	c2	C1	c2	C1	c2	e	f
5-10	1	1,08	1,00	1,13	0.98	1,07	0,96	0,08	0,06
	2	0,51	2,30	0,45	1,24	1,46	2,19	1,22	NS
	3	3,06	1,37	2,53	0,73	2,25	0,93	1,16	NS
15-20	1	1,04	1,06	1.15	0,93	1,06	0,90	0.08	0,08
	2	3,96	1.48	0,85	1,52	1,62	3,94	2,47	3,00
	3	2,34	1,12	1,82	0,70	2,14	0,78	0,09	NS
35-40	1	1,02	1,04	1,11	0,98	1,13	0,92	0,08	NS
	2	1,57	1,31	0,68	1,02	0,85	0,95	NS	0,55
	3	2 04	1.09	1,60	0,90	1 98	0,65	0,70	NS
55-60	1	1,13	1,06	1,18	1,04	1,15	1,07	0,10	NS
	2	5,11	1,45	0,36	3,79	1,24	8,02	3,75	3,89
	3	3,02	0,76	1.53	0,83	1,78	0.72	1.38	1.47

CI_1, CI_2, CI_3 the same significance like in table 1; The significance for graduations of experimental factors B, C (b_1, b_2, b_3, c_1, c_2) is presented in the text at chapter "Material and Method"; LSD = 5%; e = constant b, c different; f = constant c, b different; NS = nonsignificant at 5% significance threshold

Of the four soil depths, the highest number of significant correlations (52% of the total number of calculated cases) recorded on 15-20 cm, followed by 55-60 cm depth (42%). On the other two depths were recorded an equal number of significant correlations, respectively 8, representing 24% of all calculated cases.

Therefore, in the present paper we used the ratios between the two compaction zone (mid-interval between tree rows face of row axis) referring to the BD, K_{sat} and RP physical properties. We named these ratios as compaction indices. We calculated thus, for each of the three physical properties determined, these compaction indices which we considered as better indicators of the compaction intensity dynamics.

Data presented in table 1 showed that, between the two periods for determining the soil physical condition, was recorded generally an improvement of soil physical condition. Of the three types of soil on which we worked, the greatest compaction was achieved on the ECC and SEE, versus the TE. Within the CL system, compared to ACS one, soil compaction intensity characterized by the three compaction indices, was much higher. Analyzing the dynamic of compaction intensity within each planting system, it was noted that this process was more obviously on the first two soil depths studied in CL system. Even in this system, on the soil depths of 35-40 cm and 55-60 cm, a decrease in compaction intensity it was recorded in time. But this was very evident at all four soil depths analyzed in ACS system.

This decrease of compaction intensity in time could be explained by the positive effect of herbs from bands located between trees rows. The above, looks so, an obvious superiority of ACS planting system over CL for both the intensity of

compaction process and different evolution of this process during relatively long time analyzed period.

Table 4

Influence of experimental factors on the nature and intensity of correlations between the 3 indices of soil compaction process (CI1, CI2 and CI3)

Graduations of experimental factors	Soil depth - (cm)											
	5-10			15-20			35-40			55-60		
	Calculated correlations											
	1	2	3	1	2	3	1	2	3	1	2	3
a_1	0.719 ***	0,431 *	0,483 *	0,688 ***	0.603 **	NS	NS	NS	NS	NS	0,594 **	NS
a_2	NS	NS	NS	0,47*	NS	0,753 ***	NS	0,71 ***	NS	0,624 **	0,779 ***	0,404*
b_1	NS	NS	NS	0,515 *	NS	0,934 ***	NS	0.684 **	NS	0,624 **	0,905 ***	NS
b_2	NS	0,624 **	NS	NS	NS	NS	0.517 *	NS	NS	0,613 *	0,608 *	NS
b_3	NS	NS	0,595 *	0,698 **	0,603 *	0,581 *	NS	0,636 **	0,689 **	NS	0,759 ***	NS
c_1	NS	NS	NS	0,496 *	NS	0,881 ***	NS	NS	NS	NS	0,478 *	NS
c_2	0,452*	NS	NS	0,631 ***	NS	NS	NS	NS	NS	NS	0,748 *	NS

Calculated correlations: 1 = between compaction index related to bulk density (CI_1) and compaction index related to Ksat (CI_2) (negative character correlations); 2 = between CI_1 and compaction index related to resistance penetration (CI3); 3 = between CI_2 and CI_3 (negative character correlations); NS =nonsignificant at 5% significance threshold

The significance for graduations of experimental factors is presented in the text at chapter "Material and Method";

CONCLUSIONS

On average, for the three soil types and the two soil erosion control systems, in period of 20 years versus the 4 year one after trees planting, compaction intensity indices used showed a reduction in the compaction process, especially on the 0-20 cm soil layer. On average, for the two time periods and in the CL soil erosion control system versus ACS system, on the four soil depths analyzed, CI_1 was significantly higher by 9-12.7% and CI_2 by 112-174%. Under same conditions, CI_3 has differentiated the two soil erosion control systems in the same sense but only on 5-10 and 55-60 cm depths. Of the three soils studied, the lowest intensity of soil compaction was recorded on TE versus ECC and SEE.

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