EFFECT OF DIFFERENT SOIL TILLAGE METHODS AND FERTILIZERS ON SUNFLOWER YIELDS

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ABSTRACT

Crop management should be improved as response to concerns about environmental impacts of agriculture. Under a such context, to choose a good soil tillage management is an important decision to improve grain yield and quality.

The paper presents aspects regarding the influence of several soil tillage methods, fertilizers and three track-by-track passings of tractor prior to seedbed preparation on sunflower yield under dryland conditions. Field experiments were conducted during 1987-2004 at The National Agricultural Research and Development Institute from Fundulea (Romania) on a leached chernozem, well drained, formed on loess, with 33% clay content and 2.8% organic matter in arable layer.

The wheel pressure induced a soil compaction down to 40 cm depth as shown by an increase of bulk density and a decrease of total and air porosities, below minimum level accepted for a normal crop development. The plant height and leaf area were reduced by compaction, as a result of worsening of soil conditions for root growth; the root biomass was lower by 16-33% in compacted soil, as compared to non-compacted one. Working the soil only by disking before sowing created unfavourable conditions for root and plant growth, similar with those obtained by soil compaction. Continuous use of optimal rates of fertilizers (chemical or manure) helped obtaining more efficient sunflower cropping systems.

Key words: soil tillage, fertilization, sunflower

INTRODUCTION

Cultural practices can compact soil and affect the ability of roots to exploit the soil volume for water and nutrient uptake. Several key soil properties such as soil strength, water, aeration, and their interactions are affected by soil compaction.

Many studies have shown that plant growth and productivity decrease with soil compaction (Ţerbea et al., 1994). Furthermore, recovery and amelioration of compacted soil could be slow, if it occurs (Froehlich, 1979; Heninger et al., 1997).

Therefore, it is critical to thoroughly understand compaction processes, their effects on soil and plant growth, and the extent to which compaction effects could be minimized.

Soil is compacted in different degrees, when driven upon by heavy machinery. Generally, root growth opportunity is diminished proportionally with increasing soil density due to excessive soil strength as a soil dries, or inadequate aeration when it becomes too wet.

The paper presents some aspects concerning the response of sunflower to different cropping systems and soil compaction degrees.

MATERIAL AND METHODS

Field experiments were conducted during 1987-2004 at The National Agricultural Research and Development Institute Fundulea, Romania (44º27'N, 26º31'W, 67 m above sea level). The soil is mapped as a moderately leached chernozem, well-drained, formed on loess, with 33% clay content and 2.8% organic matter in arable layer.

The experimental design included some of the main cultural practices: crop rotation, soil tillage method, fertilizers and soil compaction.

The compaction treatments were made on a fall plowed field, by successive passings of tractor U-650 (of 3,800 kg weight) in spring time, prior to seedbed preparation.

The various degrees of compactness was obtained by four wheel traffic treatments:

a. unwheeled (C_0);
b. one pass of tractor, track-by-track (C_1);
c. two passes of tractor (C_2);
d. three passes of tractor (C_3).

After the soil compaction, the seedbed preparation was performed by disking. The used crop technology was the following: sowing time (during 15th-20th April), plant density (4.6 plants/m^2), fertilization ($N_{100}P_{75}$) and weed control (chemical and mechanical methods).

The soil samples were collected for determination of bulk density, immediately after the soil compaction and at harvesting; the total air porosities were indirectly determined taking into account the values of bulk density.

The experiment was stationary organized in a 6 year crop rotation (sunflower after winter wheat) and designed in randomized blocks in 4 replications; the size of experimental plot was 120 m^2.

RESULTS AND DISCUSSION

Table 1 presents the evolution of the main physical indicators of the soil during 1987-2004.

In the non-compacted treatment, the total air porosity was decreased from 0 to 40 cm, while

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the bulk density increased from 1.22 g/cm^3 in the superficial layer to 1.41 g/cm^3 at 30-40 cm.

Table 1. The effect of soil compaction on the main physical indicators of the soil (before sowing) Fundulea, 1987-2004

Treat-ments	Depth (cm)	Soil moisture (%)	Bulk density (g/cm^3)	Soil porosity (%)	Air soil porosity (%)
C_0	0-10	22.0	1.22	52.3	21.6
	10-20	23.7	1.31	50.0	14.8
	20-30	23.9	1.38	47.5	10.7
	30-40	24.0	1.41	46.2	7.3
C_1	0-10	22.5	1.41	44.4	6.9
	10-20	23.9	1.46	44.5	5.3
	20-30	23.5	1.47	44.2	4.8
	30-40	23.8	1.45	44.9	5.0
C_2	0-10	22.3	1.43	43.1	5.9
	10-20	23.6	1.47	43.6	4.3
	20-30	23.5	1.46	43.7	3.8
	30-40	23.4	1.45	44.1	3.6
C_3	0-10	22.2	1.51	42.9	4.5
	10-20	23.7	1.48	43.1	3.0
	20-30	23.4	1.47	43.3	3.7
	30-40	23.3	1.46	43.9	3.3

In the C_1 treatment, with compacted soil, bulk density increased, and air porosity was strongly reduced. In the C_3 treatment these soil characteristics were very much under the values recorded in the non-compacted treatment.

The increase of the volumetrical weight and the reduction of the total air porosity in the compacted variants influenced the growth and development of the root system (Table 2).

Table 2. The effect of soil compaction on the root area and biomass accumulation in sunflower*

Depth (cm)	The root area (cm^2/plant)			Biomass accumulation in root, dry matter/plant (g)		
	C_0	C_1	C_3	C_0	C_1	C_3
0-10	1286	1341	796	11.5	9.4	7.1
10-20	374	353	210	2.7	1.5	1.6
20-30	348	397	92	2.3	2.2	2.1
30-40	208	217	198	2.1	1.8	1.2
40-50	172	194	114	1.5	1.7	1.1
50-60	112	143	131	0.8	0.5	0.3
Total	2500	2645*	1541^{ooo}	20.9	17.1^{o}	13.4^{oo}

* (before 10 leaves stage)

The root area and biomass accumulation showed an important decrease in the case of C_3 variant in the superficial layer of the soil (from 0 to 10 cm).

One can notice a tendency of the root matter to increase in the 20-30 cm layer, where the compaction had not affected the structure of the soil.

Taking into account the entire weight of the root for each plant, on the whole depth of the tested soil, one can notice an important reduction of the weight of the root matter in the third treatment of soil compaction.

The whole surface of the root presents an important increase in the treatment with slight compaction (C_1) and a distinct reduction in the C_3 case (1.50 g/cm^3) (Table 2).

In the treatment with severe compaction (C_3), the root growth requires a higher energetic consumption and this has negative repercussions on root area and biomass (Russell, 1977).

The effect of the reduction of root matter caused by the narrowing of spaces between soil aggregates and by lower air porosity is reflected in the plant growth and the green matter. This effect occurs beginning from first stages of vegetation. Thus, during the flowering stage, the plant height, leaf area, biomass accumulation and yield are all negatively influenced by the soil compaction (Table 3).

Table 3. The effect of soil compaction on sunflower growth

Variants	Number of plants/ha x 1000	Plant height (cm)	Leaf area (cm^2/plant)	Dry matter accumulation (g d.m.)	Grain yield (g/plant)
C_0	44.6	168-185	3210-3460	143.6	72.1
C_1	40.7	151-163	2920-3100	128.1	69.8
C_2	40.5	160-158	2900-2780	115.7	63.6
C_3	39.5	147-159	2780-3020	90.3	60.2
LSD $P<0.05$	3.1	2.0	3.7	3.0	2.1

It is obvious that, both in the case of slight (C_1) and severe soil compaction (C_3), dry matter accumulation is reduced not only in roots but also in the shoot and leaves. This proves that the physiological activity of the plant is affected, a large part of its assimilates being necessary to obtain the energy for root penetration. The grain yield was evidently reduced, in all compaction treatments and was influenced by the weather conditions, too.

Table 4. The effect of soil compaction on sunflower yield (kg/ha) Fundulea, 1995-2004

Year of experimentation	Treatment				Annual average
	C_0	C_1	C_2	C_3	
1995	2130	2260	2260	2050	2175
1996	1590	1250	1200	1010	1263
1997	1690	1600	1360	1230	1470
1998	2540	2430	2270	2360	2400
1999	1960	2190	2330	2210	2173
2000	1340	1610	1580	1360	1473
2001	1470	1260	1300	1150	1295
2002	940	1070	1140	1340	1123
2003	1170	1670	1450	1090	1345
2004	2500	2590	2420	2240	2438
Average period	1733	1793	1731	1604^o	

LSD: $P < 0.05$ 110 (kg/ha)

These results are confirmed by other researchers, who emphasize that the first element, which acts as a stressing element for roots, is the oxygen content of the soil (Hoffmann and Wiedenrouth, 1982; Gay et al., 1999).

The changes occurred in sunflower plants under conditions of soil compaction, positively influenced the oil content of the seeds (Figure 1).

Soil tillage only by disking, once or many times generate situations similar to the compaction treatments.

The root system distribution at different depths in the case when soil was worked only by disking before sowing, showed a reduction of the root area in comparison with the ploughed plots (Table 5).

A negative correlation between yield (18 years average) and oil content was recorded (Figure 2).

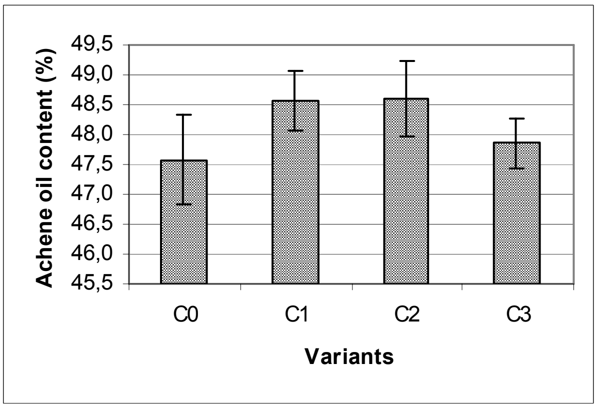

Figure 1. The effect of soil compaction on achene oil content (nine years average)

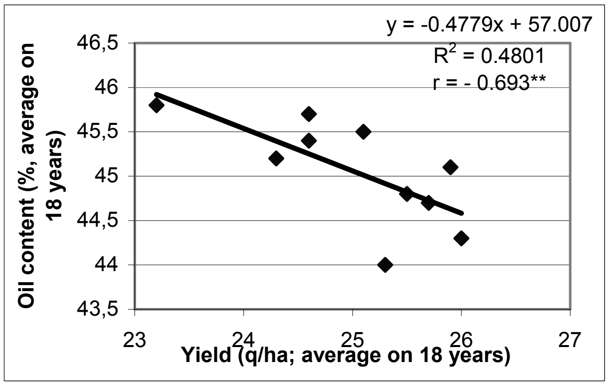

Figure 2. The effect of soil compaction on achene oil content (18 years average)

The effect of manure or chemical fertilizers (Figure 3) was strongly dependant on weather conditions (Figure 4). In the dry years, yields as well as fertilizer effects, were lower.

Table 5. The effect of soil tillage on some features of sunflower plants

Variants	Root area (cm^2/pl.) in superficial soil layer (0-20 cm)	Yield (q/ha)	% from control	Oil content (%)	Oil yield (l/ha)
Disk	860	23.2^o	89.8	45.8	1065
Plough 20 cm – (Control)	1750	25.9	100.0	45.1	1169
Plough 30 cm	1820	26.0	100.3	44.3	1150
Spring plough	1420	24.3	93.9	45.2	1101
Plough 20 cm/Disk	1250	25.1	97.0	45.5	1144
Plough 30 cm /Disk	1350	25.7	99.4	44.7	1152
Plough 20 cm/Disk (2)	1102	25.5	98.6	44.8	1143
Plough 30 cm /Disk (2)	1230	25.3	97.5	44.0	1112
Plough 20 cm/Disk (3)	853	24.6	95.1	45.7	1125
Plough 30 cm/Disk (3)	925	24.6	95.1	45.4	1116

LSD: $P < 0.05$% 2.3

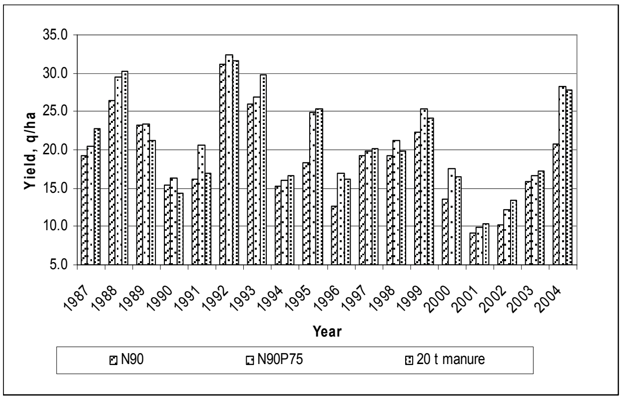

Figure 3. The influence of fertilization on sunflower yield under autumn ploughed treatment

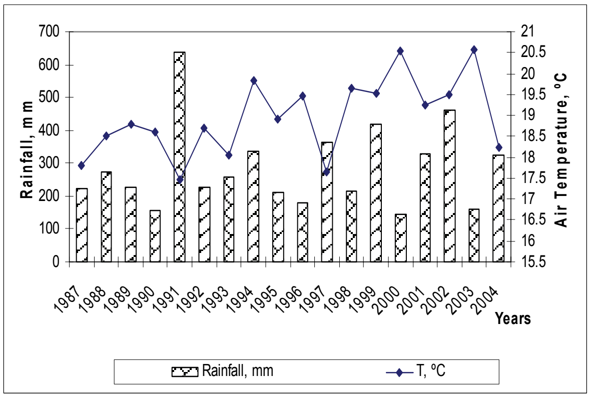

Figure 4. The rainfall and air temperature during the testing period

CONCLUSIONS

The sunflower root system is a dynamic system with different possibilities of adaptation to unfavourable soil and weather conditions.

The soil compaction determines a reduction of biomass accumulation in the root and of grain yield per plant.

Working the soil only by disking before sowing creates conditions for the growth and activity of the root system similar with those obtained by soil compacting, with similar effects on the yield.

Fertilizer effects on yield are strongly dependant on the weather conditions.

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