The effects of soil organic matter on seedling emergence in sunflower (*Helianthus annuus* L.)

F. Önemli

Tekirdag Agricultural Faculty, Trakya University, Tekirdag, Turkey

ABSTRACT

Seedling emergence is one of the most important factors in the establishment of optimum plant density for a maximum yield. Seed quality and seedbed conditions affect seedling emergence. Seedbed condition is affected by soil content, especially soil organic matter. Therefore, the objective of this study was to determine the effects of soil organic matter on germination and seedling emergence of three hybrid sunflower (*Helianthus annuus* L.) cultivars. This research was conducted in 2000 and 2001 in field and glasshouse conditions. Perlite and 20 soils with different organic matter contents were used as seedbed conditions. Soil organic matter, environment, and soil organic matter × environment factors had significant effects on seedling emergence. Decreasing soil organic matter content resulted in a decrease of seedling emergence due to the decreases in water content of the soil. This effect was clearer in adverse environmental conditions, especially in the soils with less than 2% organic matter.

Keywords: sunflower (*Helianthus annuus* L.); seedling emergence; soil organic matter; water content

It is hardly possible to reach a maximum seed yield without successful seedling establishment. The period of germination and seedling emergence prior to establishment is the most vulnerable stage in a crop's life. Poor seedling emergence results in yield reductions. This may be due to poor soil water content (Forbes and Watson 1992), seed-soil contact (Stewart et al. 1999), inaccurate seed placement, low and high soil temperatures (Forbes and Watson 1992), soil insects or soil-born disease, soil compaction or smearing (Nasr and Selles 1995), surface crusting after sowing and poor quality seeds (Ahmad 2001).

Seiler (1998) suggested that optimal seedbed conditions are needed for successful seedling emergence in sunflower. Sunflower, like other crops, requires proper seedbed conditions for optimum plant establishment.

A suitable seedbed condition for germination and seedling emergence depends on soil physical properties. The soil organic matter is an important component of the soil. Soil organic matter consists of living organisms (< 5%), fresh organic residue (< 10%), active organic fraction (33–50%) and stabilized organic matter, also referred to as humus (33–50%).

Most soils contain 2–10% organic matter. Even in small amounts, organic matter is very important. Organic matter has a profound impact on soil physical, chemical and biological properties (Bell et al. 1998, Brussoard 1998, Jonge et al. 1999, Six et al. 2000, Carter 2002). Organic matter has several functions in soil; it increases nutrient holding capacity of soil, is a pool of nutrients for plants, improves water infiltration, decreases evaporation, increases water holding capacity, reduces crusting, improves aggregation, prevents erosion, and prevents compaction (Carter 2002).

Soil organic matter has to be at least 2% for soil productivity. With conventional wheat-sunflower rotation (Bowman et al. 2000), erosion (Olson et al. 2002), incorrect tillage (Kushwaha et al. 2001), and other applications (Schjonning et al. 2002) cause negative changes in the fertility of soils in the Thrace Region of Turkey. In this region, while 35.2% of the total arable area had organic matter over 2% in 1970, only 6% of the total arable area had more than 2% organic matter in 1989 (Tok 1991).

In recent years, insufficient seed germination and seedling emergence in sunflower production areas is a major problem, especially along with poor climatic conditions. This study was designed to determine the effects of soil organic matter on seed germination and seedling emergence in sunflower (*Helianthus annuus* L.).

MATERIAL AND METHODS

This research was conducted in 2000 and 2001 in the field and in glasshouse conditions as pot experiments. A large number of soil samples were collected from different parts of the Thrace Region, Turkey. Among them, twenty different soils containing different organic matter percentages (but showing similarity for other soil properties) were chosen. Soil properties are given in Table 1. The average soil properties were 6.90 pH, 51.00% water

Table 1. Properties of the soils containing different organic matter percentages

SOM (%)	pH	WS (%)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Lime (%)	EC (dS/m)	TMON.10^5	WCF (%)	WC0 (%)	WC1 (%)
0.14	6.94	51	78	601	2.52	1.5	0.4	18.0	8.4	3.2
0.60	6.91	50	79	587	2.50	1.5	1.3	18.7	8.9	3.1
0.92	6.93	52	80	600	2.51	1.5	15	18.9	9.1	3.5
1.17	6.89	50	77	588	2.49	1.5	92	19.4	9.5	3.7
1.50	6.87	51	78	594	2.50	1.3	187	19.9	9.5	4.1
1.91	6.89	51	80	600	2.51	1.5	209	20.1	9.7	3.9
2.18	6.91	51	79	601	2.48	1.4	233	20.4	10.1	4.7
2.54	6.93	52	78	589	2.52	1.5	248	20.9	11.3	4.8
2.92	6.90	51	80	597	2.50	1.5	360	20.3	12.1	5.9
3.24	6.93	51	78	596	2.51	1.5	371	20.5	12.4	7.4
3.60	6.92	51	81	605	2.50	1.5	476	21.4	12.7	8.6
3.85	6.89	51	82	612	2.50	1.4	480	22.9	12.5	9.5
4.17	6.90	50	80	609	2.52	1.5	484	21.3	10.4	10.7
4.58	6.90	52	82	605	2.50	1.5	509	21.5	11.5	10.7
4.81	6.90	51	82	595	2.48	1.5	520	21.4	11.7	11.5
5.11	6.88	52	81	596	2.49	1.6	627	22.3	14.5	10.5
5.46	6.87	50	81	603	2.50	1.5	645	23.8	16.4	12.8
5.79	6.89	51	81	600	2.49	1.6	767	24.6	16.3	13.4
6.63	6.88	51	82	609	2.50	1.6	906	24.9	16.3	13.9
6.68	6.87	51	81	613	2.48	1.6	785	24.1	16.1	13.4

SOM = soil organic matter, WS = soil water saturation, TMON = soil total micro organism number (number/g), WCF = soil water content at field capacity, WC0 = soil water content at the end of 2000 field experiment, WC1 = soil water content at the end of 2001 field experiment

saturation, 80 kg/ha P_2O_5, 600 kg/ha K_2O, 2.50% lime and 1.5 dS/m EC. In addition, the decrease of soil organic matter results decrease the soil water content, and decreasing the total soil living organisms determined by Dilution method (Black 1965). Organic matter of the twenty soils was 0.14, 0.60, 0.92, 1.17, 1.50, 1.91, 2.18, 2.54, 2.92, 3.24, 3.60, 3.85, 4.17, 4.58, 4.81, 5.11, 5.46, 5.79, 6.63, and 6.68%, determined by a modified Walkley-Black method (Chapman and Pratt 1961). Perlite (0.00%) was used as a control. Seedling emergence tests in the field were carried out with three sunflower cultivars (Sunbro, Isera, Pioneer 6482). Experimental design was Split Split Plot Design with four replications. The sowing depth was 2 cm for all experiments. 100 seeds were sown per pot being 5.3 liter on the 20 April in both years, when soil temperature reached 15–20°C. Prior to sowing, the soil was watered once to field capacity. In the rest of the experimental period, the pots were not watered, except by rainfall. Climatic data for 2000 and 2001 are presented in Table 2.

In the glasshouse, the same experiment using the same soils and sunflower varieties was conducted. Soil temperature and water content of the seedbed were kept around optimal (20 ± 2°C) for germination and seedling emergence. Unlike the field experiments, all pots in the glasshouse were kept around field capacity during the whole experimental period (each pot in the glasshouse was watered to field capacity when it weighed less than at field capacity). Seedling vigour was determined at the 14^{th} day after sowing. Statistical analyses were carried out by SAS program.

RESULTS AND DISCUSSION

Three hybrid sunflower cultivars were grown in the glasshouse and under two field condi-

Table 2. Climatic data during experimental periods in 2000 and 2001

Day	Temperature (°C)		Relative humidity (%)		Rainfall (mm)		Soil temperature of 5 cm depth (°C)		Soil temperature of 10 cm depth (°C)	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
1	15.8	14.2	88.7	85.7	3.6	–	16.1	16.0	15.9	15.8
2	14.8	15.4	94.7	78.3	1.1	0.1	16.5	14.7	16.2	14.8
3	15.0	16.3	92.3	69.0	12.5	0.4	17.8	18.0	17.6	17.2
4	15.2	11.6	94.3	80.7	9.4	0.3	16.9	14.4	16.6	14.9
5	14.9	16.3	93.7	46.0	3.7	2.9	17.0	16.3	16.8	15.9
6	16.9	16.2	88.7	63.0	0.3	–	19.5	19.2	19.0	18.7
7	14.4	14.8	92.7	78.0	2.2	–	18.5	19.3	18.2	19.0
8	13.2	15.3	93.0	79.3	–	–	15.5	20.5	15.4	20.0
9	14.8	16.8	85.0	68.0	4.0	–	17.4	21.6	16.6	21.1
10	15.9	15.3	91.3	63.7	5.0	–	16.9	21.2	16.6	20.9
11	16.4	14.2	89.0	75.7	2.8	–	19.1	19.5	18.7	19.3
12	15.1	15.7	90.7	60.7	–	–	20.7	19.3	19.1	19.1
13	14.4	18.3	95.0	49.3	–	–	17.7	19.8	17.7	20.0
14	10.2	16.2	75.7	69.0	31.7	–	13.8	21.0	13.9	21.7
15	10.7	16.7	71.0	69.3	–	–	14.9	21.6	14.5	21.3
Total	217.7	233.3	89.1	69.1	76.3	3.7	258.3	282.4	252.8	279.7

tions, a total of three different environments using 21 different seedbeds including the control (perlite). The result of variance analysis for seedling emergence is presented in Table 3. The effects of organic matter, environment, and their interaction on seedling emergence were all significant. However, the effects of the cultivar and other interactions on seedling emergence were not significant.

A comparison of environments with respect to mean seedling emergence percentage using the *LSD* test (5%) showed that the highest seedling emergence percentage (93.42%) was obtained from glasshouse experiments in which the optimum condition was provided for seed germination and seedling emergence (Figure 1). There was also a significant difference between the results of 2000 and 2001 field tests. Seedling emergence percentage in 2001 (69.87%) was lower than that in 2000 (76.13%), as total rainfall in 2001 was less than in 2000, and total temperature during the experimental period in 2001 was higher than in

Table 3. Variance analysis of data for seedling emergence

	df	Mean square	*F*-value
Organic matter	20	12 599.350	2 939.5**
Environment	2	34 484.905	8 745.4**
Cultivar	2	4.619	1.0
Organic matter × environment	40	2 294.355	535.2**
Organic matter × cultivar	40	4.407	1.0
Cultivar × environment	4	2.935	0.6
Organic matter × environment × cultivar	80	4.655	1.0

* and ** means statistical significance at the 0.05 and 0.01 levels, respectively

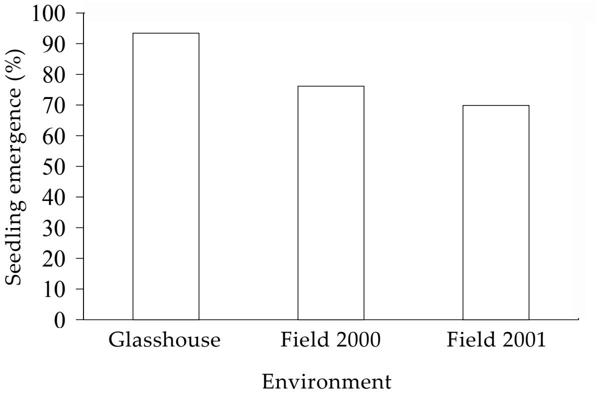

Figure 1. Comparison of environments for seedling emergence percentage (* means with different letter are significant at 0.05 significance level, $LSD_{0.05}$ = 0.362)

2000. The relatively high total temperature in 2001 caused more water evaporation from the soil.

Figure 2 indicates that seedling emergence percentage exponentially increased with increasing soil organic matter content. After about 3% organic matter content, the increase in seedling emergence slowed. All soils, except the soil containing the lowest organic matter, produced better results than the perlite control. All these clearly show that organic matter content in the soil is a very effective factor in seedling emergence, the first step of plant growth.

Although the field results in 2001 show similarity with those in 2000 at higher soil organic contents, seedling emergence in 2001 was more inhibited by soils containing low levels of organic matter, such

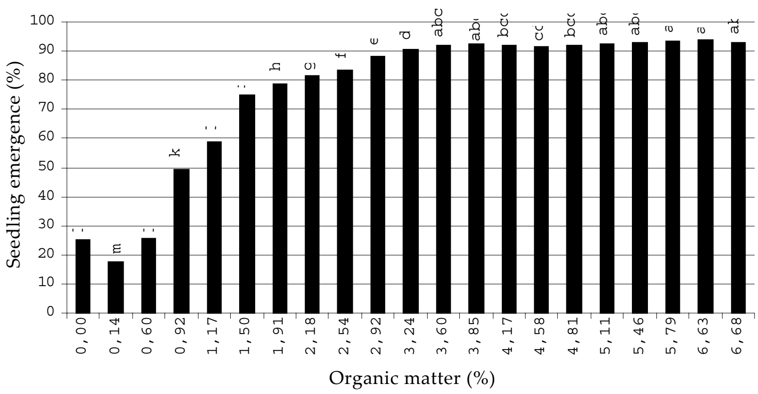

Figure 2. The effect of organic matter on average seedling emergence of three sunflower cultivars under field conditions in 2000 ($LSD_{0.05}$ = 1.660 and 0.00 organic matter indicates perlite as control)

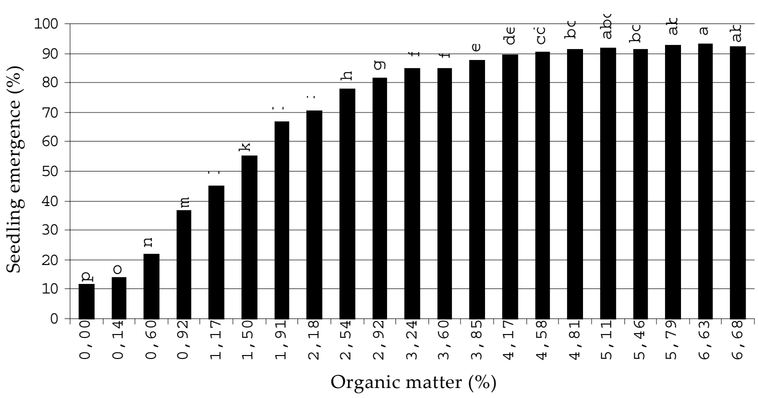

Figure 3. The effect of organic matter on average seedling emergence of three sunflower cultivars under field conditions in 2001 ($LSD_{0.05}$ = 1.660 and 0.00 organic matter indicates perlite as control)

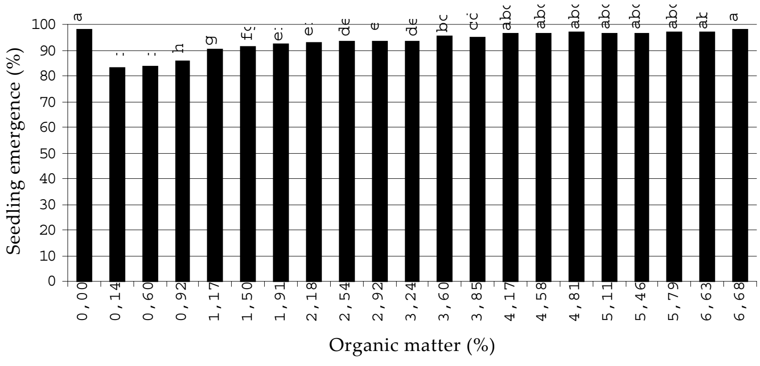

Figure 4. The effect of organic matter on average seedling emergence of three sunflower cultivars under glasshouse conditions ($LSD_{0.05}$ = 1.660 and 0.00 organic matter indicates perlite as control)

as 0.14 and 0.16% (Figure 3). This could be a result of relatively less rainfall and high temperature in 2001. Therefore, deficiency of organic matter in the soil had a more constraining effect on seedling emergence of sunflower grown in adverse environmental conditions, as in 2001. The effect of adverse environmental conditions, compared to 2000, was eased by higher soil organic matter contents (e.g. 6.63, 5.79 and 5.46%).

In addition to the field experiment, the same experiment was conducted in a glasshouse in order to see the response of hybrid sunflower cultivars to favourable conditions. Figure 4 shows the seedling emergence percentages in different soils including perlite, which were all watered and kept around optimum conditions during the whole experimental period. Temperature was also maintained at 20 ± 2°C. Seedling emergence in the glasshouse was higher than under field conditions. The highest seedling emergence was obtained in soils having the highest organic matter contents and in perlite control, whereas the lowest seedling emergence was obtained in soils with 0.14 and 0.60% organic matter. An additional point is that there was a lower variability between the lowest and highest seedling emergence values in the glasshouse experiment, compared to field conditions. However, there was still a reduction in seedling emergence with decreasing levels of organic matter. Even in the glasshouse where optimum growth conditions were provided, lower than 1% caused low seed germination and seedling emergence at unacceptable levels unacceptable for cultivation.

The results showed that the effects of environmental conditions and soil organic matter content were significant. The research also showed that, in unfavourable conditions, there would be a seedling emergence problem in soils containing less than 2.00% organic matter, possibly because of unsuitable soil physics and biological properties. It is well known that organic matter increases soil water capacity and lessens evaporation from the soil (Tisdale and Oades 1982, Jonge et al. 1999, Kushwaha et al. 2001). Good seedling emergence could reflect soil physical properties (Forbes and Watson 1992, Nasr and Selles 1995, Seiler 1998). Because a very small proportion of organic matter, the living biological part of the soil, is known to enhance seedbed conditions for desired seed (Anderson 2003). It could also be speculated that this living biological part of soil affects seed germination and seedling emergence.

In conclusion, organic matter content in the soil since it increases the water holding capacity of the soil had a significant effect on seedling emergence of the three hybrid sunflower cultivars. This effect was clearer in adverse environmental conditions. Especially in soils with less than 2% organic matter, it was found to be difficult to obtain or target optimum plant density for maximum seed yield.

This study addresses the problem of decreasing organic matter in the soil, a result of mistakes in cultivation such as tillage and, crop rotation, as well as erosion, that may cause problems in seed germination and seedling emergence. Organic matter content in poor soils should be ameliorated, for not only to obtain good seedling emergence, but also optimum plant growth at later stages.

REFERENCES

Ahmad S. (2001): Environmental effects on seed characteristics of sunflower (*Helianthus annuus* L.). J. Agron. Crop Sci., *187*: 213.

Anderson T.H. (2003): Microbial eco-physiological indicators to asses soil quality. Agr. Ecosyst. Environ., *98*: 285–293.

Bell M.J., Moody D.W., Connolly R.D., Bridge B.J. (1998): The role of active fractions of soil organic matter in physical and chemical fertility of fernasols. Aust. J. Soil Res., *36*: 809–820.

Black C.A. (1965): Methods of soil analysis. Part 2. Chemical and microbiological properties. Am. Soc. Agron., Madison, Wisconsin.

Bowman R.A., Nielsen D.C., Vigil M.F., Aiken R.M. (2000): Effects of sunflower on soil quality indicators and subsequent wheat yield. Soil Sci., *165*: 516–522.

Brussoard L. (1998): Soil fauna, guilds, functional groups and ecosystem process. Appl. Soil Ecol., *9*: 127–139.

Carter M.R. (2002): Organic matter and aggregation interactions that maintain soil functions. Soil quality for sustainable land management. Agron. J., *94*: 38–47.

Chapman H.D., Pratt P.F. (1961): Methods of analysis for soils, plant and waters. Agr. Publ. Univ. California Riverside, USA.

Forbes J.C., Watson R.D. (1992): Plant growth and development; seed and seedling. Plants in Agriculture. Cambridge Univ. Press., New York, USA: 110–129.

Jonge L.W., Jajobsen O.H., Moldrup D. (1999): Soil water repellency; effects of water content, temperature, and particle size. Soil Sci. Soc. Am. J., *63*: 437–441.

Kushwaha C.P., Tripathi S.K., Singh K.D. (2001): Soil organic matter and water-stable aggregates under different tillage and residue conditions in a tropical dryland agroecosystem. Appl. Soil Ecol., *16*: 229–241.

Nasr H.M., Selles F. (1995): Seedling emergence as influenced by aggregate size, bulk density, and penetration resistance of the seedbed. Soil Till. Res., *34*: 61–76.

Olson K.R., Jones R.L., Gennadiyex A.N., Chernyanskii S., Woods W.I., Long J.M. (2002): Accelerated soil erosion of a Mississippian Mound at Cahokia Site in Illinois. Soil Sci. Soc. Am. J., *66*: 1911–1921.

Schjonning P., Elmholt S., Munkholm L.J., Debosz K. (2002): Soil quality aspects of humid sandy loans as

influenced by organic and conventional long-term management. Agr. Ecosyst. Environ., *88*: 195–214.
Seiler G.J. (1998): Seed maturity, storage time and temperature, and media treatment effects on germination of two wild sunflowers. Agron. J., *90*: 221–226.
Six J., Elliott E.T., Paustian K. (2000): Soil structure and soil organic matter II. A. Normalized stability index the effect of mineralogy. Soil Sci. Soc. Am. J., *64*: 1042–1049.
Stewart B.W., Albrecht S.L., Skirvim K.W. (1999): Vagor transport vs. seed-soil contact in wheat germination. Agron. J., *91*: 783–786.
Tisdale J.M., Oades J.M. (1982): Organic matter and water stable aggregates in soils. J. Soil Sci., *33*: 141–163.
Tok H.H. (1991): Agriculture and environment pollution. Int. Environ. Symp. Rotary Clubs, Istanbul, Turkey: 198–213.

Received on July 22, 2003

ABSTRAKT

Vliv obsahu organické hmoty v půdě na vzcházivost nažek slunečnice (*Helianthus annuus* L.)

Vzcházivost semen je jedním z nejvýznamnějších faktorů založení porostu s optimální hustotou potřebnou k dosažení maximálního výnosu. Polní vzcházivost je dána kvalitou osiva a podmínkami seťového lůžka, které jsou ovlivněny složením půdy, a to zejména půdní organickou hmotou. Předmětem studia bylo proto stanovení vlivu organické hmoty v půdě na klíčení a vzcházivost tří hybridů slunečnice (*Helianthus annuus* L.). Výzkum byl realizován v letech 2000 a 2001 v polních a skleníkových pokusech. Perlit a 20 půdních vzorků s rozdílným obsahem organické hmoty byly použity jako varianty podmínek seťového lůžka. Obsah organické hmoty v půdě a prostředí a interakce organické hmoty s podmínkami prostředí průkazně ovlivňují vzcházivost osiva slunečnice. Se snižujícím se obsahem organické hmoty v půdě se snižuje vzcházivost osiva v důsledku poklesu obsahu vody v půdě. Uvedený vliv byl významnější za nepříznivých podmínek prostředí, zejména u půd s obsahem organické hmoty nižším než 2 %.

Klíčová slova: slunečnice (*Helianthus annuus* L.); vzcházivost semen; organická hmota v půdě; obsah vody

Corresponding author:

Yrd. Doc. Dr. Fadul Onemli, Trakya University, Tekirdag Agricultural Faculty, Tarla Bitkileri B., 59030 Tekirdag, Turkey
phone: + 90 282 2931 442 fax: + 90 282 293 1454 e-mail: fadilonemli@tu.tzf.edu.tr