THE EFFECTS OF SOIL MANAGEMENT SYSTEMS IN ORCHARDS IN THE CHERNOZEMS OF THE EASTERN PART OF DOBROGEA

C. PĂLTINEANU[1], Leinar SEPTAR[2], Irina CALCIU[1], Olga VIZITIU[1], Mihaela LUNGU[1]

[1]Institutul Naţional de Cercetare-Dezvoltare pentru Pedologie, Agrochimie şi Protecţia Mediului – INCDPAPM-ICPA Bucureşti
[2] Staţiunea de Cercetare – Dezvoltare pentru Pomicultură Constanţa
cristian_paltineanu@yahoo.com

***Abstract** . The calcaric chernozems from orchards in the eastern part of Dobrogea were less studied by now from the view point of soil physical properties. The purpose of this paper is therefore to show the physical state of the chernozems from the eastern part of Dobrogea as effect of the specific orchard tillage practices after a few decades of intensive activity. Soil samples were taken from both between tree rows (ITR) and in the rows (IR). It was found that soil physical properties worsened in ITR versus IR, and this was attributed to the compaction caused by the specific fruit growing technological traffic. Bulk density (BD), macroporosity (P50), resistance to penetration (RP) and saturated hydraulic conductivity (Ksat) showed significant differences between ITR and IR in some soil layers. The soil compaction degree (GT) values revealed the fact that only the upper part of the soil profiles having direct or close contact with the agricultural machinery and tractors underwent a moderate soil compaction. The present practical recommendations for orchard establishing for a large area of more clayey and compacted soils from the hilly regions of Romania were to plow deeply the soils at 0.5-0.6 m depth. Having done this way in the cherozems of Dobrogea, it would bring carbonates upper and humus and the nutrients deeper in the soil, and would also change the chemical reaction towards alkalinization in the Am layers, where most of the tree roots exist. Deep plowing would also cut additionally the soil structural elements and would worsen the soil structure as well. In order to improve the physical state of the chernozems of Dobrogea it is recommended to deep loosen the soil at the end of orchard life from the reasons of clearing the soil, and also to penetrate the compacted soil layers without overturning the soil, followed by cropping some ameliorative plants like alfalfa, peas or other such crop for a few years. When new orchards are established, the fruit tree rows (IR) should be placed over ITR positions and vice versa, if possible, to alleviate the soil fatigue.*

***Key words:** inter-row, in-row, soil compaction, bulk density*

INTRODUCTION

The calcaric chernozems from the eastern part of Dobrogea are known for their physical, chemical and biological properties that are favorable to agricultural crops. Specific for these soils are the high values of total porosity and macro-porosity, humus reserve, the well-developed soil structure, as well as other soil physical properties that are favorable to crops and are influenced by the above properties, such as: soil permeability and soil water storage capacity.

Soil degradation generally occurs within the intensive agriculture systems, regardless land use: arable, orchards, vineyards, pastures, etc. From the view point of the environment conservation, soil tillage in orchards is among the most aggressive, because the soil is disturbed starting with tree plantation, through deep plowing or deep loosening aimed to increase soil porosity. It goes on with plowing and repetitive hoeing in the case of clean cultivation system made to control weeds, as well as with the technological traffic through many sprayings with pesticides against diseases and pests during the year. The traffic is also intensive during the harvest. This system is frequently met in semi-arid regions with frequent droughts, as Dobrogea is.

Among the negative aspects that are inherent for agriculture, soil compaction caused by the technological traffic is a common one. The compaction was much studied in the past, both nationally and internationally, specifically during years 1970-2000 in the regions with irrigated agriculture, where the traffic of tractors and agricultural machinery was large. The German agricultural school (e.g. HORN AND FLEIGE, 2003, 2005, 2009) stressed the risk of soil compaction in agricultural fields, and also the impact of the tractor and machinery tires on soil physical properties, along with the prediction of the physical soil state using simulation models. VAN DER AKKER (1999) and VAN DER AKKER AND CANARACHE (2001) also emphasized the soil compaction risk at European level. The man-made soil compaction risk as effect of heavy machinery used in agriculture was also illustrated internationally in environments with different soil and climate conditions (HAKANSSON ȘI DANFORS, 1988). In this context, HAMZA AND ANDERSON (2005) made a revue about the causes and possible solutions to solve the so-called secondary soil compaction.

In Romania, earlier studies were carried out, among others, by IONESCU ŞIŞEȘTI (1942) who showed the negative effect of the hard-pan, then CANARACHE ET AL. (1980, 1984 AND 1987), CANARACHE AND DUMITRU (1986), CANARACHE (2000), DUMITRU ET AL. (1998, 2000), DUMITRU (2005). The above scientists worked especially with soils like chernozems and non-gleic reddish Preluvosols (former brown-reddish soils) from the Romanian Danube Plain (for instance, at Marculesti), where soil compaction was found not only in the upper soil layers (Ap, Am or Ao layers) but also within the deeper layers, underlying the risk of man-made soil compaction over a considerable soil depth. For the orchards soils from the hilly region of the Getic Platform other scientists were reported results, such as: IANCU AND NEAMȚU (1979) AND IANCU (2001), who studied the relations between the soil management systems and the representative fruit trees in the region (apple).

By performing experiments with the intensity of technological traffic, it was stressed that soil compaction occurred over a large area of Romania. STÂNGă (1978) has proposed the term of compaction degree (grad de tasare in Romanian, symbol GT) as based on the needed minimum porosity that depends on soil texture. Simota and Canarache (1988), using simulation techniques, have estimated the effects of soil compaction on soil water dynamics and yield, whereas Simota (2001) has simulated the dynamics of soil bulk density and of yield formation using soil compaction and the effects of tillage at local and regional scales.

Studies were carried out in region Dobrogea by DUMITRU (1999) AND DUMITRU AND SEITAN (1993) within vermic chernozems nearby (Research Station of Field Crops Valu lui Traian, district Constanta). These authors emphasized the remnant effects of some agricultural practices and applied mineral and organic fertilizers in field crops to improve the physical soil state.

However, the calcaric chernozems from orchards in the eastern part of Dobrogea were less studied by now from this view point. The purpose of this paper is therefore to show the physical state of the calcaric chernozems from the eastern part of Dobrogea as effect of the specific orchard tillage practices after a few decades of intensive activity and propose measures to improve it.

MATERIAL AND METHODS

The experiment was carried out within the trial field of the Research Station for Fruit Growing Constanta, village Valu lui Traian, at the elevation of 60-70 m above sea level. The studied orchards are represented by peach, apricot and cherry trees. The age of orchards is: for peach – 22 years, for apricot – 15 years, and for cherry – 11 years. Soil tillage specific to fruit growing within these orchards were continuously performed during the last four decades, because the area was administrated by the above Station and there were always orchards here, except the years of land rest to alleviate soil fatigue after land clearing.

The soils are represented by calcaric chernozems modified by deep plowing and turned into calcaric antrosols (ATka) (FLOREA AND MUNTEANU, 2012), with proper soil physical and chemical properties (Table 1).

When the land use was changed from arable into orchard, the soil was deeply plowed at about 0.5 m depth. After land clearing of the former orchards, the soils were deeply loosened and cropped with ameliorative field crops for a few years, and then the present orchards were established with peach, apricot and cherry, respectively. The soil is well structured, has profound layers with organic carbon accumulation (Am1 layer with 0.028 – 0.03 kg kg^{-1} and Am2 with 0.020-0.025 kg kg^{-1} humus content) and has a high fertility (proper values of plant available K and P). Characterization of the soils state was done for both in-row and inter-row positions in the orchards, by using soil analyses made according to the standards in force (SR EN ISO 11272: 2014 for bulk density - BD, SR EN ISO 11274: 2014 for macroporosity – P50, both as international standards, and STAS 7184/17-88 for resistance to penetration – RP and STAS 7184/15-91 for the saturated hydraulic conductivity – Ksat, as Romanian standards) (FLOREA ET AL., 1987).

The soil texture is loamy, and the soil clay content ranges between 0.21 and 0.30 kg kg^{-1} over the entire soil profile. The Ca and Mg carbonates come into sight from the upper layers and increase deeper to as much as 14.0 – 17.0 kg kg^{-1} in Cca 1 şi Cca 2 layers. Soil chemical reaction (pH) increases from Am to Cca soil layers from 7.4 to 8.5.

Table 1

Soil layers and sub-layers, and the main soil physical properties in the peach, apricot and cherry tree orchards, Calcaric Chernozem, Valu lui Traian, district Constanta

Soil layer	Depth (m)	Clay (kg kg^{-1})	Humus (kg kg^{-1})	pH (units)	Carbonate (kg kg^{-1})	K avail. (mg kg^{-1})	P avail. (mg kg^{-1})
Am1	0,0-0,1	0,27-0,29	0,030-0,033	7,40-7,50	0,0	82-146	23-28
	0,1-0,2	0,26-0,28	0,028-0,030	7,50-7,75	0,0	78-130	20-26
Am2	0,2-0,3	0,26-0,28	0,026-0,027	7,60-7,90	0,000-0,001	75-104	16-19
	0,3-0,4	0,26-0,28	0,025-0,027	7,60-8,20	0,012-0,015	68-83	10-13
	0,4-0,5	0,25-0,27	0,023-0,021	7,90-8,34	0,025-0,030	65-75	6-8
AC	0,5-0,6	0,25-0,27	0,0180-0200	8,00-8,32	0,030-0,048	62-70	4-6
	0,6-0,7	0,24-0,26	0,016-0,017	8,20-8,36	0,050-0,098	58-67	3-4
	0,7-0,8	0,23-0,26	0,013-0,015	8,25-8,41	0,113-0,127	46-53	2-3
Cca 1	0,8-0,9	0,23-0,24	0,008-0,009	8,36-8,45	0,145-0,159	44-50	1-2
Cca 2	0,9- 1,0	0,21-0,23	0,006-0,007	8,40-8,50	0,150-0,170	40-46	1-2

The phyto-sanitary treatments were done annually in a number of 10-12 on average with devices and tractors of about 2-2.8 Mg weight and 45-55 kW power. The soil and orchard management system was clean cultivation in the fruit tree rows and between rows. Herbicides were occasionally applied for IR positions, intensifying thus the technological traffic usually carried out when the soil surface was not wet. Due to the semi-arid character of the climate in Dobrogea sprinkler irrigation was applied in the orchards. However, due to the great pumping heights (more than 70 m), crop irrigation has unfortunately a local character. The annual irrigation regime was usually under sustained water stress, i.e. application of 2-3 irrigation events during summer time by using 60-70 mm of water / event and totaling about 150-220 mm per season.

The experimental data of soil physical properties were done by using the analysis of variance and test Duncan by SPSS 14 Software in order to compare the mean effect as a function of two experimental factors: factor A – position and direction versus the tree row with two graduations: 1) in the row (IR) and 2) between the rows (inter-row, ITR), and factor B – soil depth with 10 graduations (10 cm step downwards to 1 m depth) within the soil layers: Am1, Am2, AC, Cca1, Cca2. The soil analyses were performed in the ICPA labs by using the current methodology for this country. Figure 1 shows the soil profiles in the three orchards studied: peach, apricot and cherry.

Figure 1. Soil profiles in the studied orchards of peach, apricot and cherry trees to take soil samples

RESULTS AND DICUSSIONS

SOIL PROPERTIES IN ITR AND IR

As a general rule, soil properties worsened in ITR versus IR positions due to the compaction caused by the technological traffic. There were significant ($P < 5\%$) differences between these positions for some of the physical soil properties: BD, P50, RP and Ksat. The differences were bigger for the older orchards, Figures 2, 3, 4 and 5. Nevertheless, even in the most compacted areas in ITR (beneath the places where tractors usually pass) in the oldest plantations, the soil physical properties were not deteriorated to a great extent.

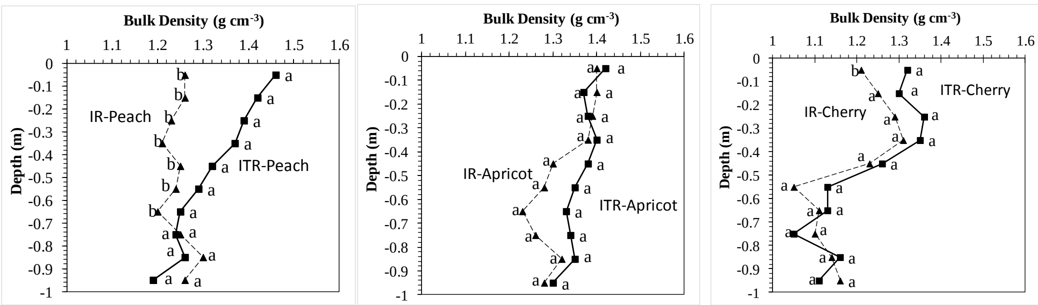

Figure 2. Soil bulk density in the two positions: IR (in-row) and ITR (inter-row) over 1 m depth in the studied orchards of peach, apricot and cherry trees, respectively; note that here and in the following figures different letters for the same depth show significant differences for the 5% probability level according to Duncan`s multiple range test

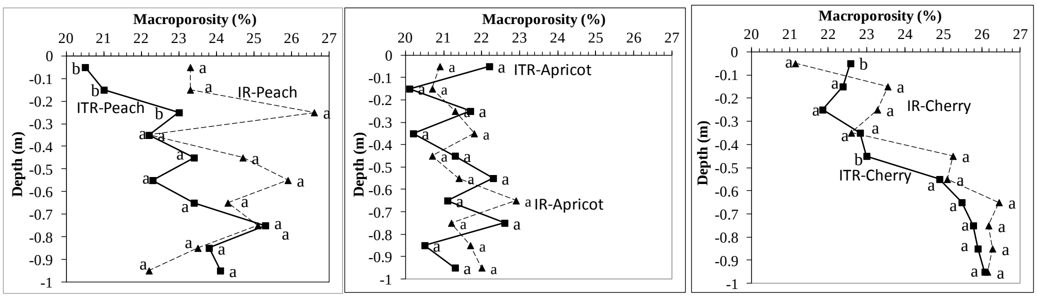

Figure 3. Soil macroporosity in the two positions: IR and ITR over 1 m depth in the studied orchards of peach, apricot and cherry trees

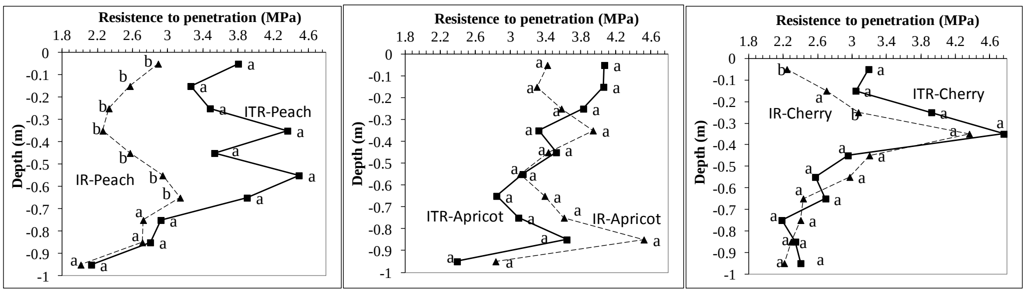

Figure 4. Soil resistance to penetration in the two positions: IR and ITR over 1 m depth in the studied orchards of peach, apricot and cherry trees

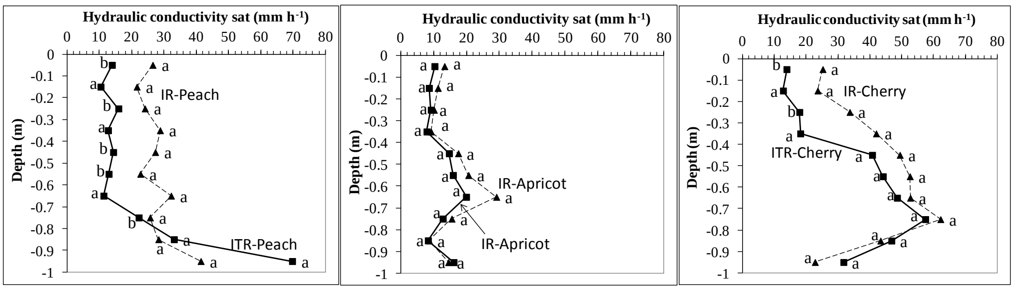

Figure 5. Saturated hydraulic conductivity in the two positions: IR and ITR over 1 m depth in the studied orchards of peach, apricot and cherry trees

Unlike other fruit tree species, e.g. apple that is usually cultivated under colder and wetter conditions in Romania, the number of tractor passes in the case of peach, apricot and cherry is lower here. Another explanation for this magnitude of soil compaction could be the considerable resistance of chernozems to worsening of soil physical properties when the technological traffic has a short- or medium term in orchards. Thus, the 22 years old peach orchard had the longest period of fruit growing technological traffic and had therefore the most significant differences between ITR and IR positions. In other words, ITR had the most severe soil state in the peach plantation. Another cause in the variability of soil compaction state could be the shorter distance between the tree rows in the case of peach (4 m) versus the other two species: apricot and cherry (5 m). A smaller distance between rows prevents tractors and agricultural machineries to use a larger space to pass and has therefore more frequent passing and compaction.

BD and RP were higher in ITR versus IR. However, some of the soil physical properties showed decent values in both ITR and IR alike, for instance P50 exceeded 20% all over the soil profiles, and even Ksat was everywhere higher than 10 mm h^{-1}. DUMITRU ET AL. (1999) also found that these soils underwent a weak compaction in the arable land use nearby. These results on the soil physical state in orchards and vineyards are consistent with data previously reported by other scientists for various fruit tree species and under different environments and technological traffic (FERRERO ET AL., 2005; VAN DIJCK AND VAN ASCH, 2002).

These results show that the trend of soil evolution in orchards is towards the worsening in soil physical properties. The older the orchard the longer the technological traffic and the more deteriorated the soil physical state.

Correlation of soil physical properties

P50, RP and Ksat were highly significantly correlated with BD that revealed the soil compaction magnitude as induced by the technological traffic, Figure 6.

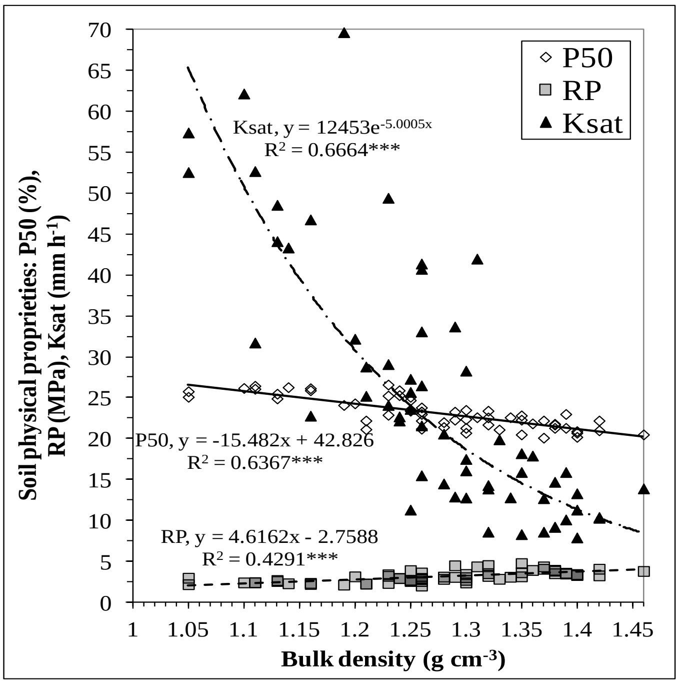

Figure 6. Correlation of some soil physical properties: RP, P50 and Ksat with BD in the studied orchards of peach, apricot and cherry trees

From these relationships, the weakest was between RP and BD, probably because RP is usually determined in the lab at a soil water content that is equal to half the total soil water capacity and that additionally differentiates between the soil samples. Determination *in situ* or in the lab of RP at the same soil water potential (e.g. at a pF = 2.5) would probably produce a more intense correlation with BD, would allow a correct comparison between soil layers and would reflect more accurate the soil state, but this should checked in the future.

SOIL COMPACTION DEGREE (GT)

GT is an index arisen from the clay content – the minimum needed porosity – and the total porosity (STÂNGĂ, 1978). From the soils with the fruit tree species investigated, the peach orchards showed the largest differences regarding GT in the two positions: ITR and IR. This was not probably because the fruit tree species itself, but due to the long-term technological traffic (orchard age) and smaller distance between tree rows. The other orchards followed as a function of age: apricot (15 years old) and cherry (11 years old).

In upper Am soil layers, GT was higher in ITR than in IR in peach and was slightly higher in the case of apricot, still remaining in the class of „moderate compaction" (GT = 0 to 10), Figure 7. In the case of cherry, the compaction class was „weak" (GT = 0 to -10).

In the other soil layers, GT ranged within the weakly compacted class (GT from 0 to -10), very weakly compacted class (GT from -11 to -18) and extremely weakly compacted class (GT ≤ 18).

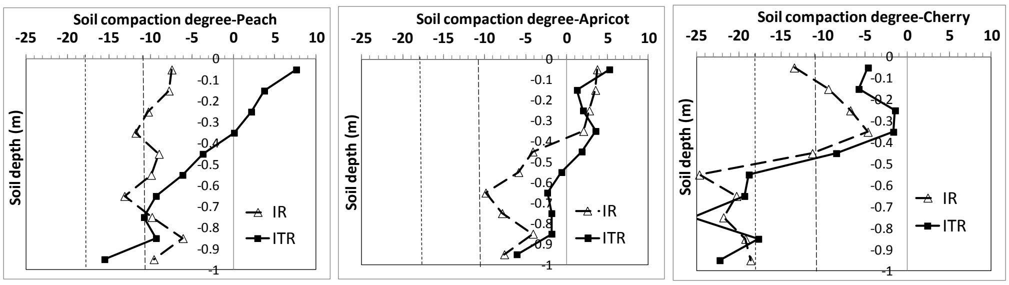

Figure 7. Variation of the soil compaction degree (GT) with depth in the studied orchards for both positions analyzed (IR and ITR), Valu lui Traian; GT from 0 to 10 = moderately compacted, from -11 to 10 = weakly compacted, from -11 to -18 = very weakly compacted, below -18 = extremely weakly compacted

CONCLUSIONS

Soil physical properties worsened in the lanes between the fruit tree rows (ITR) versus the rows (IR), and this was attributed to the compaction caused by the specific fruit growing technological traffic.

Bulk density (BD), macroporosity (P50), resistance to penetration (RP) and saturated hydraulic conductivity (Ksat) showed significant differences between ITR and IR in some soil layers.

The soil compaction degree (GT) values revealed the fact that only the upper part of the soil profiles having direct or close contact with the agricultural machinery and tractors underwent a moderate soil compaction.

The present practical recommendations for orchard establishing for a large area of more clayey and compacted soils from the hilly regions of Romania were to plow deeply the soils at 0.5-0.6 m depth. Having done this way in the cherozems of Dobrogea, it would bring carbonates upper and humus and the nutrients deeper in the soil, and would also change the chemical reaction towards alkalinization in the Am layers, where most of the tree roots exist.

Deep plowing would also cut additionally the soil structural elements and would worsen the soil structure as well.

In order to improve the physical state of the chernozems of Dobrogea it is recommended to deep loosen the soil at the end of orchard life from the reasons of clearing the soil, and also to penetrate the compacted soil layers without overturning the soil, followed by cropping some ameliorative plants like alfalfa, peas or other such crop for a few years.

When new orchards are established, the fruit tree rows (IR) should be placed over ITR positions and vice versa, if possible, to alleviate the soil fatigue.

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