SOIL COMPACTION CONSEQUENCES IN TOBACCO PRODUCTION IN CROATIA

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Introduction

Virginia type tobacco introduced in Croatia in tho 50's for the needs of tobacco production. Initially, it was planted on sandy soils and later the production spread to heavier soils in Northern Croatia, from Đurđevac to Donji Miholjac (*Bašić et al.,* 2007). Economic effects and the size of farms are the main reasons why tobacco is often grown as a monoculture oor in a very narrow rotation. Perennial tobacco growing in a monoculture on soils prone to compaction without adding organic matter led to degradation of arable layer, what was the reason of lower yield. Often shallow soil tillage on the same depth led to increased compaction in subploughing layer, especially on ploughing depth (*Birkaš,* 2008).

The major problem of tobacco soils in Croatia for current state of arable layer are of generic origin and the consequences of irregular managing of these soils are often deteriorated to the extent that water occasionally retain on the soil surface. Often emphasized compaction of plough and subplough layer makes the growth and development of the root system harder and it's the main limiting factor for acheiving higher yield and better leaf quality (*Turšić,* 1994; *Turšić, Butorac, and Bašić,* 1994).

Yield and quality of tobacco, with the genetic potential of cultivar, significantly depend on the current soil fertility, applied agricultural practices and climatic conditions during the vegetation period (*Hawks and Collins,* 1993). Approach to managing the soil-plant system in the growing area of Virginia tobacco has to include measures such as crop rotation, calcification, appropriate fertilizer application, soil tillage, erosion, control and conservation of water in soil. Not one measure can replace the other or profitable production can be maintained until all factors which affect the productivity are well balanced.

Keywords: Virginia tobacco, yield, yield quality, compaction, tillage

Tobacco soil and climate

The soil is usually sandy or silty loam with high content of fine sand and silty and low content of clay (*Table 1*), with unstable structure and tend to compaction and crust formation (*Husnjak et al.,* 2005).

Tobaco production was carried out usually on three soil types (*Picture 1-3*), characteristics of the flue-cured tobacco growing area. Because of the unstable structure and repeated shallow tillage to the same depth, increased soil compaction occurrence (*Table 2*).

Table 1 Average soil mechanical composition of soil in tobacco production in Croatia

Soil horizon	Depth (cm)	Percentage of particles				Texture
		Coarse sand (2-0.2μm)	**Fine sand** (0.2-0.02 μm)	**Silt** (0.02-0.002 μm)	**Clay** (<0.002 μm)	
A_p	0-26	15	58	17	10	sandy loam
E	26-45	18	61	15	6	sandy loam
B_i	45-90	21	36	22	21	loam

Table 2 Main characteristics of the examined soils

Type of soil	Texture	Bulk density (25-30 cm)	Organic matter (%)	pH	Total nitrogen (%)	Available nutrients (mg/100g)	
						P_2O_5	K_2O
Luvisol	Sandy loam	1.63	0.9	4.9	0.06	14.9	20.3
Semigley	Silty loam	1.65	0.13	5.1	0.05	16.3	23.8
Cambisol	Sandy loam	1.58	1.48	5.6	0.08	15.3	22.5

Soil has a volume weight close to 1.6 g cm^{-3} is very often encountered in the area where tobacco is grown. With the results of the field trials, these data obtained in a green house which also confirmed that the increase of the soil compaction is the main reason behind getting lower yield of flue cured tobacco in Croatia.

At the lowest bulk density the soil resistance came to 1.85 MPa, at the mean bulk density to 5.1 MPa and at the greatest to 9.05 MPa, with a momentary moisture content of 14.7 %, 13.1 % and 18.8 %. The increased soil resistance found with the mean and greatest bulk density resulted in the first, and 15.3 and 37.2 % respectively in the second year of research.

The research results obtained from experimental models carried out in the green house strongly suggested that soil compaction is a cause of reduced yields obtained in the field.
Soil compaction, especially in the subsoil (25-30cm), was fairly limited infiltration of the excess precipitation into deeper layers as well as growth and development of root system (*Turšić*, 1992).

Table 3 Physical properties of the examined soil

Soil horizon	Total porosity (%)	Field water capacity (%)	Air capacity (%)	Bulk density $gmcm^{-3}$
A_p	45.6	36.4	9.2	1.46
E	38.3	33.7	4.6	1.68
B_i	41.6	34.1	7.5	1.71

Air capacity is moderately low (*Table 3*) in ploughing and illuvial horizon. Field water capacity is average in the ploughing and illuvial horizon and low in the alluvial horizon. According to bulk density values soil compaction of subploughing layers is significantly higher than compaction in the ploughed layer (*Turšić*, 1992; *Turšić and Čavlek,* 1992).

The climate of tobacco growing region in Croatia has the characteristics of moderate continental climate. The precipitation deficiency is frequently ocurred in July and August

requiring irrigation to conserve tobacco quality. Aridity is also more frequent in the eastern part of the tobacco growing region (*Figure 1*). The last minimum temperature occurs in April and the first cold days comes generally in October, which are used as the basis for planting time and the lenght of the growing season, that is ripening and the last harvesting tobacco.

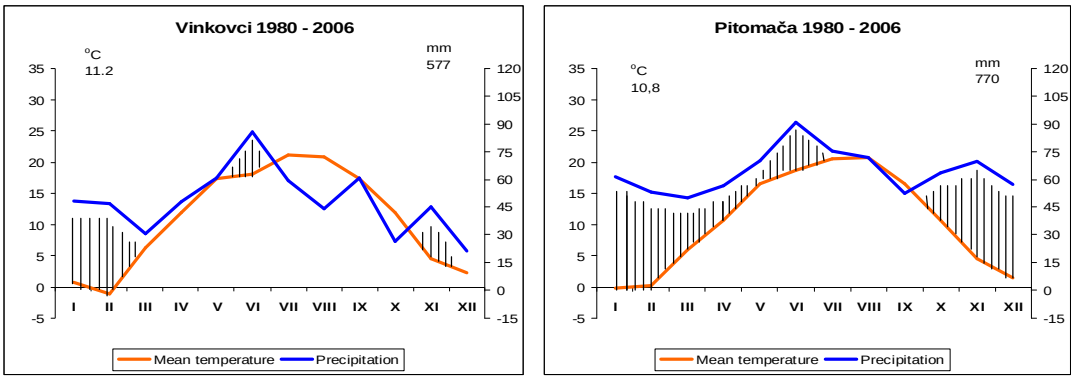


Figure 1 Mean temperature and precipitation in the region of Vinkovci (left) and Pitomaca (right) (1980, 2006)

Effects of tillage on soil compaction in tobacco production in Croatia

The application of chiesel plough on soils having unfavourable physical characteristics was greatly recommended in the literature (e.g. *Soane and Ouwerkerk*, 1994, 1992). On soils, where chisel plough was applied during soil preparation in spring, a significantly lower penetration resistance were measured (*Figure 2*), which resulted in adequately larger yield of tobacco leaf.

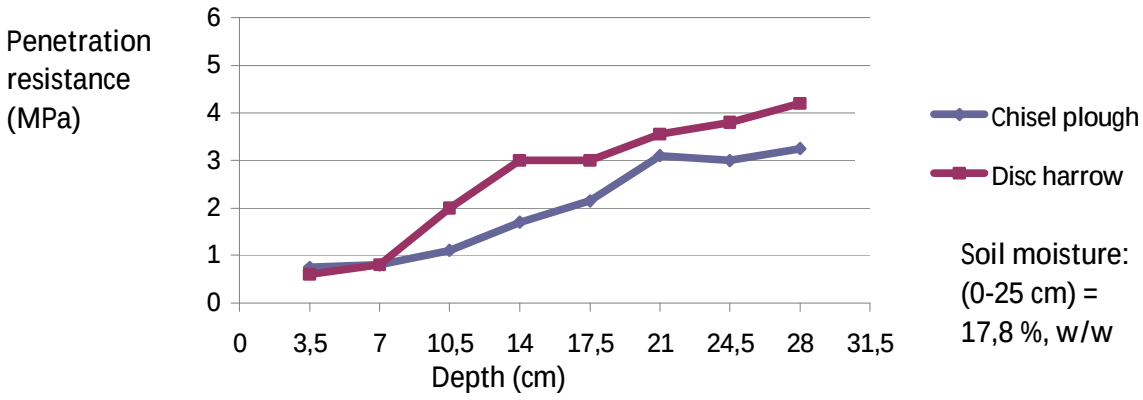


Figure 2 Influence of chisel plough tillage on soil compaction

Considering the high soil penetration resistance values in spring, chisel plough was applied from time to time in the tobacco growings fields. Increased soil compaction and deteriorated soil condition during soil preparation in spring that reduced the growth and development of root system into the deeper layers and decreased the tobacco yield (*Turšić et*

al., 2011; *Vepraskas and Miner*, 1986). However, creating a deeper loosened layer (e.g. by chisel) resulted in a higher leaf yield (*Table 4).*

Table 4 Influence of chisel plough application in soil preparation on tobacco yield

Soil tillage	Yield, kg/ha		$\bar{x}$
	2005	2006	
Chisel	2667.0	2733.3	2700.15
Without chisel	2336.3	2499.3	2417.00
$LSD_{5\%}$	131.2	210.1	

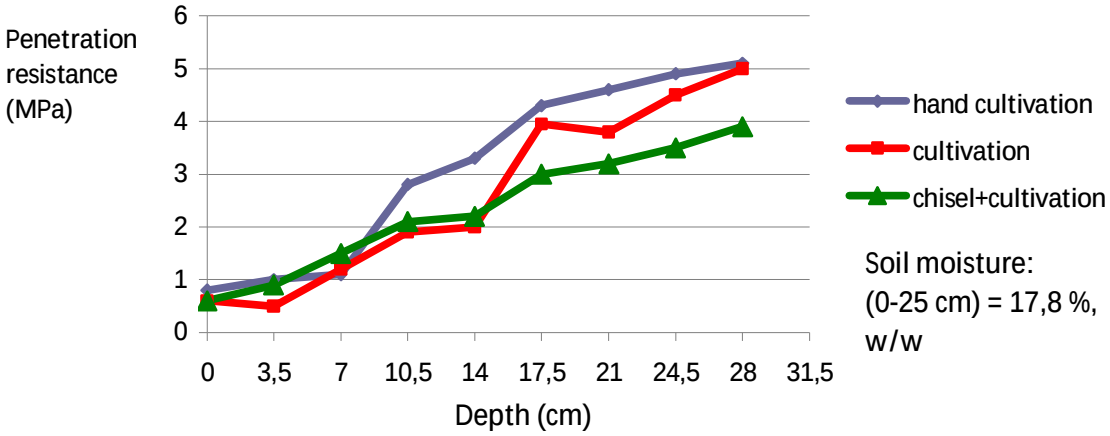


Figure 3 Influence of the inter-row chisel plough tillage on soil compaction

The largest part of tobacco root system develops at depth 30-40 cm (*Turšić,* 1994, *Vepraskas and Miner,* 1986). First two weeks after plantation tobacco develops lateral roots and that is the reason why first soil tillage intervention between rows is conducted deeper, with the machines similar to the chisel applied in this experiment (*Figure 3*).

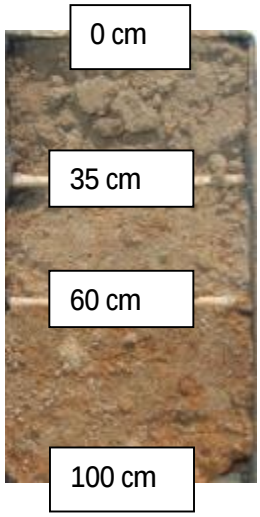
As the tobacco plants become higher and the root system develops deeper, the next cultivations are conducted shallower and their main goal is soil ventilation (crust breaking), weed removal and drainage of excess water. During the procedure in which chisel was applied between rows, the soil was less compacted and the larger tobacco yield was obtained.

A deeper ploughing increased tobacco yields effectually both on three soil types and locations (*Table 5*). Subsoiling as the separate operation applied after proceeding crop harvest that influenced yield increase on Luvic and Semigley soils (*Turšić et al.*, 2004).

Table 5 Significance of the analysis of variance

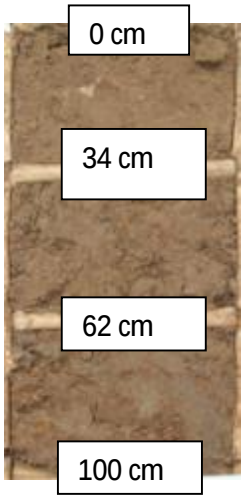
Type of soil	Depth of ploughing	Subsoiling	Chisel plough
Luvisol	**	*	*
Semigley	*	*	*
Cambisol	*	NS	NS

*LSD, 5%; **LSD, 1%



Semigley

Luvisol



Cambisol

Picture 1-3 Three soil types adaptable to tobaco production in Croatia

Application of deeper ploughing has significantly increased the soil porosity and trough this it improved the water-air regime. Similar data can be found in the literature from ***Lipiec and Simota*** (1994), and ***Turšić et al.*** (2004). However, subsoiling applied to semigley, silty loamy textured soil was beneficial on the tobacco leaf yield and quality (***Table 6***).

Table 6 Effect of subsoiling on the yield and quality of flue-cured tobacco

Type of soil	Yield kg ha^{-1}		% of 3rd grade	
	Subsoiled soil	Non -subsoiled soil	Subsoiled soil	Non-subsoiled soil
Semigley	3064*	2775	47*	34
Cambisol	2987	2860	49	46

*LSD, 5%

On Cambisoil while it has more favourable physical properties, the subsoiling resulted in a slightly higher yield and a better quality related to other soil types. Nevertheless, the obtained difference relative to the unsubsoiled soil was not significant in the case of shallow tillage which may call attention to use subsoiling repeatedly. To increase the ploughing depth from 20, 30 and 40 cm resulted in a significant increase of the tobacco leaf yield both on all three soil types and locations (***Table 7***).

Table 7 Effect of ploughing depth on the yield of flue-cured tobacco (kg ha^{-1})

Type of soil	Depth of ploughing			*LSD, 5%
	20 cm	30 cm	40 cm	
Luvisol	2269	2565*	2658*	206.0
Semigley	2260	2740*	2801*	263.0
Cambisol	2195	2546*	2567*	295.7

*LSD, 5%

A deeper tillage loosened the subsoil adequately and resulted in deeper penetration of the tobacco roots as well as better water and nutrition uptake from a larger volume of soil (***Turšić,*** 1992). Due to the silty textured properties in the tobacco region of Croatia, both crust formation and soil compaction are frequent during the growing season as the consequence of the intensive run-off, soil settling and application of heavy machinery. Analyses of long-term trials involving cultivation rendered the requiring results. Application of a deeper soil loosening between tobacco ridges, along with more ridge cultivation the yield was significantly increased (***McKee,*** 1999).

Conclusions

The investigation of diferent types of soil preparation for tobacco cultivation has shown that chiesel ploughing has significant advantage compared to other types of tillage interventions.

The application of disc plough in secondary tillage has increased soil compaction and decreased yield of tobacco leaf so it should be avoided in soil preparation.

Due to increased soil compaction in the subploughed layer (on average below 25 cm), soil in tobacco production in Croatia require deeper tillage as well as occasional subsoiling as a separate operation.

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