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TILLAGE-INDUCED DIFFERENCES IN SOME PROPERTIES OFAGGREGATES-SIZE FRACTIONS

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NOT PRESENTED

ABSTRACT

Tillage can modify the composition of soil aggregates. The objective of this study was to determine the effects of tillage application under the sunflower (Helianthus annuus L.)- barley (Hardem vulgare L.)–A mixture of Hungarian vetch (Vicia pannonica (L.) Crantz)+ triticale rotation on some characteristics of soil aggregates in a loam soil. Organic C, available P and extractable K contents of aggregate size fractions (>4.76, 4.76- 2.0, 2.0- 1.0, 1.0- 0.5, 0.5- 0.25, 0.25>, mm) were determined on soil samples collected in 0- 20 cm depth of soil from three tillage systems (Chisel plow, chisel plow+ disc, chisel plow+ combine harrow) that had been established in 2001. There were no detectable differences in organic C and available P contents of the aggregate size fractions among tillage treatments. There, however, were a significant difference in available P and extractable K contents of the aggregate size fractions. Extractable K contents of the aggregate size fractions showed a significant difference among tillage treatments

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DETERMINING SOIL SURFACE CO_2 FLUX DURING WHEAT GROWTH UNDER NO-TILL AND CONVENTIONAL TILLAGE SISTEMS

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ABSTRACT

Soil surface CO_2 flux is the second largest flux in terrestrial carbon budget after photosynthesis. Plant root and microbial respirations produce CO_2 in soil, which are important component of global C cycle and atmospheric CO_2. This study determined the amount of CO_2 released during spring wheat (*Triticum aestivum L.*) growth under no-till (NT) and conventional tillage (CT) systems. This experiment was conducted on soil previously under continuous corn production with NT and CT for more than 10 years. In this study, surface CO_2 flux and soil air CO_2 concentration were measured weekly after wheat emergence. Surface CO_2 flux was measured using a LI-COR 6200 (LI-COR Inc, Lincoln, NE, USA). Soil samples were also taken for determining microbial respiration under laboratory conditions. No-till generally had higher soil water content and greater microbial activity at the surface with decreasing from planting to harvest, while activity was constant in the deeper depths. The total amounts of CO_2 released from CT and NT to the atmosphere were accounted for 233 g C m^{-2} and 192 g C m^{-2} during spring wheat growth. Conventional tillage released 20% more CO_2 to the atmosphere compared to NT.

INTRODUCTION

Carbon dioxide in soil is produced by plant roots and microbial respiration. Soil surface CO_2 flux is the largest flux in terrestrial carbon budget except for photosynthesis. Soil CO_2 flux is positively correlated with net primary productivity because the plant is the source of energy for microorganisms (Raich and Schlesinger, 1992; Kogel-Knaber, 2002).

Some scientists have reported that terrestrial ecosystems play an important role in the global C cycle and contribute to the annual variability of atmospheric CO_2 (Schimal et al., 2001). On a global scale, soil organic matter contains twice as much C as the atmosphere (Schlesinger, 1997; Post et al., 1982; Jenkinson et al., 1991), and the source of CO_2 from this globally important pool is mediated by the activities of soil microorganisms. Carbon flow through the terrestrial ecosystem can be defined as fixation of atmospheric CO_2 by photosynthesis, and the transfer of plant, animal, and microbial biomass carbon from one trophic level to another. During this process, some of the carbon in the plant material is mineralized and returned back to the atmosphere with the remaining residing in the soil for longer periods of time in different forms of soil organic matter.

Decomposition of soil organic matter by soil heterotrophs reduces the potential for C storage in the soil. The rate of carbon loss or sequestration from soil is a function of heterotrophic respiration and net primary productivity (NPP) (Buyanovsky et al., 1987). Some studies indicate that the rate of CO_2 production in the soil is a function of soil temperature and soil water content (Norman et al., 1992; Lloyd and Taylor, 1994; Paul

and Clark, 1996; Trumbore, 1997; Knapp et al. 1998; Sotomayor and Rice, 1999; Meilnick and Dugas, 2000). Any alteration in the environmental factors affecting photoassimilation may be expected to affect the release of exudates (Hodge et al., 1997) and root respiration, and as a consequence, the total CO_2 flux from planted soil.

Soil surface flux can be affected by pore size distribution, water content, soil and air temperature, and surface wind speed (Raich and Schlesinger, 1992). The concentration of CO_2 in a soil profile is function of abiotic factors such as temperature, soil water, substrate availability, which affect biological activity and eventual CO_2 concentration in the soil (Norman et al., 1992; Lloyd and Taylor, 1994; Paul and Clark, 1996; Trumbore, 1997; Sotomayor and Rice, 1999; Knapp et al. 1998; Meilnick and Dugas, 2000). Land use and management practices are the factors that most effect the decomposition of organic materials in soils (Ajwa and Tabatabai, 1994).

Tillage causes higher fluxes of CO_2 compared to no-tillage (Dao, 1998; Lupwayi et al., 1999). Leaving residue on the soil surface minimizes the soil–residue contact and lowers surface soil temperature resulting in a lower decomposition rate. In general, the decomposition rates of residue are lower when left on the soil surface than when incorporated into soil. The reduced residue decomposition and less soil disturbance usually results in greater amounts of soil C and lower CO_2 flux in no-tillage than tilled systems.
The objective of this study was to determine soil surface CO_2 flux during spring wheat growth with two tillage (no-till and conventional tillage) systems.

MATERIALS and METHODS

This experiment was conducted at Kansas State University North Agronomy Farm, Manhattan, KS, on a Kennebec silt loam (Fine-silty, mixed, superactive, mesic Cumulic Hapludoll). The experimental site had been in continuous corn production with no-till and conventional tillage systems for more than 10 years. Spring wheat (*Triticum aestivum L.*) was planted as 130 kg seed ha^{-1} with two tillage systems (no-till (NT) and conventional tillage (CT)) as four replicates in March. All the treatments were randomly distributed to the plots. After planting, 55 kg N ha^{-1} was applied as NH_4NO_3 to the surface.

Soil surface CO_2 flux was measured using a portable gas exchange (infrared) gas analyzer (LI-COR 6200, LI-COR Inc, Lincoln, NE, USA) adapted by Norman et al. (1992). Soil surface CO_2 flux was measured weekly from randomly selected three sampling location of each plot. Soil temperature was also measured at 0 – 5 cm depth during CO_2 readings using a digital temperature probe (Fisher Scientific Inc., Pittsburgh, PA).

Soil profile gas samples were collected using a multiport gas sampler to collect soil gas samples from different depths (10, 25 cm) at each location. Four samplers were installed for each treatment. The sampler was made from polyvinyl chloride (PVC) pipe (0.5 m long, 2.54 cm diam.). Each sampler contained three lengths of stainless steel tubing (0.14 cm i. diam., 0.32 cm o. diam.) extended to the designated sampling depths. Soil

profile CO_2 concentration determined using a Shimadzu Gas Chromatography-8A (Shimadzu Scientific Instruments Inc., Columbia, MD).
Soil samples were taken weekly during wheat growth from 0–5, 5–15, and 15-30 cm depths. Soil samples were passed through a 4-mm mesh to homogenize and remove large fragments and plant materials. Soil microbial activity was measured by placing 20 g of fresh soil in a 160 mL serum bottle and incubated for 48 h at 25 ^{o}C. The CO_2-C evoled was measured 4 to 5 times during the incubation by taking gas samples from the headspace of each serum bottle.

Data Analysis

Measurements at each plot were averaged during sampling, and analysis of variance and separation of means by least significant differences test were performed on soil surface CO_2 flux using SAS procedures (SAS Institute Inc., 1996). Regression analysis was also conducted of the soil surface CO_2 flux versus soil water content and soil temperature using SAS (SAS Institute Inc., 1996).

RESULTS

Soil water content decreased from planting through harvest at 0 – 5 cm depth in both tillage systems (Fig.1). The CT plots had the lowest soil water content throughout wheat growth compared to the NT plots. A similar trend was measured at deeper depths.

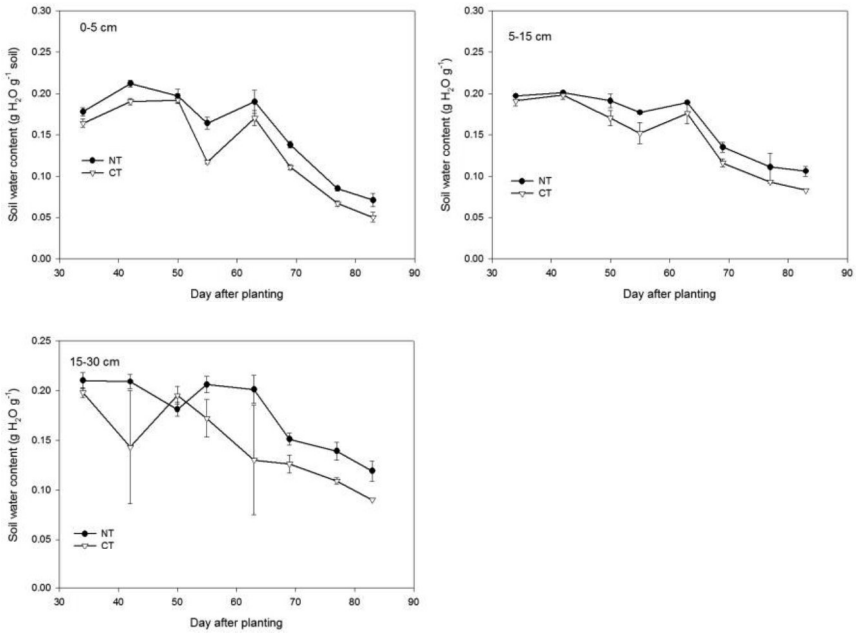


Figure 1. Soil water content in no-till (NT) and conventional tillage (CT) plots at 0-5, 5-15, and 15-30 cm depths during spring wheat growth. The bar represent the standard error.

Soil temperature was initially greater in the CT plots; however, during wheat growth, soil temperature was similar for all treatments (Fig. 2).

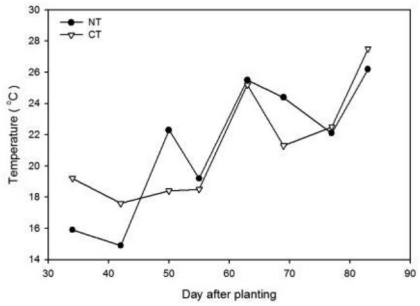


Figure 2. Soil surface temperature at 0-5 cm depth in no-till (NT) and conventional tillage (CT) plots.

Soil respiration, as an index of microbial activity was generally higher at the surface and decreased with soil depth (Fig. 3). Microbial activity generally decreased from planting to harvest at 0–5 cm depth, while microbial activity was constant at the 5–15 and 15–30 cm depths.

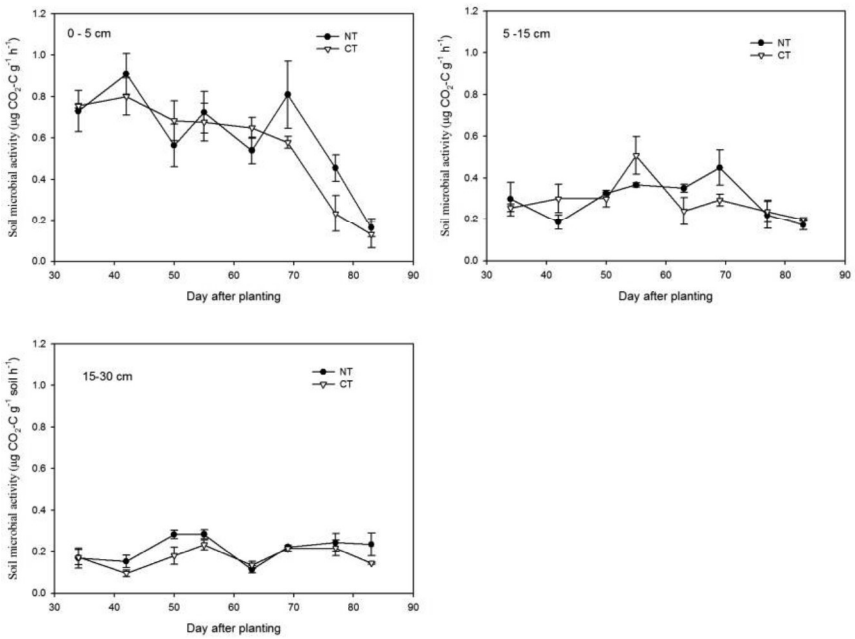


Figure 3. Soil microbial activity in no-till (NT) and conventional tillage (CT) plots at 0-5, 5-15, and 15-30 cm depths. The bar represent the standard error.

The soil air CO_2 concentration increased from planting to harvest and the greatest variation occurred in NT at 25 cm depth, ranging from 1327 to greater than 5000 μg CO_2-C L^{-1} with a mean value of 3900 μg CO_2-C L^{-1} (Fig. 4). The higher CO_2 concentration in NT could be the result of lower CO_2 diffusion at 25 cm depth.

Carbon dioxide in soil is produced by microbial and root respiration. Soil surface CO_2 flux was significantly higher ($p < 0.05$) in CT than NT (Fig. 5). The initial CO_2 flux was greater in CT plots (6.27 □mol CO_2 m^{-2} s^{-1}) compared to NT plots (2.50 □mol CO_2 m^{-2} s^{-1}). The higher CO_2 flux is probably due to disturbance from tillage and higher soil temperatures resulting in increased microbial activity in CT. Carbon dioxide flux increased during the growing season in the both tillage systems due to root and

rhizomicrobial respiration. The lowest CO_2 flux during wheat growth was measured at flowering stage as 2.93 □mol CO_2 m^{-2} s^{-1}. This lower CO_2 flux could be related to plant physiology, which would have translocated C to grain, and reduced root growth, respiration, and exudates. Total soil surface flux was 20% higher in CT than NT (Table 1). The greatest CO_2 flux was 233 g CO_2-C m^{-2} in CT while NT was 192 g CO_2-C m^{-2}.

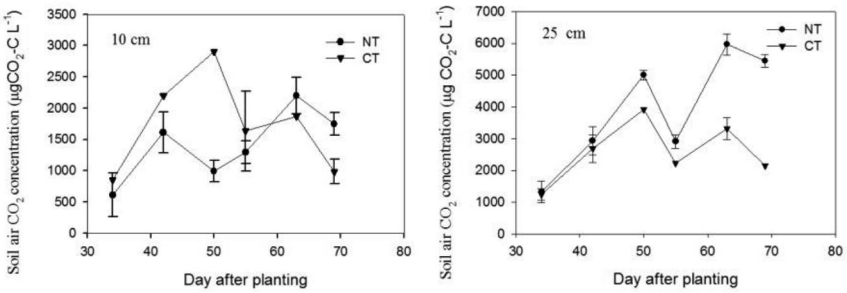


Figure 4. Soil air CO_2 concentration in no-till (NT) and conventional tillage (CT) plots at 10 and 25 cm depths. The bar represent the standard error.

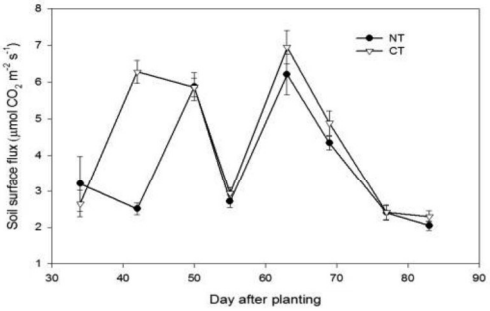


Figure 5. Soil surface CO_2 flux in no-till (NT) and conventional tillage (CT) plots.

Table 1. Total soil surface CO_2 flux during wheat growth under no-till (NT) and Conventional tillage (CT)

	g CO_2-C m^{-2}
No-till	192
Conventional tillage	233

In order to determine which environmental factors (soil temperature and water content) is more important on soil surface CO_2 flux; regression were done in the both tillage systems. There was a significant relationship (r^2=0.50 and 0.27; $p < 0.05$) between soil water content and soil CO_2 flux in the both tillage systems (Fig. 6). Generally, soil water content was the more important factor determining soil CO_2 flux in this study. There was no correlation between soil CO_2 flux and soil surface temperature in the both tillage systems (data not presented).

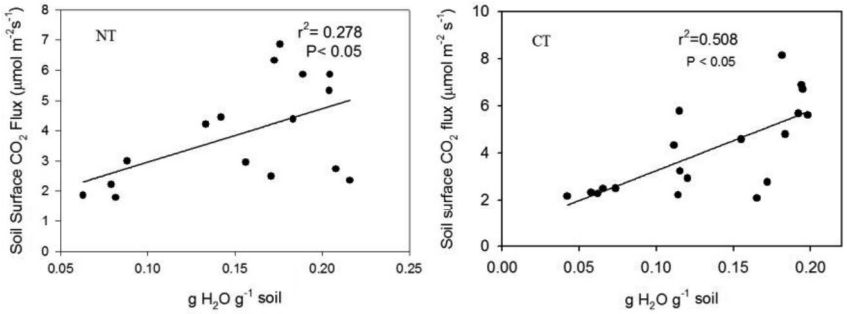


Figure 6. Soil surface CO_2 flux vs. soil water content in no-till (NT) and conventional tillage (CT) systems.

DISCUSSION

Soil microbial activity generally decreased from planting to harvest at 0-5 cm while it was constant at 5-15 and 15-30 cm depths. The decrease in microbial activity could be the result of water limiting microbial activity.

In this study, conventional tillage resulted in 20% higher CO_2 efflux compared to NT. Curtin et al. (2000) measured a similar percent (20-23%) reduction in total CO_2 flux in NT compared to CT under wheat production in Canada. No-till generally reduced CO_2 emissions, but had little or no effects on soil C inputs. Since tillage had negligible effects on C inputs, lower CO_2 emissions under NT compared to CT can be attributed to slower decomposition of crop residues resulting in net C gain. The C flux measurements and soil surface C data suggest C sequestration in NT. Based on the soil surface CO_2 flux, NT may sequester 20% higher C in soil compared to CT. The adoption of NT would increase C in stable or passive soil organic matter fractions. However, a portion of the C gained under NT would also be in the light fraction (Curtin et al., 2000), which is labile and vulnerable to rapid decomposition (Gregorich and Janzen, 1996). Beare et al. (1994) proposed that some of the organic C gained under NT may be sequestered within soil aggregates, where it would be protected from rapid decomposition.

The greater soil CO_2 flux in CT is the result of disturbance effect on decomposition of soil organic matter and increased porosity allowing for faster diffusion of gases. Tillage breaks down soil aggregates and releases physically protected organic matter in the soil, which increases microbial activity, and eventually soil CO_2 flux. Reicosky et al. (1999) reported that cumulative CO_2 flux from CT at the end of 80 h was nearly three times higher than NT. Conventional tillage also had greater soil surface temperature, which could increase microbial activity. The NT plots had lower initial soil surface temperature and greater water content that could minimize microbial activity and decomposition of soil organic matter.

Soil CO_2 flux was positively correlated with soil water content, and at higher soil water contents, soil CO_2 flux increased, but the variation was greater at higher soil water contents. The greater response to soil water could be due to higher root activity and root biomass production, which could increase root respiration and rhizomicrobial activity.

The lack of response to soil temperature indicates that soil temperature was not an important factor on soil CO_2 flux. Doyle (2001) also reported a low importance of temperature on CO_2 flux. Rochette et al. (1999) reported a high positive correlation between soil temperature and soil CO_2 flux for a warm season crop (corn) and unplanted plots in Canada (r^2=0.96 and 0.83).

In summary, conventional tillage system resulted in 20% more soil surface CO_2 flux compared to NT. Microbial activity was generally higher through wheat growth, and microbial activity decreased from planting to harvest at the surface while it was constant at the deeper depths. In this study, soil water content was the most important determining factor on soil respiration.

REFERENCES

Ajwa, H.A., and M.A. Tabatabai. 1994. Decomposition of different materials in soils. Biol. Fertil. Soils. 18:175-182.

Beare, M.H., M.L. Cabrera, P.F. Hendrix, and D.C. Coleman. 1994. Aggregate-protected and unprotected organic matter pools in conventional- and no-tillage soils. Soil Sci. Soc. Am. J. 58:787-795.

Buyanovsky, G.A., C.L. Kucera, and G.H. Wagner. 1987. Comparative analysis of carbon dynamics in native and cultivated ecosystems. Ecology 68:2023-2031.

Curtain, D., H. Wang, F. Selles, B.G. McConkey, and C.A. Cambell. 2000. Tillage effects on carbon fluxes in continuous wheat and fallow-wheat rotations. Soil Sci. Soc. Am. J. 64:2080-2086.

Dao, T.H. 1998. Tillage and crop residue effects on carbon dioxide evolution and carbon storage in a paleustoll. Soil Sci. Soc. Am. J. 62:250-256.

Gregorich, E.G., and H.H. Janzen. 1996. Storage of soil carbon in the light fraction and macroorganic matter. p. 397-407. *In* M.R. Carter and B.A. Stewart (ed.) Structure and soil organic matter storage in agricultural soils. Lewis Publ., Boca Raton, FL.

Hodge, A., E. Paterson, B. Thornton, P. Millard, and K. Killham. 1997. Effects of photon flux density on carbon partitioning and rhizosphere carbon flow of *Lolium perenne*. J. Exp. Bot. 48:1797-1805.

Jenkinson, D.S., D.E. Adams, and A. Wild. 1991. Model estimate of CO_2 emissions from soils in response to global warming. Nature. 351:304-306.

Knapp, A.K., S.L. Conard, and J.M. Blair. 1998. Determinants of soil CO_2 flux from a sub-humid grassland: Effects of fire and fire history. Ecol.Appl. 8:760-770.

Kogel-Knabner, I. 2002. The macromolecular organic composition of plant and microbial residues as inputs to soil organic matter. Soil Biol. Biochem. 34:139-162.

Lloyd, J., and J.A. Taylor. 1994. On the temperature dependence of soil respiration. Funct. Ecol. 8:315-323.

Lupwayi, N.Z., W.A. Rice, and G.W. Clayton. 1999. Soil microbial biomass and carbon dioxide flux under wheat as influenced by tillage and crop rotation. Can. J. Soil Sci. 79:273-280.

Mielnick, P.C., and W. A. Dugas. 2000. Soil CO_2 flux in a tallgrass prairie. Soil Biol. Biochem. 32:221-228.

Norman, J.M., R. Garcia, and S.B. Verma. 1992. Soil surface CO_2 fluxes and carbon budget of a grassland. J. Geophys. Res. 97:18885-18853.

Paul, E.A., and F.E. Clark. 1996. Soil microbiology and biochemistry, 2nd Ed. Academic Press, London, New York.

Post, W.M., W.R. Emanuel, P. Zinke, and A.G. Strangerberger. 1982. Soil carbon pools and world life zones. Nature. 298:156-159.

Raich, J.W., and W.H. Schlesinger. 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus 44B:81-99.

Reicosky, D.C., D.W. Reeves, S.A. Prior, G.B. Runion, H.H. Rogers, and R.L.Raper. 1999. Effects of residue management and controlled traffic on carbon dioxide and water loss. Soil Till. Res. 52:153-165.

Rochette, P., L.B. Flanagan, and E.G. Gregorich. 1999. Separating soil respiration into plant and soil components using analysis of natural abundance. Soil Sci. Soc. Am. J. 63:1207-1213.

SAS Institute Inc., 1996. SAS procedure guide, Release 6.12.

Schimel, D.S., J.I. House, K.A. Hibbard, P. Bousquet, P. Ciais, P. Peylin, B.H. Braswell, M.J. Apps, D. Baker, A. Bondeau, J. Canadell, G.Churkina, W. Cramer, A.S. Denning, C.B. Field, P. Friedlingsten, C. Goodale, M. Heimann, R.A. Houghton, J.M. Melillo, B. Moore III, D. Murdiyarso, I. Noble, S.W. Pacala, I.C. Prentice, M.R. Raupach, P.J. Rayner, R.J. Scholes, W.L. Steffen, and C. Wirth. 2001. Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. Nature. 414:169-172.

Schlesinger, W.H. 1997. Biogeochemistry: An analysis of global change. 2nd ed. Academic press, San Diego, CA.

Sotomayor, D., and C.W. Rice. 1999. Soil air carbon dioxide and nitrous oxide concentrations in profiles under tallgrass prairie and cultivation. J. Environ. Qual. 28:784-793.

Trumbore, S.E. 1997. Potential responses of soil organic carbon to global environmental change. Proc. Natl. Acad. Sci. 94:8284-8291.

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THE EFFECT OF DIFFERENT TYPE OF SALTS AND SALINITY LEVELS ON VEGETATIVE GROWTH, WATER CONSUMTION and MINERAL MATTER CONTENTS OF EGGPLANT (*Solanum melongena*, L.)

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ABSTRACT

This study was carried out to determine the effect of different type of salts and salinity levels on vegetative growth, water consumption and soil salinity of eggplant. NaCl, $MgSO_4$, $NaHCO_3$ and $CaCl_2$ salts were used to obtain 2.5 and 5.0 dS/m salinity levels. The experiment was conducted in fully randomized design with a single control group with 3 replications, and totally with 9 treatments in a green house. The experimental soils were sieved through 4 mm sieve and the pots were filled with 10 kg of air-dried soils. Irrigations were performed when 50% available water was extracted from the soil. The extraction rate of the water from the pots was observed by means of weighting the pots in 2-3 days intervals. Through the statistical analyzes the effects of both type and amount of salts on vegetative growth, biomass, length of the plants, total ash, water performed and mineral matter content in leaves were found significant. Whereas $MgSO_4$ salt caused to increase all these parameters, NaCl, $NaHCO_3$ and $CaCl_2$ salts caused to decrease. The augmentation of salinity levels for each type of salts from 2.5 dS/m to 5 dS/m made these effects more severe. Soil salinity also increased with increasing the salinity levels. Total ash rate was found to be higher when main salt in irrigation water were NaCl or $CaCl_2$.

INTRODUCTION

Salt tolerance is usually assessed as the percent biomass production in saline versus control conditions over a prolonged period of time. Dramatic differences are found between plant species. For example, after some time in 200 mm NaCl a salt-tolerant species such as sugarbeet might have a reduction of only 20% in dry weight, a moderately tolerant species such as cotton might have a 60% reduction, and a sensitive species such as soybean might be dead (Greenway and Munns 1980). A halophyte such as *Suaeda maritima* might be growing at its optimum rate (Flowers et al. 1977, 1986). Salt tolerance can also be assessed in terms of survival, which is quite appropriate for perennial species, but for annual species, particularly for broadacre or horticultural crops, the rate of biomass production is more useful, as this usually correlates with yield (Munns, 2002).

In southern and eastern Mediterranean areas renewable water resources are very scarce. Indeed, their per capita availability is the lowest worldwide. A large fraction (53%) of the population experience long periods of water shortage, and 18% of the population suffer periodical lack of water (World Bank, 1992). A salinity problem related to water quality occurs if the total quantity of the salts in the irrigation water is such that salts accumulate in the root-zone. Moreover, according to Manchanda et al. (1993) in areas where annual rainfall is less than 250 mm, saline waters (EC>4 dS m^{-1}) will cause salt toxicity in most crops. In areas where annual rainfall exceeds 500 mm, water up to an

EC=16 dS m^{-1} can be utilized for some crops. The suitability or unsuitability of irrigation water should also be evaluated on the basis of local conditions in conjunction with the prevailing climate, soil and plant growth. The effect of salts on crop growth is believed to be largely of an osmotic nature. If excessive quantities of soluble salts accumulate in the root-zone, the crop has extra difficulty in extracting enough water from the saline solution, thereby affecting the yield adversely (Somani 1991). These trends have led research to be carried out into the use of lower quality water in agriculture, in addition to renewing efforts achieve water conservation. Both saline and wastewater may be used for irrigation, but then the chemical, physical and biological properties of water have to be analyzed as a function of its intended use (Tedeschi and Menenti, 2002). In this respect different salt types,which may be present at irrigation water, have to be examined for thier usage in agricultural production. *Solanum melongena* L. commonly known as eggplant, aubergine, guinea squash or brinjal, is an economically important vegetable crop of tropical and temperate parts of the world. It is a good source of vitamins and minerals (particularly iron) making its total nutritional value comparable with tomato (Kallo, 1993). Aubergine (*Solanum melongena*) is a member of the Solanum genus of the Solanaceae family. It is an annual plant in temperate climates and a small tree in tropical climates (Davis, 1978). Aubergine is both consumed as a fresh vegetable and also dried and stored for future use in Turkey and in other countries (Dogan et. al. 2002).

Sevaral experiments were conducted to determine the effects of NaCl on tomato (Satti and Ahmad, 1992; Satti and Lopez, 1994; Inal, 2002), on radish (Yurtseven et al., 2000, Koc, 1998) and on eggplant (Hashem, 1991; Shimose et. al., 1991; Chartzoulakis and Loupassaki, 1997; Savvas and Lenz 2000; Akinci and Akinci, 2000; Ozturk, 2002;) and so on, but less data are available about different salt types such as $MgSO_4$, $NaHCO_3$ and $CaCl_2$ This study was carried out to determine the effects of different salt types and concentration levels on eggplant.

MATERIALS AND METHODS

This study was carried out to determine the effect of different type of salts and salinity levels on vegetative growth, water consumption (ET), biomasss, plant height, total ash, leaf area, Ca, Na, K, Mg and Cl of leaves of eggplant. Control (0.25 dS/m) and NaCl, $MgSO_4$, $NaHCO_3$ and $CaCl_2$ salts were used to obtain 2.5 and 5.0 dS/m salinity levels. The experiment was conducted in fully randomized design with 3 replications and 9 treatments, totally within 27 pots in a green house, in Ankara University research area. The experimental soils were sieved through 4 mm sieve and the pots were filled with 10 kg of air-dried soils. Table 1 shows some characteristics of the experimental soil. Irrigations were performed when 50% available water was extracted from the soil. The extraction rate (evapotranspration) of the water from the pots was observed by means of weighting the pots in 2-3 days intervals by digital scale. The plant biomass was determined by weighting the plant, which was oven-dried at 70^0C. Leaf areas were determined by means of digital planimater after harvest.

Soil texture was determined according to Bouyoucos (1951). Soil field capacity permanent wilting point, pH, potassium, sodium, calcium and magnesium, chloride, organic matter and EC were determined according to Anonymous (1982). Bulk density was determined according to Jury et al. (1991).

Table 1. The Physical and Chemical Characteristics of the experiment Soil

Bulk Density g/cm^3	pH	EC dS/m	P ppm	K ppm	N %	Org. Mat. %
1,24	7.69	0.4	38.6	395.92	0.15	1.06
Texture	Sand %	Clay %	Silt, %	$CaCO_3$, %	Field Capacity %	Wilting point %
(SCL)	55	24	21	10.69	24	19

RESULTS AND DISCUSSION

Water Consumption

The evapotranspiration data was collected and given in terms of liter/plant-season in Table 2. The variance analysis did not show the effect of interaction, but the single effects of the type of salts and the concentration levels were found to be significant on water consumption rates at 0.01.

Table 2. Water consumption and Duncan test results in letter/plant-season

Treatments	**NaCl**	**$MgSO_4$**	**$NaHCO_3$**	**$CaCl_2$**
2.5 dS/m	22,93	29,10	20,47	25,07
5.0 dS/m	19,60	26,40	20,80	22,93
Salts	NaCl	$MgSO_4$	$NaHCO_3$	$CaCl_2$
p= 0,000 Control=29.80 liter/plant-season	21,27 c	27,75 a	20,63 c	24.10 b
Concentration	2.5 dS/m		5.0 dS/m	
p=0,008	24,39 A		22,433 B	

Duncan test results indicated that water cunsumption depend on the type of salts (Table 2). Water consumption of eggplant was the highest when appliying water dominated with $MgSO_4$. In one-hand sodium salts, both NaCl and $NaHCO_3$ were in the same statistical group; on the other hand chloride salts such as NaCl and $CaCl_2$ were in different groups. While irrigation performed with water dominated with $CaCl_2$, water consumption was 24.10 leter/plant-season, other clorur salt, NaCl, was 21.27 leter/plant-season.

Duncan test results also indicated that the salinty concentration levels affected the water consumption (Table 2). Water consumption decreased with increasing salinty concentration by 8%.

Vegetative Yield

Vegetative yield data were collected just after harvest, weighing the whole green plant as a sign of vegetative growth (VG). The variance anlysis for VG showed that the type of salts and the concentration were individually significant at $p<0.01$ level but interaction did not exist. Table 3 shows vegetative yield data in grams.

Table 3. Vegetative yield and Duncan test results in gram/plant

Treatments	**NaCl**	**$MgSO_4$**	**$NaHCO_3$**	**$CaCl_2$**
2.5 dS/m	65,01	83,04	59,3	65,11
5.0 dS/m	41,49	71,29	48,71	37,58
Salt types	NaCl	$MgSO_4$	$NaHCO_3$	$CaCl_2$
p= 0,001 Control=66.42gram/plant	53,25 b	77,17 a	54,01 b	51,35 b
Concentration	2.5 dS/m		5.0 dS/m	
P=0,000	68,12 A		49,77 B	

Duncan test result in Table 3 indicated that NaCl, $NaHCO_3$, and $CaCl_2$ salts were all in the same Duncan group but $MgSO_4$. Comparing to $MgSO_4$, the reductions in vegetative yield for NaCl, $NaHCO_3$ and $CaCl_2$ were 31%, 30% and 34% respectively. $MgSO_4$ acted as a fertilizer because this salt, comparing to control yielded higher amount of VG. Duncan test results for concentration levels indicated that increasing salinity levels led to decrease in vegetative yield by 27%.

Biomass Yield

The effect of salt types and concentration levels on biomass yield were found to besignificant at $p< 0.01$ significance level. Duncan test results (Table 4) showed that $MgSO_4$ constituted the highest yield with 16.21 gram/plant and NaCl did the lowest with 8.60 gram/plant. It is clearly seen that $MgSO_4$ was very effective on increasing vegetative growth of eggplant. Comparing to control, $MgSO_4$ yielded more than control. Duncan test results also showed that increased concentration levels led to decrease in biomass production by 36%.

Table 4. Biomass yield and Duncan test results in gram/plant

Treatments	**NaCl**	**$MgSO_4$**	**$NaHCO_3$**	**$CaCl_2$**
2.5 dS/m	10,84	17,14	10,08	11,14
5.0 dS/m	6,36	15,28	8,36	6,23
Salt types	NaCl	$MgSO_4$	$NaHCO_3$	$CaCl_2$
p= 0,000 Control=14.61 gram/plant	8,60 b	16,21 a	9,20 b	8,69 b
Concentration	2.5 dS/m		5.0 dS/m	
P=0,000	12,30 A		9,05 B	

Leaf Area

The leaf area data were obtained at the end of the season, measuring the whole plant leaves total area with a digital planimater (Table 5). The variance analysis indicated that neither the type of salt, nor salt concentration did not statistically effect to leaf area.

Table 5. The leaf area data in cm^2

Treatments	**NaCl**	**$MgSO_4$**	**$NaHCO_3$**	**$CaCl_2$**
2.5 dS/m	778	1528	924,8	1074,3
5.0 dS/m	898	1059,1	960,8	712

Total Ash

The data obtained for total ash (%) was given in Table 6. The variance analysis for total ash showed that there is no interaction between the treatments but the salt types and concentration levels, separately, have effects on total ash (%) at $p<0.01$.

Table 6. The total ash (%) and Duncan test results in gram/plant

Treatments	**NaCl**	**$MgSO_4$**	**$NaHCO_3$**	**$CaCl_2$**
2.5 dS/m	21,51	17,68	16,87	21,72
5.0 dS/m	25,29	16,30	17,93	25,56
Salts	NaCl	MgSO4	NaHCO3	CaCl2
p= 0,000 Control= 16.17 gram/plant	23,40 A	16,99 B	17,40 B	23,64 A

Duncan test results are given in Table 6. The test results showed that among the salt types NaCl and $CaCl_2$ caused to great increase in total ash comparing to $MgSO_4$ and $NaHCO_3$. The results aslo indicated that NaCl caused more severe decreases than $NaHCO_3$. This may mean that chloride anion had more effect on total ash because both salts yielded more total ash (%).

Sodium Content in Leaves

The interactions of salt types and concentration levels were found to be sigificant at 0.01 level. Duncan test results (Table 7) shows that for 2.5 dS/m salinity level only NaCl and $NaHCO_3$ salts caused to increase in Na content. The amount of Na accumulation in leaves did not depend on the anions, Cl or HCO_3 with which Na compounded. Increased concentration level, 5 dS/m, caused to increase in Na in leaves for both Na compounds.

Table 7. Duncan test results for Na% in leaves, interaction p= 0.000, Control= 0.050, %

Salts*Concentration	**NaCl**			**$MgSO_4$**			**$NaHCO_3$**			**$CaCl_2$**		
2.5 dS/m	1,304	⇓b	⇒A	0,1073	⇓a	⇒B	1,35	⇓b	⇒A	0,083	⇓a	⇒B
5.0 dS/m	2,862	⇓a	⇒A	0,034	⇓a	⇒B	2,678	⇓a	⇒A	0,1260	⇓a	⇒B

Potassium Content in Leaves

The variance analysis for potassium content in leaves showed that the type of salts and the concentration levels did not yield an interaction but increasing concentration levels caused to decrease in K accumulation in leaves. The obtained data for K absorption in leaves were given in Table 8. The variance anlysis for K comparing to concentration levels was found to be significant at 0.05. The effect salt type did not exist. Duncan test results shows that increased concentration levels led to decrease in the accumulation of potassium in leaves. The decrease was 22%, corresponding to increase from 2.5 to 5.0 dS/m concentration level.

Table 8. K in leaves and Duncan test results, in %

Treatments	**NaCl**	**$MgSO_4$**	**$NaHCO_3$**	**$CaCl_2$**
2.5 dS/m	4,16	4,65	3,51	4,49
5.0 dS/m	3,21	3,52	2,61	3,73
Concentration levels	2.5 dS/m		5.0 dS/m	
p=0,006 Control= 4.21%	4,203 A		3,245 B	

Magnesium Content in Leaves

The variance analysis shows that the salt types and the concentration levels interaction did not exist but the salt types affected Mg accumulation in leaves at 0.05. Table 9 shows Duncan test results, Mg (%), in leaves for the treatments. Duncan test results indicated that $MgSO_4$ led to increase in Mg accumulation in leaves, comparing to NaCl, $NaHCO_3$ and $MgSO_4$, 29%, 53% and 23%, respectively.

Table 9. Mg in leaves and Duncan test results, in %

Treatments	**NaCl**	**$MgSO_4$**	**$NaHCO_3$**	**$CaCl_2$**
2.5 dS/m	0,11	0,154	0,078	0,152
5.0 dS/m	0,12	0,195	0,08	0,112
Salt types	NaCl	MgSO4	NaHCO3	CaCl2
p= 0,004 Control= 0.092%	0,12 AB	0,17 A	0,08 B	0,13 AB

Calcium Content in Leaves

The variance analysis for Ca% shows that the interaction between the salt type and the concentration level is significant at 0.05 (Table 10). The results for 2.5 dS/m concentration level indicated that NaCl caused the maximum Ca accumulation in leaves, however $CaCl_2$ was in the same Duncan group**.** $NaHCO_3$ showed a great decrease in Ca content in leaves. This decrease, comparing to $CaCl_2$ was 46%. For 5.0 dS/m concentration level, these relation was quite different because at this level $CaCl_2$ led to maximum accumulation of Ca with 0.52%. Increased concentration of $MgSO_4$ and $NaHCO_3$ brought about the decrease of Ca% the portion of 69% and 77%, respectively. The augmentation of NaCl concentration did not affect Ca accumulation in leaves.

Table 10 Duncan test results for Ca% in leaves, in relation to the salt types and the concentrations interaction

Salts*Concentration	**NaCl**			**$MgSO_4$**			**$NaHCO_3$**			**$CaCl_2$**		
2.5 dS/m	0,31	⇓a	⇒A	0,24	⇓a	⇒AB	0,14	⇓a	⇒B	0,26	⇓b	⇒AB
5.0 dS/m	0,30	⇓a	⇒B	0,16	⇓a	⇒BC	0,12	⇓a	⇒C	0,52	⇓a	⇒A

p=0.015, Control=2.453%

Clor content in leaves

The variance analysis for Cl% did not indicate an interaction, however, the single effects of type of salts and concentration of salts, were sigificant at 0.01. Duncan test results (Table 11) for salt types shows that both NaCl and $CaCl_2$ salt types caused the accumulation of Cl in leaves more than other salts. The results also indicate that the Cl accumulation increased by 39% with increasing salinty concentrations.

Table 11 Cl accumulation in leaves (%) and Duncan test results

Treatments	**NaCl**	**$MgSO_4$**	**$NaHCO_3$**	**$CaCl_2$**
2.5 dS/m	7,53	3,45	2,87	5,99
5.0 dS/m	9,29	3,14	3,08	10,33
Salt types	NaCl	$MgSO_4$	$NaHCO_3$	$CaCl_2$
p= 0,000	8,41 a	3,33 b	2,97 b	8,16 a
Concentration levels	2.5 dS/m		5.0 dS/m	
p=0,006 Control= 4.21%	4,203 A		3,245 B	

CONCLUSION

Depending on the results, it was seen that eggplant growth parameters and water consumption, and also the mineral matter contents had changed significantly. Increasing the salt concentrationof irrigation water decreased the water concumption of the plant by 8%, due to the augmention of osmotic pressure of the soil substract. Beside this, Na salts, in general, caused to decrease the mineral metter composition comparing with the Mg and Ca salts by 24,4% and 13,1%, respectively. These results showed that Na not only effect negatively to the physical properties of soil, but also effect the water uptake of plant as well and decreased also the vegatative growth by 31.5% as on avarage in fresh weight and 45.5 % in biomass yield with $CaCl_2$ salt.

The mineral metter contents showed clearly the antoganistic effects of each mineral matter accumulation in leaves. Applying Na, Mg or Ca, caused to increase thier contents in leaves. Increasing the total salinty caused to decrease the K availability in contrast to increased Cl availability. The exictance of HCO_3 in the solution caused to decrease in Mg availability.

REFERENCE

Akinci, S., Akinci, I.,E., 2000. Responses of Solanaceae species to salt in seedling stage. Bahce. 1999, publ. 2000, 28: 1-2, 79-86; 32 ref.

Chartzoulakis, K.S., Loupassaki, M., H., 1997. Effects of NaCl salinity on germination, growth, gas exchange and yield of greenhouse eggplant. Agricultural-Water-Management, 32(3) p. 215-225.

Davis, P.H.,1978. Flora of Turkey and East Aegean Islands, Vol. 6, Pp. 442. Edinburgh: Edinburgh University Press.

Dogan, M., Arslan, O., Dogan, S., 2002. Substrate specificity, heat inactivation and inhibition of polyphenol oxidase from different aubergine cultivars. International Journal of Food Science and Technology. 37, 415–423

Flowers T.J., Troke P.F., Yeo A.R.,1977. The mechanism of salt tolerance in halophytes. Annual Review of Plant Physiology
28, 89–121.

Flowers T.J., Yeo A.R., 1986. Ion relations of plant under drought and salinity. Australian Journal of Plant Physiology 13, 75–91.

Greenway H., Munns R., 1980. Mechanisms of salt tolerance in nonhalophytes. Annual Review of Plant Physiology 31, 149–190.

Hashem,M., M., 1991Effect of saline water on germination and seedling growth of eggplant, Solanum melongena growing in Egypt. Egyptian-Journal-of-Horti
culture 18(2) p. 123-130..

Inal, A., 2002. Growth, proline accumulation and ionic relations of tomato as influenced by NaCl and $NaSO_4$. TUBITAK, Turk J Bot 26(2002)285-290.

Kalloo, G., 1993. Eggplant (*Solanum melongena*). In: Kalloo, G. (Ed.), Genetic Improvement of Vegetable Crops. Pergamon Press, Oxford, pp. 587–604.

Koc, O., 1998. Sulamasuyu kalitesinin turp (Raphanus sativus L.) verimine etkisi. (Yuksek lisans tezi). Ank. U. Fen Bilimleri Enstitusu, Tarimsal Yapilar ve Sulama Anabilim Dali, Ankara.

Manchanda, H.R., Karwasra, S.P.S., Sharma, H.C., 1993. Salinity research at HAU. In: Manchanda, H.R., Karwasra, S.P.S., Sharma, H.C. (Eds.), CSC Haryana Agricultural University, 109 pp.

Munns, R., 2002. Comparative physiology of salt and water stres. Plant, Cell and Environment. 25;139-250.

Ozturk, A., 2002. Farkli gelisme donemlerinde uygulanan tuzlu ve normal sularin patlican (Solanum melongola L.) bitkisinin bazi ozelliklerine ve toprak tuzluluguna etkisi. S.U. Ziraat Fakultesi Dergisi 16(30): (2002)14-20.

Satti, S.M.E., Ahmad, R., 1992. Salinity Tolerance in Tomato. Pak.J Bot. 24, 35-39.

Satti, S.M.E., Lopez, M., 1994. Effect of Increasing Potassium Levels for Alleviating Sodium Chloride Stress on The Growth and Yield of Tomato. Commun. Soil Sci. Plant Anal., 25 (15&16), 2807-2823.

Savvas, D., Lenz, F., 2000. Effects of NaCl or nutrient-induced salinity on growth, yield, and composition of eggplants grown in rockwool. Scientia-Horticulturae. 2000, 84: 1-2, 37-47; 23 ref.

Shimose, N., Sekiya, J., Kimura, O.,Suzuki, I., 1991. Salt tolerance of amaranth, mugworth, eggplant and perilla. Japanase Jor. Tropica Agri., 35:1, 16-19;6 ref.

Somani, L.L., 1991. Crop production with saline water. In: Crop Production with Saline Water. Agro Botanical Publishers, India, 308 pp.

Tedeschi A., Menenti, M 2002. Simulation studies of long-term saline water use: model validation and evaluation of schedules. Agricultural Water Management 54(2):123-157. World Bank, 1992. World Bank Development Report. Oxford Press, New York Yurtseven, E., Kutuk, C., Demir, K., Ozturk, A., Parlak, M., 2000. Turp (Raphanus sativus L.) bitkisinde sulama suyu tuzlulugu ve Ca/Mg orani uygulamalari: II. Bitkide biokutle ve mineral madde icerigine etkisi. Ankara Uni. Ziraat Fak. Tarim Bilimleri Dergisi. Cilt: 6 (1): 92-98.

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SOIL RESPIRATION IN YOUNG AND OLD ORIENTAL SPRUCE STANDS AND IN ADJACENT GRASSLANDS IN ARTVIN, TURKEY.

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ABSTRACT

Soil respiration is a good indicator of soil quality. In this study, influence of species type and sampling time on soil respiration in young and old oriental spruce (*Picea orientalis* (L.) Link.) stands without understory and with *Rhododendron ponticum* L. understory and in adjacent grasslands were investigated in Genya Mountain, Artvin, Turkey. Soil respiration was measured approximately monthly from May to November using the soda-lime technique. Mean daily soil respiration across all sites ranged from 0.26-2.66 g C m^{-2} d^{-1}. There were significant differences between grasslands and old forest sites, but there was no significant differences between young forest sites and grasslands. Seasonal changes in soil respiration were strongly related to temperature changes. Over all sites, soil temperature and soil moisture together accounted for 75 % of the seasonal variability in soil respiration. Mean soil respiration rates correlated strongly with fine root (<2 mm) biomass ($R = 0.91$, $P<0.001$), surface (0-15 cm) soil sand content ($R = 0.71$, $P<0.05$), surface soil silt content ($R = -0.69$, $P<0.05$), and subsurface (15-35 cm) soil pH ($R=0.60$, $P<0.05$).

Key words: soil biological activity, oriental spruce, grasslands, C cycle

INTRODUCTION

Soil respiration is the release of CO_2 from soils to atmosphere and it is an important process in carbon cycle in forest and grassland ecosystems. Soils are major global sources and sinks of CO_2 and therefore play an important role in regulating atmospheric concentrations of CO_2. Almost 10% of the atmosphere's CO_2 passes through soils each year. This is more than 10 times the CO_2 released from fossil fuel combustion (Raich and Schlesinger, 1992).

Soil respiration is a sensitive indicator of several essential ecosystem processes, including: metabolic activity in soil, persistence and decomposition of plant residue in soil, and conversion of soil organic carbon to atmospheric CO_2 (Rochette et al., 1997). In addition, Parkin et al. (1996) stated that soil respiration is a good indicator of soil quality.

Soil moisture and soil temperature are two significant determinants of soil respiration (Singh and Gupta, 1977; Raich and Tufekcioglu, 2000). Rochette et al. (1997) observed that soil respiration in moist soil was two to three times greater than in drier soils. Most researchers also reported an increase in soil respiration with increasing soil temperature (e.g., Kowelenko et al., 1978).

Soil respiration varies with vegetation type (Raich and Tufekcioglu, 2000). However, analyzing published soil respiration data Raich and Tufekcioglu (2000) found no

predictable significant ($P<0.05$) differences in soil respiration between cropped and vegetation-free soils, between grassland and cropped soils or between forested and cropped soils. They did find higher rates of soil respiration in grasslands than in forests, and in grasslands and forests than in adjacent croplands.

Estimates of soil respiration have been made in a variety of ecosystems and have been summarized in reviews by Schlesinger (1977), Singh and Gupta (1977), Raich and Schlesinger (1992) and Raich and Tufekcioglu (2000). Despite this considerable body of information on soil respiration in different parts of the world, there is no soil respiration study in forest and grassland ecosystems of Turkey.

The objectives of this study were to compare rates of soil respiration among young oriental spruce stands (SSY), old oriental spruce stands with no understory (SSO), old oriental spruce stands with *Rhododendron ponticum* L. understory (SSR) and in adjacent grasslands; and to identify the underlying environmental variables most likely causing differences in soil respiration among sites, and among seasons within sites. We hypothesized that grasslands have higher rates of soil biological activity, and therefore have higher rates of soil respiration than do adjacent spruce stands.

MATERIALS AND METHODS

The study site is located at Genya Mountain of Artvin, Turkey. The site with a northern aspect and gentle slope (10-20%), ranges in elevation from 1490 m to 1510 m. Soil at the site is a podsolic well-drained sandy-loam. Soil respiration were measured in young oriental spruce stands (SSY), in old spruce stands with no understory (SSO), in old oriental spruce stands with *Rhododendron ponticum* L. understory (SSR) and in adjacent grasslands. Young stands were around 15 years-old and established after a clearcutting by planting and natural regeneration. Old stands were around 90 years-old with normal canopy cover. Plot sizes were 20 x 20 m. Dominant grass species in the grassland sites were smooth brome (*Bromus inermis* Leysser.), *Agrostis tenuis* L., timothy (*Phleum pratense* L.), Kentucky bluegrass (*Poa pratensis* L.) and *Festuca sp*. Grassland sites were under heavy grazing until last year when grazing was stopped.

Soil samples were taken randomly from 0-15 cm and 15-35 cm soil depths by digging a soil pit in each plot. Soil samples were air-dried, ground and pass through 2 mm mesh-sized sieve. Organic matter contents of the soils were determined according to wet digestion method described by Kalra and Maynard (1991)(Modified Walkley-Balck Method). Soil texture determined by Bouyoucos` Hydrometer Method. Soil pH was determined by a combination glass-electrode in H_2O (soil-solution ratio 1: 2.5).

The biomass of fine (0-2 mm) roots was assessed by collecting six 35-cm deep, 6.4-cm diameter cores per plot in October (Harris et al., 1977; Tufekcioglu et al., 1999). Roots were separated from the soil by soaking in water and then gently washing them over a series of sieves with mesh sizes of 2.0 and 0.5 mm. Roots were sorted into diameter classes of 0-2 mm (fine root), 2-5 mm (small root) and 5-10 mm (coarse root) root classes. The roots from each size category were oven-dried at 65 °C for 24 h and weighed.

Soil respiration rates were measured approximately monthly in three randomly selected locations in each of the three plots per sites from May 2003 to November 2003 using the soda-lime method (Edwards, 1982; Raich et al., 1990). The soda-lime method may underestimate actual soil respiration rates at high flux rates (e.g. Ewel et al., 1987; Haynes and Gower, 1995). However, the method does distinguish between higher and lower flux rates and, therefore, it is an appropriate method for comparing sites.

Buckets 20 cm tall and 27.5 cm in diameter were used as measurement chambers. One day prior to measurements, plastic rings with the same diameter were placed over the soil and carefully pushed about 1 cm into the soil. All live plants inside the plastic rings were cut to prevent aboveground plant respiration. Carbon dioxide was absorbed with 60 g of soda-lime contained in 7.8 cm diameter by 5.1 cm tall cylindrical tins. In the field, the plastic rings were removed, measurement chambers were placed over the tins of soda-lime, and the chambers were held tightly against the soil with rocks. After 24 h the tins were removed, oven dried at 105° C for 24 h, and weighed. Blanks were used to account for carbon dioxide absorption during handling and drying (Raich et al. 1990). Soda-lime weight gain was multiplied by 1.69 to account for water loss (Grogan, 1998). Soil temperature was measured at 5 cm soil depth adjacent to each chamber in the morning. Diurnal variations in soil temperature were expected to be smaller at these sites because of shading of sunlight by the plant canopy. Gravimetric soil moisture was determined by taking soil samples at 0-5 cm depth and drying them at 105 ˚C for 24 h on the day that the soda-lime tins were removed from the plots.

Statistical comparisons were made using SPSS program. We used ANOVA to compare soil respiration rates, soil temperatures, and soil moisture contents among sites. Paired comparisons among sites and sampling dates were determined with Least Significant Difference test at α=0.05. Step-wise multiple regression analysis was performed to evaluate the importance of soil temperature and soil moisture on seasonal soil respiration rates. The possible effects of soil properties and fine root biomass on soil respiration rates were evaluated with correlation analysis.

RESULTS AND DISCUSSION

Mean daily soil respiration ranged from 0.26 to 2.66 g C m^{-2} d^{-1} among all sites (Fig. 1A). These values are within the ranges reported by Singh and Gupta (1977), Hudgens & Yavitt (1997), Coleman (1973), Jurik et al. (1991), Kucera & Kirkham (1971) and Lessard et al. (1994), Tufekcioglu et al. (2001). Highest rates were observed in mid August when soil temperatures were high, while lowest rates were observed in May when soil temperatures were minimal (Fig. 1B). Soil respiration increased from spring to summer and decreased from summer to fall, as is typical in temperate latitudes (e.g., Hudgens and Yavitt, 1997; Kowalenko et al., 1978). Our results indicated that temperature was limiting during the fall and spring and moisture was limiting during the summer or fall. Kowalenko et al. (1978) reported that temperature was limiting during the winter and spring and moisture was limiting during the summer or fall on soil respiration in field soils in Canada.

Soil respiration varied significantly among sites ($P<0.01$). Soil respiration was significantly lower in old spruce stands (SSO and SSR) than in grassland sites (Table 1).

Similar results were reported by Raich and Tufekcioglu (1999). They reported that grasslands had ~20% higher soil respiration rates than did comparable forest stands.
Higher soil respiration rates in grassland sites were probably due to higher soil temperatures and fine root biomass values in these sites. Soil temperature and fine root biomass are significant determinants of soil respiration in temperate latitudes (e.g. Tufekcioglu et al., 2001; Kelting et al., 1998).

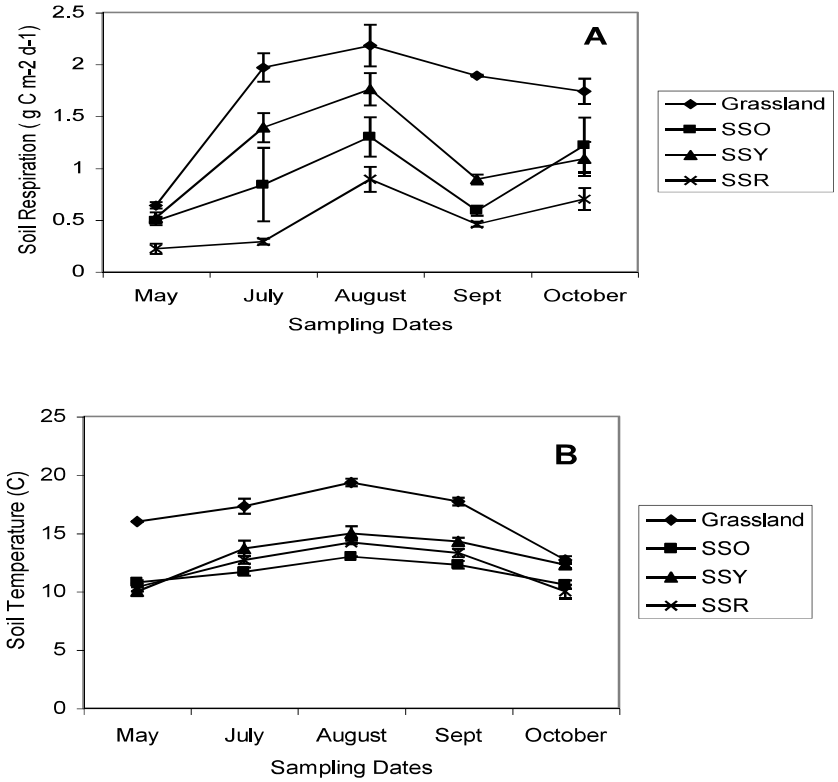


Figure 1: Mean monthly (± 1 SE) soil respiration rates (A) and soil temperature (B) in young (SSY) and old oriental spruce stands with (SSR) / without understory (SSO) and in adjacent grasslands.

There were significant differences in soil respiration among sampling dates, but with different temporal patterns for forest and grassland vegetation types. Soil respiration increased from May to August in all sites and it decreased from August to November in grasslands while decreasing from August to September, and increasing from September to November in the other sites. These differences in temporal patterns of soil respiration were probably driven by moisture and temperature differences among sites. There was no change in soil moisture from August to September in grassland sites but in the same period, soil moisture content decreased with an average value of 26.3% in the other sites. Transpiration from the aboveground tissues and interception of rain by the forest canopy might account for these soil moisture differences among sites.

Soil temperature varied significantly among sites and sampling dates ($P<0.01$) (Fig. 1B). Soil temperatures in the grassland sites were significantly different from those in the other sites ($P<0.05$) (Table 1). There was no other significant temperature

differences among sites. Averaged over all sites, soil temperatures were significantly higher in July than in October.

Soil moisture content differed significantly between sampling dates. Overall soil moisture content were significantly higher in October than in May, July and September ($P<0.05$) (Fig. 2). Mean soil moisture contents (average of five sampling dates) were 35.3%, 31.4%, 35.1% and 27.1 in grasslands, in SSO, in SSY and in SSR sites, respectively (Table 1). Higher soil moisture contents in July, September and October in grassland sites compared to SSO and SSR sites were probably result of higher canopy interception in the forest stands than in grasslands. Cepel (1971) reported that interception ranged from 17-31% for forest stands and 6-17 for grasslands in Turkey.

Within sites, seasonal changes in soil respiration were correlated most highly with soil temperature. When all sites were considered together, mean daily soil respiration varied with soil temperature and moisture ($r^2 = 0.75$, $P<0.001$):

$$SR = 0.14\ T + 0.0429\ M - 2.194$$

where SR is the soil respiration rate (g C m^{-2} d^{-1}), T is morning surface-soil (0-5 cm depth) temperature (°C) and M is surface-soil (0-5 cm depth) gravimetric moisture content (% H_2O). All three parameters were significant ($P<0.01$). According to step-wise regression results, 46% and 29% of variation in soil respiration explained by soil temperature and soil moisture, respectively. This indicated that soil temperature was the most important determinant of soil respiration in these high elevation sites.

Among sites, mean annual soil respiration rate correlated positively with fine root biomass, surface soil (0-15 cm) sand content, mean soil temperature, mean soil moisture and subsurface soil (15-35 cm) pH; and correlated negatively with surface soil silt content ($P<0.05$) (Table 2). Soil temperature and soil sand content were positively correlated, suggesting that high soil temperatures were associated with sandy soils (Kantarci, 2000).

Soil respiration had the highest correlation with mean fine root biomass ($r=0.91$). Respiration by roots and their associated microbial components represent a significant part of soil respiration in most ecosystems (Bowden et al., 1993; Kelting et al., 1998). While live roots directly contribute to soil respiration, dead roots and root exudates provide carbon as an energy source and nutrients for microbial biomass. Grayston et al. (1996) reported that root exudates stimulate microbial growth and activity because they are readily assimilated, and they may act as primers for the degradation of existing soil organic matter.

In a native prairie, belowground litter contributed 20-25 %, root respiration contributed 25-30 %, and decay of organic matter contributed 30-35 % of the total soil respiration (Buyanovsky et al., 1987). Root respiration accounted for 33-50 % of total soil respiration in broad-leaved forests, 17-40 % in grasslands, and 12-38 % in crop fields in temperate regions (Raich and Tufekcioglu, 1999).

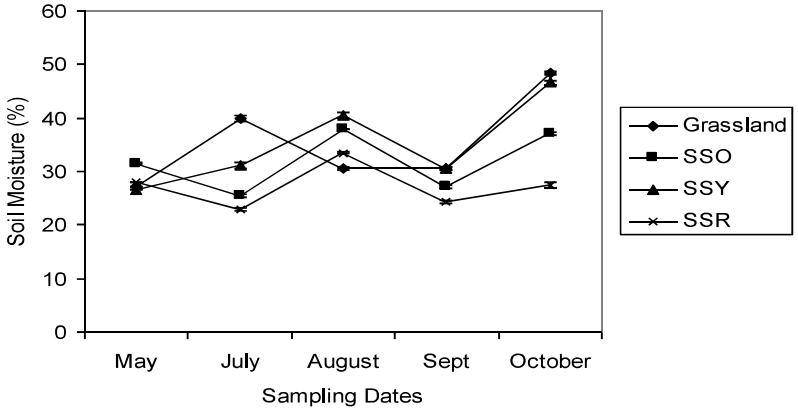


Figure 2: Mean monthly (± 1 SE) soil moisture contents (0-5 cm depth) in young (SSY) and old oriental spruce stands with (SSR) / without understory (SSO) and in adjacent grasslands

CONCLUSIONS

In this study, grasslands had higher rates of soil respiration than adjacent old forest sites did. These higher rates of soil respiration are evidence of high rates of the biological activity and C cycling through the soil. Our results suggest that old forests might be better than grasslands in terms of carbon accumulation into soil and forest floor in these high elevation sites.

Table 1: Mean soil respiration, soil temperature, soil moisture, soil organic matter, soil sand, clay and silt content, pH and root biomass in the four sites investigated in this study (n=3 plots per site). Root data refer to the surface 35 cm of soil.

Vegetation types		Grassland	Old spruce stand with no	Young spruce stand	Old spruce stand with
Mean soil respiration (g C m^{-2} d^{-1})		1.68	0.89	1.13	0.59
Mean soil temperature(ºC)		16.6	11.7	13.1	12.5
Mean soil moisture (%)		35.3	31.4	35.1	27.1
Mean soil organic matter (%)	0-15 cm	5.58	7.57	6.54	6.11
	15-35 cm	2.90	4.43	3.39	3.69
Mean sand content (%)	0-15 cm	66.4	57.5	58.2	52.3
	15-35 cm	44.9	53.24	56.2	51.59
Mean clay content (%)	0-15 cm	16.8	25.5	24.0	23.2
	15-35 cm	30.7	27.0	28.4	27.6
Mean silt content (%)	0-15 cm	16.9	17.1	17.8	24.5
	15-35 cm	24.4	19.8	15.6	20.8
Mean soil pH	0-15 cm	5.33	5.29	5.41	4.98
	15-35 cm	5.57	5.32	5.17	4.83
Mean fine root biomass (<2mm)(gm^{-2})		785	498	564	404

Table 2: Pearson correlation coefficients among measured variables in the study area (n=12). Asterisks refer the level of significance; *, P<.05; **, P<.01; ***, P<.001

Variables	FRB	T	M	pH	Sand(%)	Clay(%)	Silt(%)	SOC
SR[1]	0.91***	0.83***	0.65*	0.28	0.71*	-0.50	-0.68*	-0.33
FRB[2]	1.0	0.87***	0.75**	0.28	0.65*	-0.53	-0.54	-0.23
T[3]		1.0	0.43	0.17	0.62*	-0.69*	-0.25	-0.47
M[3]			1.0	0.24	0.33	-0.06	-0.54*	0.07
pH				1.0	0.61*	-0.51	-0.49	0.25
SOC[1]					-0.28	0.41	0.01	1.0

SR: soil respiration (g C m^{-2} d^{-1}); SOC: Mean soil organic matter content (%).
FRB:fine root biomass (kg ha^{-1}),
M: Mean soil moisture (%), T: Mean soil temperature (C˚)

REFERENCES

Bowden, R. D., K.J. Nadelhoffer, R.D. Boone, J.M. Melillo and J.B. Garrison. 1993. Contributions of aboveground litter, belowground litter, and root respiration to total soil respiration in a temperate mixed hardwood forest. Can.J. For. Res. 23,1402-1407.

Buyanovsky, G. A., C.L. Kucera and G.H. Wagner. 1987. Comparative analyses of carbon dynamics in native and cultivated ecosystems. Ecology 68 (6), 2023-2031.

Coleman, D. C. 1973. Soil carbon balance in a successional grassland. Oikos 24, 195-199.

Cepel, N. 1971. Toprak yuzeyine varan yagis miktarina bitkilerin yaptigi etki ve Belgrad Ormaninda yapilan bir arastirmaya ait bes yillik sonuclar. I.U. Orman fakultesi Dergisi, XXI, 2/B, s. 54-59.

Davidson, E. A., E. Belk and R.D. Boone. 1998. Soil water content and temperature as independent or confounded factors controlling soil respiration in a temperate mixed hardwood forest. Global Change Biology 4, 217-227.

Edwards, N. T. 1982. The use of soda-lime for measuring respiration rates in terrestrial systems. Pedobiologia 23, 321-330.

Ewel, K. C., W. C. Cropper and H. L. Gholz. 1987. Soil CO_2 evolution in Florida slash pine plantations. I. Changes through time. Canadian J. of Forest Research 17, 325-329.

Grayston, S. J., D. Vaughan and D. Jones. 1996. Rhizosphere carbon flow in trees, in comparison with annual plants: the importance of root exudation and its impact on microbial activity and nutrient availability. Applied Soil Ecology 5, 29-56.

Grogan, P. 1998. CO_2 flux measurement using soda-lime: Correction for water formed during CO_2 adsorption. Ecology 79, 1467-1468.

Harris, W.F., Kinerson, R.S. Jr and N. T. Edwards. 1977. Comparison of belowground biomass of natural deciduous forest and Loblolly pine plantations. P. 27-29, *in* The Belowground Ecosysytem: A Synthesis of Plant -Associated Processes, JK Marshall (Ed.). Range Science Department, Science Series No: 26, Fort Collins, Colorado, USA.

Haynes, B. E. and S. T. Gower. 1995. Belowground carbon allocation in unfertilized and fertilized red pine plantations in northern Wisconsin. Tree Physiol.15,317-325

Hudgens, D. E. and J. B. Yavitt. 1997. Land-use effects on soil methane and carbon dioxide fluxes in forest near Ithaca, New York. Ecoscience 4(2), 214-222.

Jurik, T. W., G. M. Briggs and D. M. Gates. 1991. Soil respiration of five aspen stands in Northern Lower Michigan. Am. Midl. Nat. 126, 68-75.

Kalra, Y. P. and D. G. Maynard. 1991. Methods Manual for Forest Soil and Plant Analysis. Forestry Canada, Northern Forestry Publications. Alberta, Canada.

Kantarci, M. D. 2000. Toprak Ilmi. I.U. Orman Fakultesi Yayinlari, Yayin No: 462. Istanbul, Turkiye.

Kelting, D. L., J.A. Burger and G.S. Edwards. 1998. Estimating root respiration, microbial respiration in the rhizosphere, and root-free soil respiration in forest soils. Soil Biology and Biochemistry 30, 961-968.

Kowalenko, C. G., K. C. Ivarson and D.R. Cameron. 1978. Effect of moisture content, temperature and nitrogen fertilization on carbon dioxide evolution from field soils. Soil Biology and Biochemistry 10, 417-423.

Kucera, C. L. and D.R. Kirkham. 1971. Soil respiration studies in tallgrass prairie in Missouri. Ecology 52, 912-915.

Lessard, R., P. Rochette, E. Topp, E. Pattey, R.L. Desjardins and G. Beaumon. 1994. Methane and carbon dioxide fluxes from poorly drained adjacent cultivated and forest sites. Canadian Journal of Soil Science 74, 139-146.

Parkin, T. B., J. W. Doran and E. Franco-Wizcaino. 1996. Field and Laboratory tests of soil respiration in Methods for Assessing Soil Quality. Ed. J.W. Doran and A.J. Jones. Soil Science Society of America special publication no 49, Madison, Wisconsin, USA.

Raich, J. W. and W. H. Schlesinger. 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus 44B, 81-99.

Raich, J. W. and A. Tufekcioglu. 2000. Vegetation and soil respiration: Correlations and controls. Biogeochemistry 48 (1), 71-90.

Raich, J. W., R. D. Bowden and P. A. Steudler. 1990. Comparison of two static chamber techniques for determining carbon dioxide efflux from forest soils. Soil Science Society of America Journal 54,1754-1757.

Rochette, P., B. Ellert, E. G. Gregorich, R. L. Desjardins, E. R. Pattey Lessard and B. G. Johnson. 1997. Description of a dynamic closed chamber for measuring soil respiration and its comparison with other techniques. Canadian Journal of Soil Science 77, 195-203.

Schlesinger, W. H. 1977. Carbon balance in terrestrial detritus. Ann. Rev. Ecol. Syst. 8, 51-81.

Singh, J. S. and S. R. Gupta. 1977. Plant decomposition and soil respiration in terrestrial ecosystems. Bot. Rev. 43, 449-528.

Tufekcioglu, A., J. W. Raich, T. M. Isenhart and R. C. Schultz. 1999. Fine root dynamics, coarse root biomass, root distribution, and soil respiration in a multi species riparian buffer in Central Iowa, USA. Agroforestry Systems 44, 163-174.

Tufekcioglu, A. J. W. Raich, T. M. Isenhart and R. C. Schultz. 2001.Soil respiration within riparian buffers and adjacent crop fields. Plant and Soil 229: 117-124.

Tufekcioglu, A. J. W. Raich, T. M. Isenhart and R. C. Schultz. 2003. Biomass, carbon and nitrogen dynamics of multi-species riparian buffers within an agricultural watershed in Iowa, USA. Agroforestry Systems 57: 187-198.

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INFLUENCE OF CROP ROTATION ON SOIL QUALITY UNDER IRRIGATED AGRICULTURE IN THE HARRAN PLAIN IN SOUTHEASTERN TURKEY

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ABSTRACT

With the completion of the GAP project. about half of the 3.2 million ha of agricultural land (1.7 million ha) will be used for irrigated agriculture. New intensive agricultural systems are expected to change the soil quality in the region. It is, therefore, imperative to monitor the soil quality for sustainable use and management in the region. The objective of this research was to determine the effect of selected rotation systems on soil characteristics of the Harran series, currently under dryland agriculture. Soil samples were collected in fall season for two years, from the parcels under selected management systems.

Among the 18 selected rotation systems, broad bean/wheat and barley/lentil crop rotation had higher bulk density and lower porosity than fallow/wheat, lentil/wheat, and continuous barley treatments in the first year. In the second year the values for the two groups were statistically not different from each other. Irrigation has caused an increase in soil porosity and decrease in bulk density. As expected, soils under irrigated agriculture had more moisture than under dryland agriculture.

INTRODUCTION

The area under the GAP project is about 3.2 million ha. About 1.7 million ha of this land mass is suitable for irrigated agriculture. New intensive agricultural systems can cause dramatic changes in the soil quality in short time. It is, therefore, important to monitor the soil quality for sustainable use and management in the region (Saglamtimur ve Ark., 1990). We, therefore, intend to determine the effect of selected rotation systems on soil characteristics of the Harran series, currently under dryland agriculture. We used soils from an area of the Harran Series which is used for TARP 1774 project since 1988 in two consequtive years.

MATERIALS AND METHODS

Some characteristics of the soils studied:

The soils in the region are mapped as the Harran and Akoren series (Dinc et al., 1988). Our experiments were conducted only on the Hararan soil series, Soils occurring in the Harran plain are generally clayey and has level and nearly level topography with reddish brown color. The soils are well developed and have complete A, B, C horizon sequence. The surface horizon has angular medium blocky and granular structure and subsoils have strong large prismatic and strong medium blocky structures. Soils contain 28-32 % total carbonate and accumulation of secondary carbonate is very common and the content increases with depth. As expected, soil organic matter contents are low and pHs are neutral and slightly basic.

Agricultural pattern and production:

Until very recently, the soils in the Harran plain were used for monoculture. Integrated policultural systems are now increasing with increased irrigated agricultural system. Low and unpredictable rainfall limits the cultivation of several crops under dryland management systems.

Climate of the area:

While Sanliurfa is within the climatic zone of the Southeastern Turkey, it carries some characteristics of the Mediterranean region as well. The majority of soils of the Harran plain have xeric moisture regime (Soil Survey Staff, 1996). In this climatic regime the summers are hot and dry and winters are mild and usually rainy. The rainfall increases from the south to north and from the west to east.

Field works:

We collected soils from the parcels used for selected crop rotation systems in the GAP region, under dryland and irrigated agriculture. The crop rotation systems used in the study are given in Table 1.

Table 1. Crop rotation systems in the study area.

System No	Crop rotation system	System No	Crop rotation system
1	fallow/wheat	10	Cotton/wheat + corn
2	lentil/wheat	11	Cotton/ wheat + sunflower
3	bean/wheat	12	Barley + soja /cotton
4	continuous barley	13	Barley + corn/cotton
5	barley/lentil	14	wheat +sorghum / cotton
6	continuous cotton	15	Wheat+soja / lentil + corn
7	(Vicia sativa+barley)+cotton	16	Wheat+sunflower/lentil+corn
8	alfalfa / cotton	17	lentil +sunflower / wheat + corn
9	cotton /wheat +soja	18	wheat cotton

Note: systems 1, 2, 3, 4 and 5 represent dryland and others are irrigated agriculture

Methods of Soil Analyses:

Soil profiles were dug in the years 1999 and 2000 and disturbed and undisturbed samples were taken from 0-20, 20-40, and 40-60 cm depths for the following physical and chemical analyses. The results reported here are the average of three samples.

As described in Richards (1954) texture was determined using hydrometer method (Bouyucos, 1951), soil reaction (pH) was measured in the saturation past using glass electrode. Total salt was measured by electrical conductivity as described in Soil Survey Manuel (1951), total carbonates using Scheibler calcimeter (Caglar (1958), Volume and specific densities were determined according to Black (1965), total porosity was calculated using the volume and specific density values by the following formula (Munsuz, 1982).

% Total porosity = (specific density – volume density) / specific density x 100

RESULTS AND DISCUSSIONS

Soil characteristics:

The results of the soil analyses are given in Table 2.

Table 2. Soil analyses results from the samples collected in 1999 and 2000.

Treat	Depth (cm)	Sat. (%)	pH	E.C. (dSm^{-1})	$CaCO_3$	Clay (%)	Silt (%)	Sand (%)	Texture
1	0-20	58	7.62	0.080	25.8	58	20	22	Clay
	20-40	60	7.60	0.080	24.7	58	20	22	Clay
	40-60	64	7.58	0.080	22.0	51	28	21	Clay
2	0-20	55	7.58	0.082	23.6	61	16	23	Clay
	20-40	57	7.60	0.085	22.9	59	19	22	Clay
	40-60	59	7.58	0.089	24.7	61	16	23	Clay
3	0-20	56	7.60	0.067	25.0	58	24	18	Clay
	20-40	56	7.60	0.067	26.9	62	22	16	Clay
	40-60	56	7.60	0.070	22.8	61	18	21	Clay
4	0-20	58	7.65	0.068	25.0	62	18	20	Clay
	20-40	58	7.61	0.076	23.1	51	29	20	Clay
	40-60	57	7.58	0.090	23.9	51	29	20	Clay
5	0-20	58	7.60	0.096	24.3	51	29	20	Clay
	20-40	59	7.63	0.085	23.9	51	29	20	Clay
	40-60	60	7.63	0.089	22.4	59	23	18	Clay
6	0-20	55	7.65	0.096	25.0	51	28	21	Clay
	20-40	54	7.65	0.090	25.4	45	33	22	Clay
	40-60	56	7.62	0.090	24.3	45	33	22	Clay

As can be seen in Table 2. saturation percentage were between % 54 and 60, pH (paste) 7.55- 7.65, EC 0.070 – 0.098 dS m^{-1}), total carbonates ($CaCO_3$) % were 22.00–26.20, clay % 42–62 silt % 12–33 sand % 16–24 and textures were generally clayey. It is hypothesized that influence of the long time application of the crop rotation system on the soil characteristics will not be significant. Our results confirmed this hypothesis. However, when the EC values were analyzed we noticed that values are higher in the parcel under the intensive rotation system. Due to clay texture, continuous irrigation and rotation systems applied there is a danger of salt accumulation in the soil.

Volume density and total porosity in undisturbed soil samples:

The mean value for the specific density of the samples was 2.70 g cm^{-3} The soil volume densities are given in Table 3. Considering all the rotation systems we noticed that volume densities are higher and total porosities are lower in the parcels under dryland agriculture. When crop rotation systems were combined with irrigated agriculture volume densities were lower and consequently porosity values were higher in the soil.

In the first year broad bean/wheat and barley/lentil crop rotation systems had higher bulk density and lower porosity than fallow/wheat, lentil/wheat and continuous barley treatments, In the second year the values for the two groups were statistically not different from each other,

Table 2. Soil analyses results from the samples collected in 1999 and 2000.

Treatment	Depth (cm)	Sat. (%)	pH	E.C.(dSm^{-1})	CaCO3	Clay (%)	Silt (%)	Sand (%)	Texture
7	0-20	56	7.67	0.090	25.4	54	24	22	Clay
	20-40	61	7.60	0.092	23.8	58	20	22	Clay
	40-60	61	7.60	0.092	24.0	56	20	24	Clay
8	0-20	57	7.70	0.075	25.8	61	18	21	Clay
	20-40	57	7.62	0.080	23.9	61	18	21	Clay
	40-60	59	7.60	0.080	23.9	61	18	21	Clay
9	0-20	57	7.60	0.105	24.7	51	28	21	Clay
	20-40	59	7.57	0.080	24.7	61	18	21	Clay
	40-60	60	7.68	0.089	23.6	65	12	23	Clay
10	0-20	56	7.64	0.092	24.7	54	24	22	Clay
	20-40	56	7.63	0.088	24.7	51	28	21	Clay
	40-60	56	7.66	0.096	24.7	54	24	22	Clay
11	0-20	58	7.60	0.075	25.8	43	36	21	Clay
	20-40	60	7.60	0.082	23.6	46	33	21	Clay
	40-60	61	7.62	0.080	25.8	61	16	23	Clay
12	0-20	59	7.65	0.069	25.0	42	36	22	Clay
	20-40	59	7.62	0.070	24.7	45	33	22	Clay
	40-60	61	7.64	0.075	22.8	61	16	23	Clay
13	0-20	55	7.60	0.090	24.7	58	24	18	Clay
	20-40	57	7.60	0.095	23.9	56	25	19	Clay
	40-60	57	7.58	0.108	25.0	56	25	19	Clay
14	0-20	58	7.60	0.081	23.4	62	18	20	Clay
	20-40	59	7.66	0.090	23.1	58	20	22	Clay
	40-60	60	7.60	0.085	25.4	62	18	20	Clay
15	0-20	56	7.62	0.080	24.7	57	24	19	Clay
	20-40	55	7.60	0.073	23.6	58	23	19	Clay
	40-60	59	7.60	0.069	22.0	58	24	18	Clay
16	0-20	53	7.58	0.070	22.9	59	19	22	Clay
	20-40	56	7.58	0.075	22.9	59	19	22	Clay
	40-60	59	7.67	0.088	24.7	59	23	18	Clay
17	0-20	58	7.65	0.096	24.7	59	23	18	Clay
	20-40	57	7.62	0.096	24.7	59	23	18	Clay
	40-60	59	7.60	0.096	25.8	58	20	22	Clay
18	0-20	55	7.62	0.090	24.7	56	22	22	Clay
	20-40	58	7.65	0.094	25.0	62	18	20	Clay
	40-60	60	7.65	0.094	25.2	62	18	20	Clay

Table 3, Specific and volume densities and porosities of the soils in the samples collected in the year 1999 and 2000,

years		*values of 1999 year*		values of *2000*	
Location of	*Depth (cm)*	*olume*	*Total*	*olume*	*Total*
1	*0 – 20*	1.41	47.7	1.40	48.2
	20 – 40	1.42	47.4	1.41	47.7
	40 – 60	1.43	47.0	1.42	47.4
2	*0 – 20*	1.40	48.2	1.40	48.2
	20 – 40	1.41	47.7	1.41	47.7
	40 – 60	1.42	47.4	1.43	47.0
3	*0 – 20*	1.40	48.2	1.40	48.2
	20 – 40	1.41	47.7	1.41	47.7
	40 – 60	1.41	47.7	1.42	47.4
4	*0 – 20*	1.37	49.2	1.38	48.8
	20 – 40	1.39	48.5	1.39	48.5
	40 – 60	1.40	48.2	1.40	48.2

Table 3. Specific and volume densities and porosities of the soils in the samples collected in the year 1999 and 2000.

years		*values of 1999 year*		values of *2000*	
Location of the	*Depth (cm)*	*olume density*	*Total porosity*	*olume*	*Total*
5	*0 – 20*	1.40	48.2	1.41	47.7
	20 – 40	1.41	47.7	1.41	47.7
	40 – 60	1.41	47.7	1.42	47.4
6	*0 – 20*	1.36	49.6	1.36	49.6
	20 – 40	1.37	49.2	1.38	48.8
	40 – 60	1.38	48.8	1.39	48.5
7	*0 – 20*	1.35	50.0	1.36	49.6
	20 – 40	1.36	49.6	1.36	49.6
	40 – 60	1.38	48.8	1.38	48.8
8	*0 – 20*	1.35	50.0	1.36	49.6
	20 – 40	1.36	49.6	1.36	49.6
	40 – 60	1.39	48.5	1.39	48.5
9	*0 – 20*	1.33	50.7	1.33	50.7
	20 – 40	1.34	50.3	1.35	50.0
	40 – 60	1.36	49.6	1.36	49.6
10	*0 – 20*	1.32	51.1	1.33	50.7
	20 – 40	1.33	50.7	1.34	50.3
	40 – 60	1.35	50.0	1.35	50.0
11	*0 – 20*	1.35	50.0	1.35	50.0
	20 – 40	1.37	49.2	1.37	49.2
	40 – 60	1.38	48.8	1.38	48.8
12	*0 – 20*	1.34	50.3	1.35	50.0
	20 – 40	1.36	49.6	1.36	49.6
	40 – 60	1.38	48.8	1.39	48.5
13	*0 – 20*	1.32	51.1	1.33	50.7
	20 – 40	1.36	49.6	1.37	49.2
	40 – 60	1.39	48.5	1.39	48.5
14	*0 – 20*	1.33	50.7	1.33	50.7
	20 – 40	1.34	50.3	1.35	50.0
	40 – 60	1.36	49.6	1.37	49.2

Table 3. Specific and volume densities and porosities of the soils in the samples collected in the year 1999 and 2000.

years		values of 1999 year		values of 2000	
Location of the sample	Depth (cm)	olume density cm^{-3}	Total porosity (%)	olume ensity g cm^{-3}	Total porosity (%)
15	0 – 20	1.32	51.1	1.32	51.1
	20 – 40	1.33	50.7	1.34	50.3
	40 – 60	1.35	50.0	1.34	50.3
16	0 – 20	1.32	51.1	1.33	50.7
	20 – 40	1.33	50.7	1.34	50.3
	40 – 60	1.36	49.6	1.35	50.0
17	0 – 20	1.35	50.0	1.35	50.0
	20 – 40	1.36	49.6	1.35	50.0
	40 – 60	1.38	48.8	1.38	48.8
18	0 – 20	1.35	50.0	1.36	49.6
	20 – 40	1.36	49.6	1.36	49.6
	40 – 60	1.38	48.8	1.38	48.8

The influence of crop rotation systems on soil characteristics under irrigated agriculture for two consecutive years were similar. We observed that the continuous cotton (broad + barley) + cotton, alfalfa, Cotton, cotton/wheat + sunflower, barley + soja /cotton and wheat + sorghum / cotton crop rotation systems had higher volume densities and lower porosities in both years.

The volume densities of cotton / wheat + soja, cotton / wheat + corn, barley + corn / cotton, wheat + Soja / lentil + corn, wheat + sunflower / lentil + corn, lentil + sunflower / wheat + corn, wheat / cotton rotation systems were lower than the other rotation systems in both years.

CONCLUSIONS AND SUGGESTIONS

Among the selected 18 crop rotation systems broad bean/wheat and barley/lentil crop rotation had higher bulk density and lower porosity than fallow/wheat, lentil/wheat and continuous barley treatments in the first year. No influence of any specific rotation system on soil physical characteristics was found for the second year. Irrigation has caused an increase in soil porosity and decrease in bulk density. As expected, soils under irrigated agriculture had more moisture than under dryland agriculture.

Crop rotation system did not influence basic characteristic such as pH of the soil. Parcel used for selected crops under irrigated agriculture had lower bulk densities than those under dryland agriculture. This is due to the fact that soils had more moisture under irrigated agriculture than under dryland agricultural practices.

In southeast Turkey atmospheric moisture is low and therefore, evaporation is considerably higher than in the Mediterranean region. Continuous cropping of heavy soils may have an increase in salt contents (increased EC). We, therefore, suggest that among the selected plants that were found suitable for irrigated agriculture alfalfa

should be used and the amount of water should be decreased for sustainable use and management of land resources in the Harran Plain.

REFERENCES

BLACK C.A., Methods of Soil Analysis, Part l and ll The American Society of gronomy - Wisconsin – USA, 1965.

BOUYOUCOS G.J., A recalibration of the hydrometer method for making mechanical analysis of soils, Agron, J. 43. 434-438, 1951.

CAGLAR O.K., Toprak Bilgisi, A.U. Ziraat Fakultesi Yayinlari Sayi: 10. Ankara, 1958.

DINC U., SENOL S., SAYIN M. ve ark., Guneydogu Anadolu Bolgesi Topraklari I, Harran Ovasi Tubitak - TOAG Gudumlu Arastirma Projesi Kesin Raporu Proje No: TOAG 534, Ankara 1988.

MUNSUZ N., Toprak Su Iliskileri, A.U. Ziraat Fakultesi Yayinlari, 798. Ders Kitabi:221, Ankara, 1982.

RICHARDS L.A., Diagnosis and Improvement of Saline and Alkali Soils, Ed. U.S. Salinity Lab. Staff. Agricultural Handbook No: 60, Washington DC. USA, 1954.

SAGLAMTIMUR T., GENC I., BAYTEKIN H., KIRTOK Y., ARIOGLU H.H., TANSI V., YAGBASANLAR T., ULGER A.C., Guneydogu Anadolu Projesi (GAP) Alaninda Urun Deseni, TMMOB Ziraat Muhendisleri Odasi-Ankara Universitesi Ziraat Fakultesi, Turkiye Ziraat Muhendisligi 3. Teknik Kongresi Bildirileri, 08-12.01.1990, s. 761-775. Ankara, 1990.

SOIL SURVEY STAFF, Soil Survey Manual, Agricultural Research Administration U.S. Dept. Agriculture, Handbook No: 18. 1951.

SOIL TAXONOMY, Keys to Soil Taxonomy, United States Department of Agriculture, Seventh Edition, 1996.

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A MOISTURE CONTROL SYSTEM TO MAINTAIN CONSTANT SOIL WATER POTENTIAL IN GREENHOUSE AND LABORATORY EXPERIMENTS

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ABSTRACT

Maintaining controlled soil water potential in laboratory and greenhouse experiments conducted on water and nutrient use efficiency may significantly decrease the error caused by the fluctuations in soil water potential during the experimentation. A soil moisture regulator system (SMR), which maintains constant soil water potential in the pots at a desired level during a long time of experimentation, was developed. The SMR is a combination of regulator, ceramic tips, and water suppliers. A pot experiment was carried out with four replicated pots to test the SMR. Each pot was filled with a loam (27% clay, 43% silt, and 30% sand), was saturated and then dried under –32 cbar and –45 cbar soil water pressures. A constant soil water pressure in the pots was reached after 36 days under –32 cbar and after 60 days under –45 cbar soil water pressure. Average volumetric soil water content was 0.236 cm^3 cm^{-3} under –32 cbar and 0.205 cm^3 cm^{-3} under –45 cbar. The SMR adequately controlled the soil water pressure after the constant soil water pressure was reached.

Key words: regulator, ceramic, soil water potential, moisture control

INTRODUCTION

Fluctuation of soil water potential during experimentation in water and nutrient use efficiency studies may cause significant error. One of the most important factors effecting research outputs in pot experiments is water status of the soils in the pots. Only few methods designed and developed to keep soil moisture constant in pots during experimentation (Krizek, 1985). The method weighing pots and adding water as it is lost by evapotranspiration seems reasonable but it is tedious and time consuming to weight too many pots (Andrew and Cowper, 1973; Schwaegerle, 1983). Using porous bulbs in pots to keep soil moisture constant was initially proposed in 1900s (Livingston, B.E. 1908; Livingston B.E. 1918; Karnoski et al., 1984), and a moisture control system for pot experiments was developed and designed using porous bulbs by Karnoski et al. (1984). The method developed by Karnoski et al.(1984) seemed more reasonable due to being less expensive and requiring less labor. However, early experiments did not perform well due to the air entry occurred into the bulbs. Some researchers preferred to conduct research adding porous linings, instead of porous bulb, on interior of pots. However, this method failed in media having low hydraulic conductivity.

Increasing needs on soil moisture control for pot experiments still encouraged scientist to work this topic, and to design more precise and less expensive systems. Today, advanced porous ceramics with low air entry values are being produced for many purposes. Among them, ceramics are highly considered for development and design of soil moisture control systems

The purpose of this study was to design and develop a system, using porous ceramics, which control moisture level in pot experiments through controlling the soil water potential. This system will minimize the cost, labor, energy and time required for the watering during the experimentation, and increase the precision of the results of the experiments, maintaining soil water potential in the pots unchanged during long term of experimentation

MATERIAL and METHODS

SMR system developed by Kutlu (2000) is a combination of a water container, water distributors, ceramic tips, and a moisture or tension regulator, which is the most important part of the system (Figure 1). Each water distributor is a hose with a ceramic tip at one end; the other end of the hose is connected to the regulator. The moisture or tension regulator controls the soil water potential in the experimental pots. The ceramic tip is connected to the soil in the pot through a hole opened at the side of pot.

To test the system a pot experiment was conducted in the laboratory conditions with four-replicated pot experiment conducted under –32 and –45 cbar soil water pressures. Each pot was filled with a loam (27% clay, 43% silt, and 30% sand), then covered with paper towel and slowly saturated by pouring water on pots. Here, the paper towel prevented soil to be disturbed due to the sudden entrance of water that destroys the soil structure because of air entrapment effect. After saturation completed, the pots were connected to the SMR and let dry out until targeted soil water potential was reached. The change in the soil water potential was observed daily and recorded. As water potential decreased to –32 cbar, then very little change in soil water pressure was observed. To ensure that the system work accurately, the observation was continued for 30 days. A parallel experiment was conducted under –45 cbar soil water pressure. Small size soil samples were taken from pots to determine moisture content after steady-state conditions were reached.

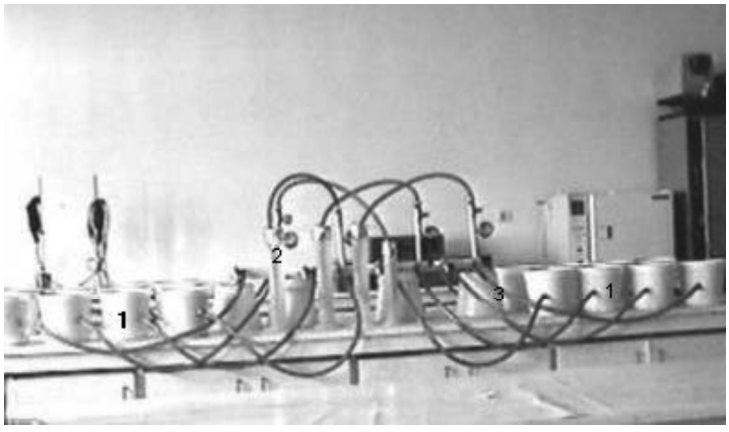


Figure1. Scheme of the Soil Moisture Regulator System. Water is supplied from water source (1) through regulator (2) to each pot (3).

RESULTS and DISCUSSION

It took 40 days to reach - 32 cbar constant soil water pressure and 60 days under - 45 cbar soil water pressure from beginning of drying. After targeted soil water pressure reached, SMR adequately controlled the soil water. The average volumetric moisture content was 0.236 cm^3/cm^3 under –32 cbar soil water pressure and 0.205 cm^3/cm^3 under –45 cbar soil water pressure. The soil water potential was maintained quite unchanged in both experiments after steady-state conditions were reached (Figures 2 and 3).

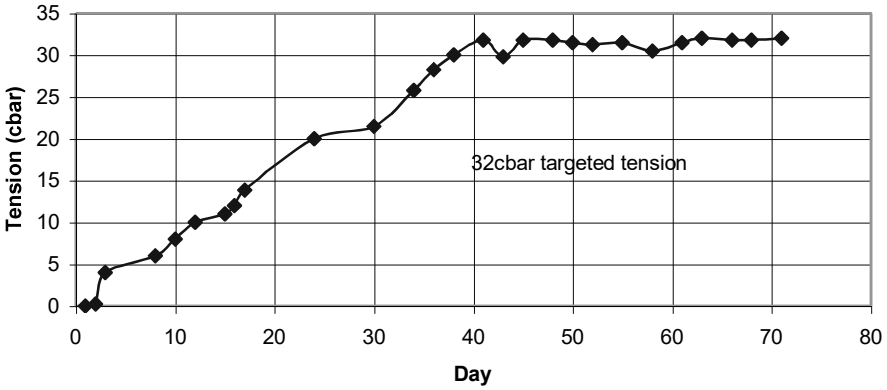


Figure 2. Time to reach targeted soil water pressure after initial wetting and maintance of constant soil water pressure after reaching to 32 cbar.

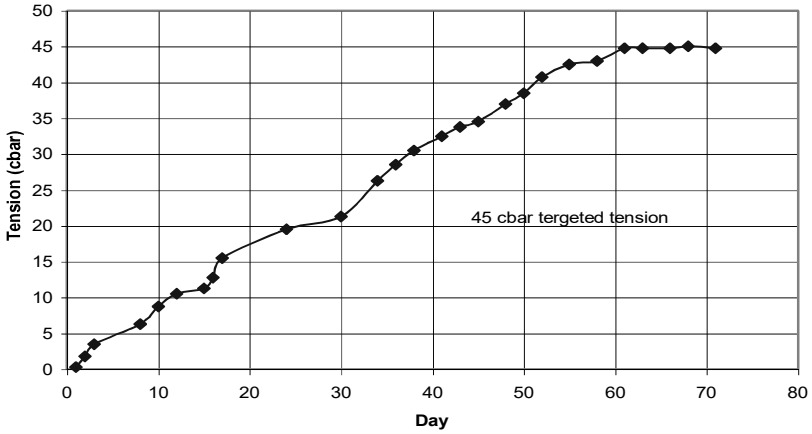


Figure 3. Time to reach targeted soil water pressure after initial wetting and maintance of constant soil water pressure after reaching to 45 cbar.

The system was proved to be quite precise that fluctuations occurred in either soil water content or soil water potential were unimportant during 30 days under –32 cbar and 11 day under –45 cbar of soil water pressure. The air entry occurred in to the system was insignificant that it did not clag the system compared to that developed by Karnoski et al.(1984). This air entry was far less effective due to the high air entry value of ceramic tips used and better control in the SMR system.

The system still needs improving in some aspects: First, Cracks forms during the drying significantly decrease the hydraulic conductivity of the soil, which in turn decrease the water supply from ceramic due to insufficient contact area of soil to ceramic. This can be overcome by increasing number of ceramic tips used in a single pot or increasing the size of the ceramic tips used. Second, the plant roots may have negative effect on the system by decreasing the contact area of the soil-ceramic. Hence, more sophisticated experiments with plants should be conducted to examine the effect of plant roots on the system.

REFERENCES

Andrew C.S., and J.L. Cowper. 1973. Automatic plant pot watering machine. Lab. Pract. 22:364-367

Karnoski, T.C., D.H. Willits, R.W. Skaggs. 1984. Porous Bulbs to Control Water Content in Container Media. Hort. Science 19: 393-395

Krizek, D.T. 1985. Methods of Inducing Water Stress in Plants. Hort. Science. 20:1028-1038

Kutlu, T. 2000. Research on Design and Development of Soil Moisture Regulator to Keep Soil Moisture Constant. Unpublished Data.

Livingston B.E. 1908. A method for controlling plant moisture. Plant World. 11:39-40

Livingston B.E. 1918. Porous Clay Cones for the Auto-Irrigation of Potted Plants. Plant World. 21:202-208

Schwaegerle, K.E. 1983. A method for maintaining constant soil moisture availability for potted plants. Soil Sci. Soc. Am. J. 47:608-610

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EFFECT OF AGGREGATE SIZE ON SOIL COMPACTION

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ABSTRACT

The purpose of this study was to determine effect of aggregate size on compressive behavior of cultivated soils. Two soils with different textures and organic matter contents referred to as coarse texture-low organic matter (T_C-OM_L) soil and fine texture-high organic matter (T_F-OM_H) soil, respectively, were taken from 0-20 cm depth in Erzurum region. Six different aggregate size groups (12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm) were prepared by dry sieving of two dry soils. Partical size distribution, maximum dry density, optimum moisture content, air permeability and degree of aggregation values were measured for each soil and aggregate size groups. The initial dry density, and final dry density of T_C-OM_L and T_F-OM_H soils at each aggregate size groups was determined at three different moisture contents and compaction levels. The water permeability of T_C-OM_L and T_F-OM_H soils at each aggregate size group was determined at saturated water condition and three different compaction levels. For aggregate size groups, maximum dry density and air permeability values of the T_C-OM_L soil was significantly higher than that of the T_F-OM_H soil, but degree of aggregation and optimum moisture content values of the T_F-OM_H soil was significantly higher than that of the T_C-OM_L soil. The initial and the final dry density values of the T_C-OM_L soil was significantly higher than those of the T_F-OM_H soil. The water permeability under saturated soil condition of the T_C-OM_L soil was significantly higher than that of the T_F-OM_H soil.

Keywords: Soil aggregate size; soil compaction; organic matter; texture; dry density; permeability.

INTRODUCTION

Compaction, a common process and a significant problem in cultivated soils, directly relates to compaction force, soil organic matter content, soil texture, aggregate size and stability, and water content at time of compaction. Coarse textured soils are less susceptible to compaction than those with a fine texture (McBride and Joosse, 1996). Soil reaction to compaction is also influenced by organic matter content (Larson el al., 1980). Soil organic matter improves compaction resistance. Soil water content has been widely realized as a determinant of soil compressibility (Sanchez-Giron et al., 1998; Imhoff, 2004). Dry soils are much more resistant to compaction than moist or wet soils. Under moisture conditions, the potential for compaction increases as soil clay content increases and soil organic matter decreases (Jones et al., 1988). Many soil physical properties and crop yield are affected by compaction (Abu-Hamdeh, 2003). Soil compaction has negative effects for agriculture as well as the environment: it adversely affects soil structure, reduces crop production, increases runoff and erosion, and accelerates potential pollution of surface water by organic wastes and applied agro-chemicals (Assouline, 2002). Soil aggregation is one of the main factors controlling the chemical, physical, and biological processes that contribute to agricultural sustainability. Little is known about the relationship between aggregate size and soil compaction. Soil aggregate size distribution analysis presents an important characterization of soil structural state. Experiments with dry soil aggregates have shown that the mass of aggregates changes with their size so that the aggregates become

looser as their size increases. Determining aggregate size distribution is a common way of characterizing soil structure. The effects of different agronomic practices on structure or aggregate size distribution of surface soils should be taken under control for maintaining soil productivity. Many factors influence aggregate size and stability. Information about soil structure can also be derived from examining the aggregate mass or density on aggregate size.

The soil compression behavior is also affected by soil bulk density (Imhoff et al., 2004). The dry density can be used to predict soil behavior and some plant response trends, given knowledge of other soil physical parameters. Dry density is the most common measure of soil compaction. Dry density is more useful if used relative to a plant response threshold, within that particular soil or soil type. Several common soil physics calculations are also of use in evaluating compaction. Porosity as calculated from dry density is a useful tool when making multiple comparisons within the same material. Direct density tests including Proctor density are widely used in construction of infrastructure.

Shepherd et al., (2001) studied the effects of increasing cropping and soil compaction on aggregate stability and dry-sieved aggregate-size distribution, and their relationship to total organic C and the major functional groups of soil organic carbon. Canbolat et al., (2002) were studied to determine the compactibility of soil aggregate size groups at different moisture contents, and to explain the relation with maximum dry density, optimal moisture content, porosity, pore volume, and penetration resistance. Assouline (2002) studied on the relationship between soil dry density and applied stresses during compaction. Zobeck et al., (2003) determined the most accurate and precise dry aggregate-size distributions to estimate aggregate-mean diameter. Lado et al.(2004) investigated the effects of the interaction between organic matter (OM) content and aggregate size on the saturated hydraulic conductivity. Díaz-Zorita et al. (2001) emphasized that the compactability of a soil could be determined from parameters derived from laboratory compaction curves generated using the Proctor test. Soil compactability depends on both intrinsic and transient soil properties like texture, soil organic matter, and soil moisture (Kay et al., 1997**).**

In the present study, the effect of aggregate size on compressive behavior of cultivated soils with different texture and organic matter content were studied. The specific objectives were to (i) quantify the compaction characteristics of the soils (maximum dry density and optimum moisture content), the degree of aggregation, air permeability of the soils for dry condition before compaction test, the dry density of the soils before and after application of the selected compactive forces and the water permeability of the soils for saturating condition after compaction test, and (ii) the determine the effect of aggregate size on these indicators.

MATERIALS and METHODS

Two soil samples with differing textures and organic matter contents were collected from to 0.20 m layer in two fields from Agricultural Research Farm of the Ataturk University Erzurum, Turkey. The study area cultivated with wheat, root crops and sunflower for over 40 years, has a wide range of texture and organic matter. The region is characterized by a harsh-continental climate. The average annual temperature over 42 years meteorological data is 6 °C. Temperature does not fall below zero from April to November, but it is usually lower than zero from December to March. The annual rainfall is 447.4 mm (Doganay et al., 1998).

Some physical and chemical properties of the soils are presented in Table 1. The mechanical composition was determined by sieve and pipet methods (Gee & Bauder 1986), organic matter content by the Smith-Weldon (Nelson and Sommers, 1982), and exchangeable Na was determined by the procedure described by Thomas (1982), cation exchange capacity was determined by the procedure described by Rhoades (1982), soils reaction (pH) was measured in saturated extracts of soils (McLean 1982). Soils classified as Ustorthents (Soil Survey Staff, 1999). The sandy loam textured soil with 1.5% OM was referred as the T_C-OM_L soil, and silty loam textured soil with 2.9% OM as the T_F-OM_H soil.

Table 1. Selected properties of the soils used in the experiment

Characteristics	Soil sample	
	T_C-OM_L	T_F-OM_H
Sand (%)	66	21
Silt (%)	24	61
Clay (%)	10	18
pH (1:2.5 in water)	7.8	7.6
Organic matter content (%)	1.5	2.9
Cation exchange capacity (cmol kg^{-1})	14.3	32.2
Exchangeable Na (cmol kg^{-1})	0.76	0,12

Soil samples were air dried and sieved for obtaining of aggregate size groups (12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm). The mechanical composition (Fig. 1.), aggregation of particles less than 50 μm as degree of aggregation (Richards, 1954), air permeability (Corey, 1982), water permeability (Klute and Dirksen, 1986) and Proctor test (Head, 1974) were also determined for each aggregate size group in both soil samples.

Particle size distribution curve for each aggregate fraction is shown in figure 1. It is clearly seen that increased the aggregate size fraction increased the amount of coarse particles. The rate of increase was low in T_F-OM_H.

The water permeability experiment was performed in 5-cm long brass cylindrical columns with an internal diameter of 5 cm. Each column was filled with the aggregate size groups at air dry state. The aggregate size group for each column was packed carefully for establishing uniformity throughout the column. A filter paper was placed on the top of the aggregate size group layer in the column. Each column was putted in a tray and the samples were saturated from the bottom with distilled water for 24 h. After saturation was reached, the columns were drained and air dried for one-half and quarter of water content in saturation except for columns under saturation condition. This experiment, to study the effect of the compactive force on the soil compaction, was conducted using a completely randomized factorial design as follows. At the experiment there were two soils, six aggregate size groups, three soil water contents (SWC1 - approximately saturation-, SWC2 -one half of water content in saturation - and SWC3 - quarter of water content in saturation), three compactive forces (control, 45 kPa and 90 kPa), and three replicates totaling 324 columns. The compaction treatments were applied to each aggregate size group in the column for all water content by a compaction mechanism (Fig. 2).

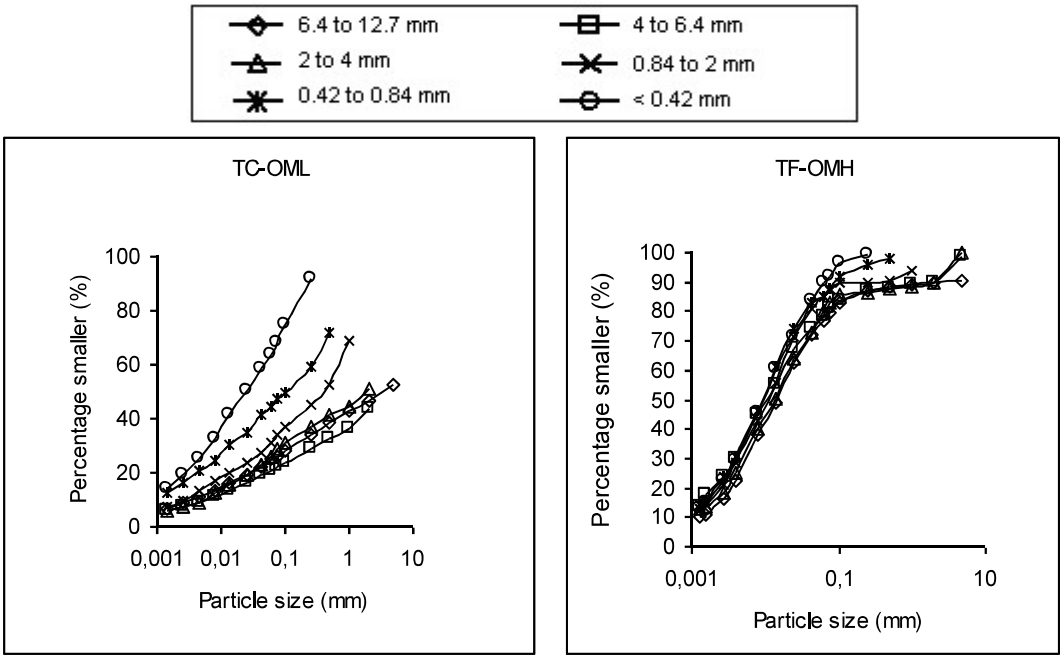


Figure 1. Particle size distribution curves of six aggregate size groups for T_C-OM_L soil and T_F-OM_H soil.

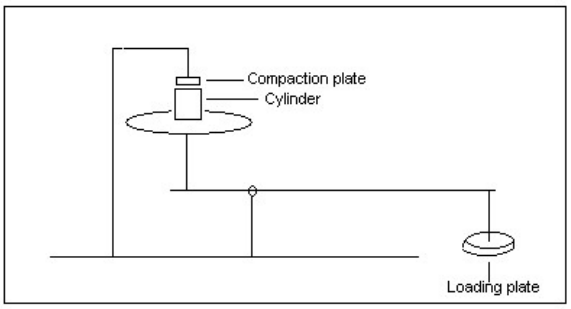


Figure 2. Compaction mechanism (This mechanism established by an ohaus ballance).

Heights and weights of aggregate size group in the column were measurmed before and after wetting procedure and compaction. The volume and the dry density of aggregate size group in the column were calculated from these values. The dry density of the soil before application of the selected compactive forces was defined as the initial dry density. The dry density of the soil after application of the selected compactive forces was defined as the final dry density.
All statistical analyses (ANOVA and Duncan tests) were performed according to Dowdy and Weardin (1983).

RESULTS and DISCUSSION

Effect of Aggregate Size on Degree of Aggregation

Degree of aggregation values of the two soils determined by the aggregation of particles less than 50 μm, for 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and

<0.42 mm aggregate sizes were presented in Table 2. The results of ANOVA indicated that the effects of soils and the aggregate size on degree of aggregation were statistically significant at the 0.01 probability level. There were significant differences in degree of aggregation at 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm among the aggregate sizes.

No significant differences were observed between 2-0.84 mm and<0.42, 4-2 mm and <0.42 mm aggregate sizes in T_C-OM_L and T_F-OM_H soils and between 4-2 mm and 2-0.84 mm aggregate size for the T_C-OM_L soil.

The results generally indicated that significantly higher dispersion of particles less than 50 μ particle in the T_C-OM_L soil than in the T_F-OM_H soil. These results suggest that the degradation of the soil structure was more extensive in the T_C-OM_L soil than in the T_F-OM_H soil. The high organic matter content acted as a binding, holding the particles in the aggregate together against the slaking forces (Lado, 2004), whereas in the T_C-OM_L soil, the organic matter content was too low to prevent the slaking.

Table 2. Compaction parameters, air permeability and degree of aggregation of aggregate size groups.

Soils	Max. Dry density ($Mg\ m^{-3}$)	Optimum moisture content (%)	Degree of aggregation (%)	Air permeability (μm^2)
T_C-OM_L	1.75 a	16.0 b	68,8 b	306 a
T_F-OM_H	1.34 b	28.9 a	82,7 a	224 b
Aggregate size(mm)				
12.7-6.4	1.65 a	18.5 f	86,3 a	407 a
6.4-4	1.61 b	19.9 e	83,0 b	402 a
4-2	1.58 c	21.3 d	77,2 c	340 b
2-0.84	1.54 d	21.9 c	76,3 d	278 c
0.84-0.42	1.49 e	25.2 b	72,2 e	158 d
< 0.42	1.39 f	27.8 a	59,5 f	6 e

Means followed by the same letter are not significantly different (P < 0.05).

Effect of Aggregate Size on Maximum Dry Density and Optimum Moisture Content

Maximum dry density and optimum moisture content of the both soils with different texture and organic matter contents for 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm aggregate sizes were presented in Table 2. In both the T_F-OM_H and the T_C-OM_L soils, the maximum dry density values of the 12.7-6.4 mm aggregate size were one order of magnitude higher than those of the others aggregate sizes but optimum moisture content of the 12.7-6.4 mm aggregate size were one order of magnitude lower than those of the others aggregate sizes.

The results of ANOVA indicated that the effects of soils and the aggregate size on maximum dry density and optimum moisture content were statistically significant at the 0.01 probability level. Multiple comparison tests were determined for maximum dry density and optimum moisture content. Test results were given Table 2. The Duncan test results indicated that soil with T_F-OM_H had the lowest mean maximum dry density and highest optimum moisture content. There were significant differences in maximum dry density and optimum moisture content at 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm among the aggregate sizes.. For the six aggregate

sizes, 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm, the maximum dry density values of the T_C-OM_L soil were significantly higher than those of the T_F-OM_H soil (Fig. 3).

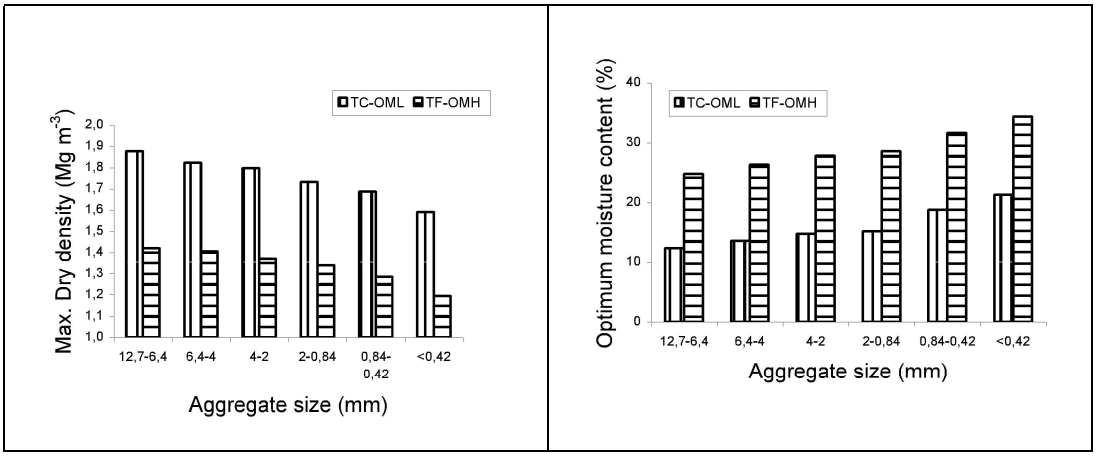


Figure 3. Aggregate size versus maximum dry density and optimum moisture relation for two soils.

Fig. 3 clearly shows that maximum dry density decreases with decreasing aggregate size in both the T_F-OM_H and the T_C-OM_L. The decreasing rates were 2.8, 4.3, 7.7, 10 and 15.3% for the T_C-OM_L soil and 1.1, 3.4, 5.6, 9.4 and 15.8% for the T_F-OM_H soil at 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm aggregate sizes according to 12.7-6.4 mm aggregate size respectively. The optimum moisture content increases with decreasing aggregate size in both the T_F-OM_H and the T_C-OM_L. The rate were 9,7, 19,3, 23, 51,8 and 72,6% for the T_C-OM_L soil and 6,3, 12,3, 15,4, 27,7 and 38,7% for the T_F-OM_H soil at 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm aggregate sizes according to 12.7-6.4 mm aggregate size respectively.

These results suggest that the degradation of the soil structure during the field traffic process was more extensive in the T_C-OM_L soil than in the T_F-OM_H soil. The results of the maximum dry density measurements indicate that aggregate size distribution and organic matter content improved the resistance of soils to the effect of compaction. Indeed, organic matter content can also stimulate the production of binding agents those aggregate soil particles into a more stable soil (Nemati et al., 2000).

Our results indicate that the maximum dry density of soils increased with decreasing in aggregate size for two soils, and the 12.7-6.4 mm aggregate size produced the highest density values. However, the optimum moisture content of soils decreasing with increasing in aggregate size for two soils, and the 12.7-6.4 mm aggregate size produced the lowest moisture values.

The T_F-OM_H soil had the lowert mean of maximum dry density. This may indicate that organic matter and fine texture makes soil more resistant to compaction as stated by Canbolat (1992) and Arvidsson (1998). Díaz-Zorita & Grosso (2000) found that higher total organic carbon levels reduced the maximum dry density and that the critical water content was independent from textural class.

Effect of Aggregate Size on Air Permeability

Air permeability of the both soils with different texture and OM contents for 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm aggregate sizes are presented in Table 2. In both the T_F-OM_H and the T_C-OM_L soils, the air permeability values for dry aggregates in uncompacted columns decreased with decreasing in aggregate size for two soils, and the 12.7-6.4 mm aggregate size produced the highest and <0.42 mm aggregate size produced the lowest air permeability.
The results of ANOVA indicated that the effects of soils and the aggregate size on air permeability were statistically significant at the 0.01 probability level. The Duncan test results indicated that soil with T_F-OM_H had the lowest mean air permeability (Table 2). There were significant differences in air permeability at 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm among the aggregate sizes. For the six aggregate sizes, 4-2 mm, 2-0.84 mm, 0.84-0.42mm and <0.42 mm, the air permeability values of the T_C-OM_L soil were significantly higher than those of the T_F-OM_H soil. No significant differences were observed between 12.7-6.4 mm, 6.4-4 mm, aggregate sizes in T_C-OM_L and T_F-OM_H soil, also were observed between the T_C-OM_L and T_F-OM_H soils for 12.7-6.4 mm aggregate size.
The results indicate that pore structure of soils (dry) were affected by aggregate size. Air permeability is highly dependent on both air-filled porosity and soil pore structure (Moldrup et al., 1998). Air permeability is an easy to measure soil parameter that is of direct importance in gas transport studies. Its values can also be used as indicators of soil hydraulic conductivity. Near the soil surface, both air and water permeability values are important for hydrological and agricultural studies involving (Jalbert and Dane, 2003).

Soil Behavior Against Compactive Forces

The influences of the application compactive force on six different aggregate sizes were determined. Dry density and water permeability were evaluated for predicting efect on soil behavior of application compactive forces. The initial and the final dry density values of the two soils with different texture and organic matter content as functions of the application compactive force for three different water content and 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm aggregates sizes are presented and the water permeability is also presented for water saturated condition in Table 3.

The result of ANOVA for the data of initial and final dry densities, and water permeability indicated that all the factors (soils, aggregate size, soil water content and compactive force) had significant effect on the measured properties. The Duncan test results showed that there were significant differences for the measured properties among soils, aggregate sizes, water contents and compactive forces (Table 3).
For both soils and aggregate sizes, the water content values of the T_C-OM_L soil were significantly lower than those of the T_F-OM_H soil. For both soils and aggregate sizes initial and final dry density decreased with decreasing aggregate size except for aggregate size <0.42mm.

Table 3. The dry density values of the two soils before and after application compactive force for three different water content and six aggregates sizes and the water permeability values for water saturated condition.

	Water content (%)	Dry density (Mg m^{-3}) Initial	Final	Water permeability (μm^2)
Soils				
T_C-OM_L	33,0	1,18 a	1,30 a	2,63 a
T_F-OM_H	43,6	0,93 b	1,02 b	2,15 b
Aggregate size (mm)				
6.4 to 12.7	42,4 a	1,09 b	1,21 a	7,89 a
4 to 6.4	39,1 b	1,07 c	1,19 b	2,73 b
2 to 4	36,9 d	1,05 d	1,17 d	1,76 c
0.84 to 2	36,5 e	1,00 e	1,14 e	1,05 d
0.42 to 0.84	38,8 c	0,98 f	1,09 f	0,84 e
< 0.42	36,1 f	1,14 a	1,18 c	0,07 f
Water content (%)				
SWC 1	67,1 a	1,06 a	1,17 b	
SWC 2	31,9 b	1,05 a	1,19 a	
SWC 3	15,8 c	1,05 a	1,12 c	
Compactive force (kPa)				
Control	38,2 a	1,05 a	1,05 c	6,42 a
45	38,4 a	1,06 a	1,18 b	0,56 b
90	38,3 a	1,05 a	1,25 a	0,19 c

Means followed by the same letter are not significantly different ($P < 0.05$).

The results of the dry density measurements indicate that compactive forces increased dry density values according to not application compactive force. Compaction was caused an increase in soil dry density probably due to increases in soil strength, and decreases in water permeability.

In both the T_F-OM_H and the T_C-OM_L soils, the water permeability values for water saturated condition in uncompacted columns decreased with decreasing in aggregate size for two soils, and the 12.7-6.4 mm aggregate size occurred the highest and <0.42 mm aggregate size also produced the lowest water permeability. The effects of soils and the aggregate size on water permeability were statistically significant at the 0.01 probability level. The Duncan test results indicated that soil with T_F-OM_H had the lower mean water permeability. There were significant differences in water permeability values at 12.7-6.4 mm, 6.4-4 mm, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm among the aggregate sizes.

For the six aggregate sizes, 4-2 mm, 2-0.84 mm, 0.84-0.42 mm and <0.42 mm, the water permeability values of the T_C-OM_L soil were significantly higher than those of the T_F-OM_H soil. No significant differences were observed between the T_C-OM_L and T_F-OM_H soils for 6.4-12.7-mm , 4-6.4 mm aggregate size. It was also observed between 4-6.4 mm and 2-4 mm aggregate size in T_C-OM_L and T_F-OM_H soils. The results indicate that pore structure of soils (wet) was affected by aggregate size. T_F-OM_H soil with well developed structure and high aggregate stability has greater strength to resist compression than T_C-OM_L soil.

REFERENCES

Abu-Hamdeh, N.H. 2003. Compaction and subsoiling effects on corn growth and soil bulk density. Soil Science Society of America Journal. *67:12*13-1219.

Arvidsson, J. 1998. Influence of soil texture and organic matter content on bulk density, air content, compression index and crop yield in field and laboratory compression experiments. Soil and Tillage Research 49 (1-2):159-170.

Assouline, S. 2002. Modeling soil compaction under uniaxial compression. Soil Sci. Soc. Amer. J.; 66: 1784-1787.

Canbolat, M.Y. 1992. Effects of adding organic material into the soils on organic matter, aggregate stability and permeability of soils. Ataturk Uni. Agriculture Fac. J. 23 (2): 113-123.

Canbolat, M., Oztas T., Barik K. and Aksakal E. L. 2002. Compactibility of Soils at Different Moisture Contents. International conference on sustainable land use and management. 10-13 June 2002 Canakkale Turkey.

Corey, A.T. 1986. Air permeability. p. 1121–1136. In A. Klute (ed.) Methods of soil analysis. Part 1. Physical and mineralogical methods. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Díaz-Zorita, M. and Grosso G.A. 2000. Effect of soil texture, organic carbon and water retention on the compactability of soils from the Argentinean pampas. Soil Tillage Res. 54:121–126.

Díaz-Zorita, M., Grove J. H. and Perfect E. 2001. Laboratory compaction of soils using a small mold procedure Soil Science Society of Amer. Journal 65:1593-1598.

Doganay, H., Guner U. and Yazici H. 1998. Geography In Erzurum. Erzurum Valiligi. p. 87-134.

Dowdy, S., Weardin, S., 1983, Statistics for Research. John Wiley and Sons Inc. New York, USA.

Gee, G.W. and Bauder J.W. 1986. Particle size analysis. A. Klute (ed.) Methods of Soil Analysis Part 1. Physical and Mineralogical Methods. 2nd Edition 9, 383-411 American Society ofAgronomy, Madison, WI.

Head, K.H. 1984. Manual of Soil Laboratory Testing. Vol. 1: Soil Classification and Compaction Tests, p. 339. London.

Imhoff, S., Da Silva A P and Fallow D, 2004 Susceptibility to Compaction, Load Support Capacity, and Soil Compressibility of Hapludox. Soil Sci. Soc. Am. J. 68:17-24

Jalbert, M. and Dane J.H. 2003. A Handheld Device for Intrusive and Nonintrusive Field Measurements of Air Permeability Vadose Zone J. 2: 611-617.

Jones, A.J., R.D. Grisso, and C.A. Shapiro. 1988. Soil Compaction...Fact and Fiction Common Questions and Their Answers. NE. Coop. Ext. Serv. CC 342

Kay, B.D., Da Silva A.P. and Baldock J.A. 1997. Sensitivity of soil structure to changes in organic carbon content: Predictions using pedotransfer functions. Can. J. Soil Sci. 77:655–667.

Klute, A. and Dirksen C.. 1986. Hydraulic conductivity and diffusivity; laboratory methods: In A. Klute (ed). Methods of soil analysis, Part 1. Rev. Physical and Mineralogical Methods. Amer. Soc. of Agron. Monogr. 9. pp.687-732.

Lado, M., Paz A. and Ben-Hur M. 2004. Organic matter and aggregate-size interactions in saturated hydraulic conductivity. Soil Sci. Soc. Amer. J. 68: 234-242.

Larson, W.E., S.C. Gupta, and R.A. Useche. 1980. Compression of agricultural soils from eight soils order. Soil Sci. Soc. Am. Proc. 44:450–457.

McBride, R.A. and P.J. Joosse. 1996. Overconsolidation in agricultural soils: II. Pedotransfer functions for estimating preconsolidation stress. Soil Sci. Soc. Am. J. 60:373-380.

McLean, E. O. 1982. Soil pH and lime requirement. In Page, A. L., R. H. Miller and D. R. Keeney (eds.) Methods of soil analysis. Part 2 Chemical and microbiological properties. (2nd Ed.). Agronomy 9. pp. 199-223.

Moldrup, P., Poulsen T.G., Schjønning P., Olesen T., and Yamaguchi T. 1998. Gas permeability in undisturbed soils: Measurements and predictive models. Soil Sci. 163:180–189.

Nelson D.W. and Sommers L.E. 1982. Total carbon, organic carbon and organic matter. In Page A L Miller R H and Keeney D R (Eds.) Methods of Soil Analysis Part 2.Chemical and Microbiological Properties. 2nd Edition Agronomy 9, 539–579.

Nemati, M.R. Caron J. and Gallichand J. 2000. Stability of structural form during iinfiltration laboratory measurements on the effect of de-inking sludge. Soil Sci. Soc. of Amer. J. 64: 543-552.

Rhoades, J. D. 1982. Soluble salts. In Page A L Miller R H and Keeney D R (Eds.) Methods of Soil Analysis Part 2. Chemical and Microbiological Properties. 2nd Edition Agronomy 9, 167–178.

Richards, L. A. 1954. Diagnosis and improvement of saline and alkaline soils. U.S.D.A. Agriculture handbook, no.60, Washington, U.S.A.

Sanchez-Giron, V.; Andreu, E.; Hernanz, J. L. 1998. Response of five types of soil to simulated compaction in the form of confined uniaxial compression tests. Soil and Tillage Research 48: 37-50.

Shepherd, T.G., Saggar S.R., Newman H., Ross C. W. and Dando J.L. 2001. Tillage-induced changes to soil structure and organic carbon size groups in New Zealand soils. Australian Journal of Soil Research 39(3): 465 – 489.

Soil Survey Staff 1999 Soil Taxonomy a Basic System of Soil Classification for Making and Interpreting Soil Surveys 2nd ed. US Department of Agriculture Soil Conservation Service Washington.

Thomas, G. W. 1982. Exchangeable cations. In Page A L Miller R H and Keeney D R (Eds.) Methods of Soil Analysis Part 2. Chemical and Microbiological Properties. 2nd Edition Agronomy 9, 159–164.

Zobeck, T. M., Popham T. W., Skidmore E. L., Lamb J. A., Merrill S. D., Lindstrom M. J., Mokma D. L., and Yoder R. E. 2003. Aggregate-Mean Diameter and Wind-Erodible Soil Predictions Using Dry Aggregate-Size Distributions. Soil Sci. Soc. Amer. J. 67: 425-436.

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THE EFFECT OF AGGREGATE SIZE DISTRUBUTION ON ROOT GROWTH OF PLANT AND PHYSICAL PROPERTIES OF SOIL

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ABSTRACT

The purposes of this study were to determine the effect of soil aggregate size distribution on root growth of plant using of some physical properties of soil. Three soil samples were taken from the 0-20 cm depth in Erzurum region. Five different aggregate combinations (25.4-12.7 mm; 12.7-6.4 mm; 6.4-4 mm; 4-2 mm; 2-0.84 mm and <0.84mm) were preperated and physical, mechanical and chemical properties of these samples were determined. As size of aggregates got larger the applied stress to crush the aggregate got higher but strength aggregates against crushing and modules of rupture decreased. The relationship between soil moisture and time for drying indicated that moisture content of samples were significantly affected by aggregate size distribution. On the other hand, the root and shoot growth of beans (Phaseolus vulgaris var. contender) grown in pots of different size distribution on these samples were investigated. It was obtained that aggregate size distribution had an significant effect in plant growth.

Keywords: aggregate size, root growth, crushing forces, modulus of rupture.

INTRODUCTION

The structure of soil can be modified by soil and management practices. Changes in soil structure can cause changes in plant growth. One such soil structural variable is the size of aggeragtes in the seedbed. The optimum aggregate size under field conditions varies with the crop and the amount of precipitation received durring the early growth period (Jain and Grawel, 1970; Taylor, 1974; Donald et al., 1987). The degree of root-soil contact is important for both aeration and uptake activities of the root. The chance that roots will obtain sufficient oxygen to survive periods of reduced soil aeration after heavy rainfall decreases with a higher degree of root-soil contact (De Willigen and Van Noordwijk, 1984,1989)

The structure of the seedbed determines the ease with which water can move to the seed and the roots. A seedbed composed of soil aggregates smaller than 5 mm geometric mean diameter provided the optimum combination of seed-soil contact and soil hydraulic conductivity for corn emergence (Larson, 1964).

Donald et al. (1987) investigated the direct effects of aggregate size on shoot and root growth of maize (*Zea mays L.*) seedlings when water and nutrients were not limiting. They observed that decreasing shoot growth with increasing aggregate size could be explained by neither water relations nor nutrient status.

Soil aggregate size has been found to influence emergence, early shoot growth and root growth of maize (Zea mays L.) (Donald et al., 1987).

Logsdon et al. (1987) described that the diameters of roots grown in 3-6 mm aggregates did not impede significantly, whereas, root lengths were not always signficantly decreased. The smaller aggregates did not impede root growth and were readily displaced by roots. Large aggregates were more of an impedance to lateral roots than to main axes.

Canbolat (1990) found that soil crushing affected modulus of rupture significantly. As the degree of soil crushing increased the modulus of rupture values measured increased.

Oztas et al. (1999) determined the relative strength of indivividual soil aggregates of different, sizes and shapes against crushing forces. They emphasized that as the aggregate size increased, so did the applied stress required to crush the aggregate.

The purposes of this study were to determine the effect of soil aggregate size distribution on root growth of plant, water content for drying process, crushing forces and modulus of rupture.

MATERIALS AND METHODS

In this study, three soil samples were taken from the 0-20 cm depth of Ispiryolu (S 1), Pasayurdu (S 2) and Ciftlik (S 3) series in Erzurum. Samples were carried to the laborotory and allowed to air dry. The soils were sieved into the following aggregate size fractions;<0.84mm, 0.84-2mm, 2-4mm, 4-6.4mm, 6.4-12.7mm and 12.7-25.4mm. Five different aggregate combinations were prepareted and physical, mechanical and chemical properties of these samples were determined.

In this study bean (Phaseolus vulgaris var. contender) was used. In order to preserve aggregate form, irrigation was made by wetting bottom of pots , as shown in the figure 1.

Texture of the soil samples was determined with Bouyoucos hydrometer method (Gee and Bouder, 1986) and organic matter content was determined by Smith-Weldon method (Nelson and Sommers, 1982). Soil bulk density was determined by the core method (Blake and Hartge, 1986). Aggregate stability was determined by wet sieving method (Kemper.and Rosenau, 1986). Cation exchange capacity of the samples was determined with ammonium acetate-sodium acetate method (Rhoades, 1982 a). Electrical conductivity was determined on the saturation paste extract (Rhoades, 1982b), Liquid limit tests by the Casagrande method plastic limit tests as per the conventional rolling thread method and plasticity index of the soils were calculated from difference between the liquid and the plastic limit water contents of the soil (Head, 1992). Aggregates against disruptive forces were determined crushing method (Oztas et al., 1999), Modulus of rupture was determined by briquet method (Canbolat, 1990).

The data of this study were evaluated by ANOVA, and Duncan's multiple range test, in order to determine the relationships among variables (Dowdy ve Wearden, 1983).

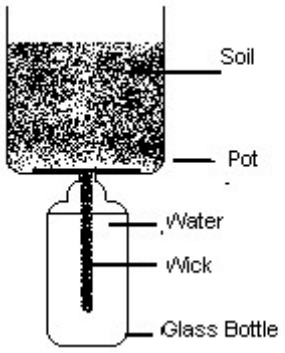


Figure 1. Irrigation system

RESULTS AND DISCUSSION

The clay content of soil samples varied from 18% to 48%, silt content from 29% to 32%, sand content from 20% to 53%, organik matter content from 1.14% to 1.70%, electrical conductivity between 0.32 and 0.58 mmhos/cm, pH between 7.9 and 8.4, cation exchange capacity between 16 and 39 me/100gr, liquid limit between 33% and 60%, plastic limit between 22.3% and 43%, plasticity index between 11 and 20, aggregate stability between 36% and 47%, bulk density between 1.46 and 1.71g/cm^3 (Table 1.).

Table.1. Physical, mechanical and chemical characteristics of soils.

Soil properties	Soil samples		
	S 1	S 2	S 3
Sand (%)	20	31	53
Silt (%)	32	29	29
Clay (%)	48	40	18
PH	8.4	7.9	8.2
Organic matter (%)	1.40	1.14	1.70
Cation exchange capacity (cmol kg^{-1})	39	37	16
Electrical conductivity (dS m^{-1})	0.32	0.36	0.58
Bulk density (Mg m^{-3})	1.46	1.58	1.71
Aggregate stability (%)	47	41	36
Liquid limit (%)	60	52	33
Plastic limit (%)	43	32	22
Plasticity index (%)	17	20	11

The influence of crushing forces and strenght of aggregates against crushing forces on three different aggregate size (6.4-4mm, 12.7-6.4mm and 25.4-12.7mm) were determined. The analysis of variance and multiple range test results were shown in Table 2.

The results of ANOVA for applied crushing force and strength of aggregates against crushing forces indicated that soils had not significant effect on the measured properties. But aggregate size had significant effect for applied crushing force and strength of aggregates against crushing forces. The multiple range test results showed that there were significant difference in applied crushing force and strength of aggregates against crushing forces among aggregate sizes.

Modulus of rupture test was performed for <0.84 mm, 0.84-2 mm 2-4 mm aggregate sizes on the soil samples of Ispiryolu (S 1) and Pasayurdu (S 2) series. The ANOVA and multiple range test results were shown in Table 3. The results of ANOVA for modulus of rupture test indicated that soils and aggregate sizes had significant effect on the breaking strength of soil briquet

The multiple range test results showed that there were significant difference in modulus of rupture among aggregate sizes and soils. As the aggregate diameter decreased, the modulus of rupture values measured increased. This result is supported by the results of Canbolat (1990) The tendency of different soils for hard-setting and crusting, as a result of structural collapse, was reflected in the modulus of rupture.

Table 2. The effect of aggregate mean diameter of three different soils on the crushing forces and strenght of aggregate

Properties		Crushing force (kPa)	Strength of aggregate (kPa)
Soils			
S 1		149.6 a	106.5 a
S 2		134.8 a	100.7 a
S 3		131.4 a	78.4 a
Aggregate mean diameter (mm)			
5.2 (6.4-4)		75.2 c	165.7 a
9.55 (12.7-6.4)		116 b	82.7 b
19.05 (25.4-12.7)		224.7 a	37.2 c
Source	D. F.		ANOVA
Soils (S)	2	NS	NS
Aggregate size (AS)	2	**	**
S×AS	4	**	NS
Error	81		

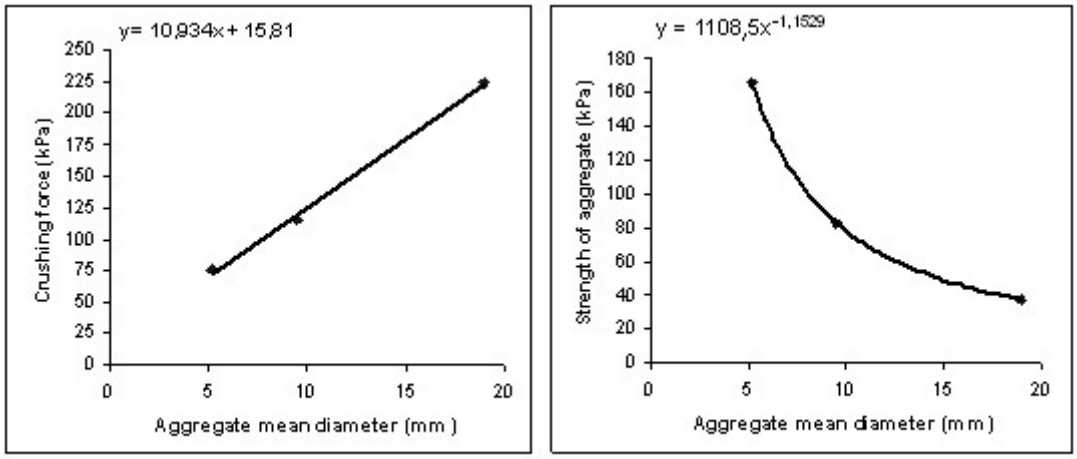
Values followed by same letter did not differ significantly from Duncan multiple range tests at 5% significance; *, ** significant at 0.05 and 0.01 probability levels, respectively.

Table 3. The effect of three different aggregate size, of two soils samples on modulus of rupture.

Properties		Modulus of rupture (kPa)
Soils		
S 1		11.5 b
S 2		21,2 a
Aggregate size (mm)		
<0.84		21.1 a
0.84-2		17.5 b
2-4		10.5 c
Source	D. F.	ANOVA
Soils (S)	2	**
Aggregate size (AS)	2	**
S×AS	4	NS
Error	81	

Values followed by same letter did not differ significantly from Duncan multiple range tests at 5% significance; *, ** significant at 0.05 and 0.01 probability levels, respectively.

The realtionship between mean aggregate diameter and applied crushing force is shown in Figure 1.a. It indicates that as the size of an aggregate increases, the applied crushing force required to break up the aggregate is greater. However, strength of aggregates against crushing forces decreased with increasing mean aggergate diameter (Figure 1.b). This indicates that small aggregates were more stable than large aggregates against applied crushing forces. Since the stability of aggregates is a function of whether the cohesive forces between particles withstand the applied crushing forces (Kemper and Rosenau, 1986), the strength of small aggregates may be due to strong bonds between particles. Under applied crushing stress aggregate deformation occurs at the weakest points. Thus, large aggregates may be broken into small aggregates (Oztas et al., 1997).



a b

Figure 1. Relationships between aggregate mean diameter and crushing force (a). Relationships between aggregate mean diameter and strength of aggregates against crushing forces (b).

The influence of six different aggregate size on soil water content were determined at drying process. The analysis of variance and multiple range test results were shown in Table 4 .A statistical summary of analyses of variance shows that all the factors (soils, aggregate size and time) had significant influence on the water content. The Duncan test results showed that there were significant differences in water content among soils, aggregate sizes and drying time (Table 4). This could be attributed to the clay content of soil. The water content of 6.4-12.7 mm aggregate fractions were highest than those of the others. This may due to highest micro porosity, clay and organic matter content of these aggregate fractions. The water content of 2-4 mm aggregate fractions was lower than those of the others (Figure 3). This may due to lower micro porosity of this aggregate fraction.

Table 4. The effect of six different aggregate size of three soils samples on water content.

Properties		Water content (%)
Soils		
S 1		44,6 a
S 2		38,1 b
S 3		19,5 c
Aggregate size (mm)		
<084		35.0 b
0.84-2		34.4 c
2-4		30.8 e
4-6.4		33.2 d
6.4-12.7		36.9 a
Time (h)		
0		82.5 a
24		55.9 b
48		39.1 c
96		17.1 d
120		7.1 e
240		2.7 f
Source	D. F.	ANOVA
Soils (S)	2	**
Aggregate size (AS)	4	**
Time (T)	5	**
S×AS	8	**
S×T	10	**
AS×T	20	**
S×AS×T	40	**
Error	90	

Values followed by same letter did not differ significantly from Duncan multiple range tests at 5% significance; *, ** significant at 0.05 and 0.01 probability levels, respectively.

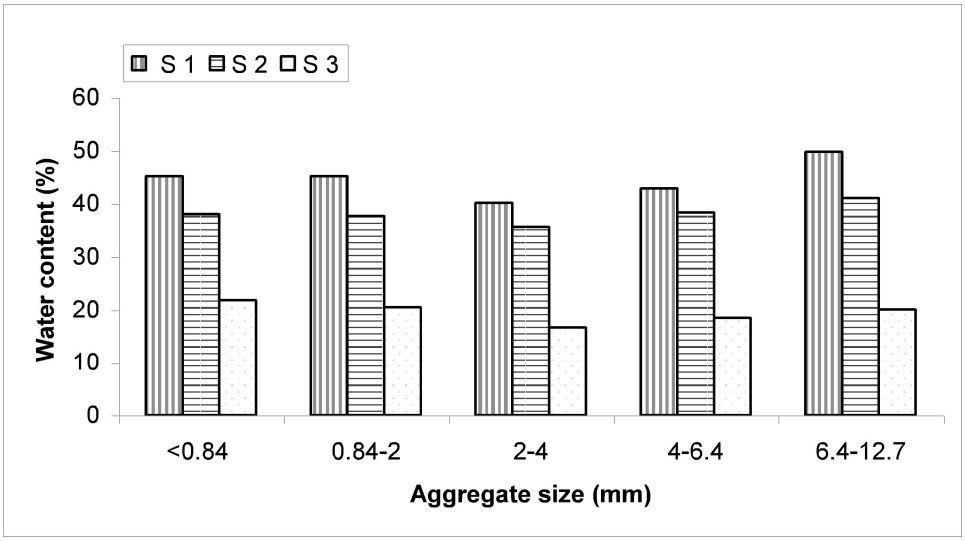


Figure 3. The relationship between the aggregate size and water content of the three soils.

On the other hand, beans (Phaseolus vulgaris var. contender) were growth on pots with different aggregate size distribution, and the root and shoot growth on these samples were investigated. The statistical results were shown in Table 5. The influence of different aggregate size on plant shoot and root growth were determined. The results of ANOVA indicated that soils and aggregate sizes had significant effect for shoot and root weight. The multiple range test results showed that there were significant difference in shoot and root weight among soils and aggregate sizes. Donald et al. (1987) were suggeted that some factor other than nutrients or water supply was responsible for declining shoot growth with increasing aggregate size. The factor must related to the role that aggregate charactreristics play inroot development and or physiology and the distribution of photosynthate between shoots and roots.

Table 5. Plant root and shoot dry weights for soil and aggregate size.

Properties		Root dry weight (g)	Shoot dry weight (g)
Soils			
S 1		0,482 a	0,775 b
S 2		0,386 b	0,611 c
S 3		0,371 c	0,848 a
Aggregate size (mm)			
<084		0,407 c	0,544 d
0.84-2		0,479 a	0,800 b
2-4		0,386 d	0,829 a
4-6.4		0,387 d	0,752 c
6.4-12.7		0,415 b	0,799 b
Source	D. F.	ANOVA	
Soils (S)	2	**	**
Aggregate size (AS)	4	**	**
S×AS	8	**	**
Error	15		

Values followed by same letter did not differ significantly from Duncan multiple range tests at 5% significance; *, ** significant at 0.05 and 0.01 probability levels, respectively.

CONCLUSIONS

The results of this study showed that the strength of aggregates against applied crushing forces was directly related to aggregate size. It indicates that as the size of an aggregate increases, the applied crushing force required to break up the aggregate is greater. However, strength of aggregates against crushing forces decreased with increasing mean aggergate diameter. As the aggregate diameter decreased, the modulus of rupture values measured increased. The results showed that there were significant differences in water content among soils, aggregate sizes and drying time. There were also significant differences in root and shoot weights between soils and aggregate sizes. This study clearly indicated the size distrubition importance of aggregates for soil physical properties and plant growth.

REFERENCES

Blake, G.R., Hartge, K.H., 1986. Bulk density. In: Klute, A. (Ed.), Methods of Soil Analysis: Part 1. Physical and Mineralogical Methods, 2nd ed. American Society of Agronomy, Madison, WI, pp. 363–375.

Canbolat, M.Y., 1990, Igdir Yoresi Topraklarinda Kaymak Sertligi (Kirilma Degeri) ile Ilgili Arastirmalar. Ataturk Uni. Fen Bilim. Enst. (Doktora Tezi). Erzurum.

De Willigen, P. and Van Noordwijk, M., 1984 Mathematical models on diffusion of oxygen to and within plant roots, with special emphasis on effects of soil root contact. I. Derivation of models, II. Applications. Plant Soil, 77: 215-241.

De Willigen, P. and Van Noordwijk, M., 1989. Model calculations on the relative importance of internal longitudinal diffusion for aeration of roots of non-wetland plants. Plant Soil, 113: 111-119.

Donald, R.G., Kay, B.D. and Miller, M.H., 1987, The effect of soil aggregate size on early shoot and root growth of maize ((Zea Mays L.). Plant and Soil, 103: 251-259.

Dowdy, S. and S. Weardin 1983, Statistics for Research. John Wiley and Sons Inc. New York, USA.

Gee, G. W. and Bauder, J.W. 1986, Partical-Size Analysis. p. 383-411. In A. Klute (ed.) Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI. USA.

Head, K.H., 1984, Manual of Soil Laboratory Testing. Vol. 1: Soil Classification and Compaction Tests, p. 339. London.

Jain, N. K. and Grawel, J. P. 1970; Effect of clod size in the seedbed on development and yield of sugarcane. Soil Sci. Soc. Amer., 34: 795-797.

Kemper, W.D.and Rosenau, R.C., 1986, Aggregate stability and size distribution. p. 425-442. In A. Klute (ed.) Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI. USA.

Larson, W. E., 1964. Soil parameters for evaluating tillage needs and operations. Soil Sci.Soc. Amer. Proc., 28: 118-122.

Logsdon, S.D., Parker, J.C. and Reneau, R.B. 1987, Root growth as influenced by aggregate size. Plant and Soil, 99: 267-275.

Nelson D.W and Sommers, L.E., 1982. Total carbon, organic carbon and organic matter. In: A.L. Page, R.H. Miller and D.R. Keeney, Editors, *Methods of Soil Analysis, Part 2*, ASA-SSSA, Madison, pp. 539–579.

Oztas, T., Canbolat, M.Y. and K Sonmez 1999.Strenght of individual soil aggregates against crushing forces II. Influence of selected soil properties. TUBITAK, Tr. J. of Agriculture and Forestry, 23: 573-577.

Oztas, T., Sonmez, K. and Canbolat, M.Y., 1999,Strenght of individual soil aggregates against crushing forces 1.Influence of aggregate characteristics. TUBITAK, Tr. J. of Agriculture and Forestry, 23: 567-572.

Rhoades, J. D., 1982a. Cation exchange capacity. In: A.L. Page, R.H. Miller and D.R. Keeney, Editors, *Methods of Soil Analysis, Part 2*, ASA-SSSA, Madison, pp. 149–157.

Rhoades, J. D., 1982b. Soluble salts. In: A.L. Page, R.H. Miller and D.R. Keeney, Editors, Methods of Soil Analysis, Part 2, ASA-SSSA, Madison, pp. 167–178.

Taylor, M.S., 1974. The effect of aggregate size on seedling emergence and early growth. E. Afr. Agric. And for. J., 40: 204-213.

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EVALUATION OF SOIL CONSISTENCY LIMIT METHODS

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ABSTRACT

Liquid limit (LL), plastic limit (PL) and shrinkage limit are frequently used as indicators of the behavior of cohesive soils. Various methods for consistency limit are used in practice. The objective of this paper were to compare and evaluate the values of consistency limit of soils from liquid and plastic limit tests and to obtain relationships between values of consistency limit and physical and chemical properties of soil and to determine the optimal soil moisture content for tillage operations without causing any damage in soil structure. The liquid limit of soils was determined by Casagrande method (CM), cone penetrometer method (CPM), Casagrande one-point method (COPM) and cone penetrometer one-point method (CPOPM). Plastic limit was determined by standard method. At this study, 25 soils samples from each of 0-30 cm and 30-60 cm of soil profiles were collected. Physical and chemical properties of soil samples were determined.

Keywords: Soil consistency limit methods; Physical properties; Plasticity; Workability; Correlation.

INTRODUCTION

Soil consistency limits indicate the plasticity characteristics of a soil. The main advantage of the concept of consistency is the opportunity to reliably check the soil behavior in the field (Boden, 1994). Plasticity is an inherent property of cohesive soils. Plasticity of a soil is represented behaviour of soil again applied forces to soil.

The soil plasticity is determined by observing the different physical states that a plastic soil passes through as the moisture conditions change. The boundaries between the different states, as described by the moisture content at the time of change, are called consistency limits or Atterberg limits. The Atterberg test cannot be applied for sands and fibric soils. The liquid limit is the moisture content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil. Above this value, the soil is presumed to be a liquid and behaves as such by flowing freely under its own weight. Below this value, it deforms under pressure without crumbling, provided the soil exhibits a plastic state. Liquid limit were determined by Casagrande, cone penetrometer, Casagrande one-point and cone penetrometer one-point methods. The plastic limit is the moisture content at an arbitrary limit between the plastic and semisolid state. It is reached when the soil is no longer pliable and crumbles under pressure. The plastic limit is determined by the rolling thread method. Between the liquid and plastic limits is the plastic range.The numerical difference in moisture content between the two limits is called the plasticity index.

The mechanisms controlling the liquid limit of montmorillonitic and kaolinitic soils are different. The percussion method is well suited to the liquid limit of montmorillonitic soils.The cone method is suits to the liquid limit of kaolinitic soils. (Sridharan and Prakash, 2000).

The evaluation of the Atterberg limits is a very basic soil mechanical test allowing a first insight into the chemical reactivity of clays. Basically, the liquid limit and the plasticity index are highly and mainly influenced by the ability of clay minerals to interact with liquids. (Schmitz et. all, 2004).

Feng (2001) was studied on a linear logarithm–logarithm model for the fall cone penetration depth versus water content. At this study that both the liquid limit and the plastic limit determined from the linear logarithm–logarithm flow curve are in close agreement with those determined from conventional methods. A one-point method for determination of the liquid limit is developed from the model and is verified by applying statistical analysis to a large volume of experimental data

The objective of this paper is to compare and to evaluate the values of consistency limit of soils from liquid and plastic limit test and to research relationships between values of consistency limit and physical and cemical properties of soil and to determine the optimal soil moisture content for tillage operations without causing any damage in soil structure.

MATERIALS and METHODS

Total of 50 soil samples were collected from the depths of 0-30 and 30-60 cm of soil profiles at the Sakalikesik plan in Erzurum.

After sampling, the soils were stored indoors and dried until they could be crumbled to passing through 2 mm sieves for analyses of physicochemical properties. The soils are classified as various types of Ultisols according to USDA soil taxonomy (Soil Survey Staff, 1999). Soils samples were analyzed for pH (McLean, 1982), particle size analysis (Gee and Bouder, 1986), organic matter (Nelson and Sommers, 1982), cation exchange capacity (Rhoades, 1982). The results of soil properties measured in the investigation are presented Table 1.

Table 1. Characterization of some physical and chemical properties of soil samples studied

Variable	Mean	Minimum	Maximum	Mean	Minimum	Maximum
	0-30 cm (n:25)			30-60 cm (n:25)		
Clay, %	28.3	12	56	26	8	48
Silt, %	34.3	21	54	36	27	56
Sandy, %	37.6	11	52	38	12	63
pH (1:2.5 in water)	7.50	7	8.5	7.6	7	9
Organic matter; %	1.76	0.98	3.3	1.3	0.85	2.1
Cation exc.capac.($cmolkg^{-1}$)	24.7	8.7	47	22.	8.6	41.8
Plastic limit (%)	25.3	20.6	34	25	19.4	35

Soil consistency limits were measured from the following tests. Liquid limit tests by the Casagrande method, cone penetration method, Casagrande one-point method and cone penetration one-point method (Head, 1992). Plastic limit tests as per the conventional rolling thread method. Plasticity index of the soils were calculated from difference between the liquid and the plastic limit water contents of the soil. (Head, 1992). Skempton (1953) method was used to obtain Activity (A).

Statistical analysis was performed using the correlation, regression and t-tests. (Dowdy ve Wearden, 1983).

RESULTS and DISCUSSION

Liquid Limit

Liquid limit values were obtained for all soil samples the four different methods. The liquid limit methods were compared with each other. According to t-test results there were no significant difference between Casagrande, cone penetrometer, Casagrande one-point and one-point cone penetrometer methods when comparing liquid limits values of the soil samples taken from 0 - 30 cm and 30 - 60 cm depths.

Statistical comparison of liquid limit methods was showed Table 2. For liquid limits values of the soil samples taken from 0-30 cm depths the highest correlation coefficients were obtained between CM-CPM, COPM CPOPM and CP-CPOPM (r: 0.99). The second best correlation coefficients were obtained between CM vs. COPM and COPM vs. CPM (r: 0.98). The lowest correlation coefficients was obtained between CM vs. CPOPM (r: 0,97).

For liquid limits values of the soil samples taken from 30-60 cm depths, between CM and COPM with CPOPM were obtained the lowest correlation coefficients (r: 0,91). The highest correlation coefficients were obtained between methods of COPM vs. CPOPM (r: 0.99). Sridharan and Prakash (2000) was observed that the cone method gives higher values at lower liquid limit ranges and lesser values at higher liquid limit ranges than the percussion method. For the soils of lower plasticity, the cone method gives values higher than those by cone penetration method. For the soils of higher plasticity, the cone penetration method yields higher values. Budhu (1985) has attributed the difference in the results between the methods (i.e., cone penetration method giving higher values than the cone method) to the clay content in the soil and to the behavior of the clay under different deformation modes imposed by the two devices.

The observed difference between the liquid limits obtained by the two methods has been attributed to the type of clay mineral and its proportion in the clay content rather than the clay content alone. The clay mineral type and its proportion in the clay content decide which of the two methods gives higher liquid limit values than the other.

Table 2. Statistical comparison of liquid limit methods

Liquid limit (LL)	0-30 cm				30-60 cm			
	Mean	Mean	t-value	r	Mean	Mean	t-value	r
LL_{CM} vs. LL_{COPM}	42.1	42.8	-0.26	0.98	44.1	46.0	-0.63	0.91
LL_{CM} vs. LL_{CPM}	42.1	43.0	-0.39	0.99	44.1	45.4	-0.49	0.94

LL_{CM} vs. LLCPOPM	42.1	43.8	-0.67	0.97	44.1	46.0	-0.66	0.91
LL_{COPM} vs. LL_{CPM}	42.8	43.0	-0.08	0.98	46.0	45.4	0.20	0.98
LL_{COPM} vs. LL_{CPOPM}	42.8	43.8	-0.35	0.99	46.0	46.0	-0.20	0.99
LL_{CPM} vs. LL_{CPOPM}	43.0	43.8	-0.32	0.99	45.4	46.0	-0.21	0.97

Plasticity Index

At this study plasticity index was calculated from the difference between results of four analyses were performed for assessing liquid limit and the plastic limit . Statistical comparison of plasticity index was showed Table 3. The plasticity index were compared with each other. According to t-test results there were no significant difference between plasticity index values calculated from results of different liquid limit for 0 - 30 cm and 30 - 60 cm depths.

For plasticity index values of the soil samples taken from 0 - 30 cm depths the highest correlation coefficients were obtained between CM vs. CPM and COPM vs. CPOPM (r: 0.99). The lowest correlation coefficients was obtained between CM vs. CPOPM (r: 0,95)

For plasticity index values of the soil samples taken from 30-60 cm depths, between CM vs. CPOPM methods were obtained the lowest correlation coefficients (r: 0,84). The highest correlation coefficients were obtained between COPM vs. CPOPM (r: 0.99).

Table 3. Statistical comparison of plasticity index values computed from liquid limit methods

	0-30 cm				30-60 cm			
Plasticity index (PI)	Mean	Mean	t-value	r	Mean	Mean	t-value	r
PI_{CM} vs. PI_{COPM}	16.8	17.5	-0.32	0.96	19.0	20.8	-0.76	0.85
PI_{CM} vs. PI_{CPM}	16.8	17.7	-0.48	0.99	19.0	20.2	-0.61	0.90
PI_{CM} vs. PI_{CPOPM}	16.8	18.5	-0.82	0.95	19.0	20.8	-0.82	0.84
PI_{COPM} vs. PI_{CPM}	17.5	17.7	-0.09	0.97	20.8	20.2	0.24	0.97
PI_{COPM} vs. PI_{CPOPM}	17.5	18.5	-0.43	0.99	20.8	20.8	-0,25	0.99
PI_{CP} vs. PI_{CPOPM}	17.7	18.5	-0.40	0.97	20.2	20.8	-0.26	0.94

Activity

At this study activity was calculated by division to clay content of plasticity index. Statistical comparison of activity was showed Table 4. According to t-test results there were no significant difference between activity values calculated for 0 - 30 cm and 30 - 60 cm depths, according to different liqud limit methods.
For activity values of the soil samples taken from 0 - 30 cm depths the highest correlation coefficients were obtained between of CPM vs. CPOPM (r: 0.99). The lowest correlation coefficient was obtained between methods COPM vs CPM (r: 0.95).
For activity values of the soil samples taken from 30-60 cm depths, between CM vs. COPM were obtained the lowest correlation coefficients (r: 0,85). The highest correlation coefficients were obtained between COPM vs. CPOPM and CPM vs. CPOPM (r: 0.95).

Table 4. Statistical comparison of activity values computed from plasticity index and clay content

	0-30 cm				30-60 cm			
Activity (A)	Mean	Mean	t-value	r	Mean	Mean	t-value	r
A_{CM} vs. A_{COPM}	0.66	0.68	-0.18	0.97	0.80	0.85	-0.68	0.85
A_{CM} vs. A_{CPM}	0.66	0.70	-0.48	0.98	0.80	0.85	-0.65	0.93
A_{CM} vs. A_{CPOPM}	0.66	0.72	-0.72	0.97	0.80	0.87	-0.88	0.86
A_{COPM} vs. A_{CP}	0.68	0.70	-0.28	0.95	0.85	0.85	0.05	0.93
A_{COPM} vs. A_{CPOPM}	0.68	0.72	-0.52	0.98	0.85	0.87	-0.20	0.95
A_{CP} vs. A_{CPOPM}	0.70	0.72	-0.24	0.99	0.85	0.87	-0.26	0.95

The Relationships Between Liquid Limit, Plasticity Index and Activity Values and Soil Properties.

Table 5. presented regression coeficients (a and b) and correlation coefficients (r) determined for relationships between liquid limits, plasticity index with activity and clay content, and cation exchange capacity values of the soil samples taken from 0 - 30 cm and 30 - 60 cm depths

There were positive significant correlation between clay content and liquid limit determined by different methods. The correlation coefficients in the 0–30 cm layers are higher than in the 30-60 cm layers

There were positive significant correlation between clay content and plasticity index calculated from liquid limit values determined by different methods. There were negative significant ($P<0.01$) correlation between clay content and activity values calculated from plasticity index and clay content.

There were also positive significant ($P<0.01$) correlation between cation exchange capacity and liquid limit determined by different methods. There were positive significant correlation between cation exchange capacity and plasticity index. There were negative significant correlation between cation exchange capacity and activity.

Sridharan and Prakash (2000) were emphasised that the liquid limit obtained by the cone penetration method can be more than that obtained by the cone method even at very low clay contents. The cone method liquid limit can be more than the cone penetration method liquid limit even at high clay contents. Soil consistency limits were effected by dominant clay minerals, clay content, exchangable cation type and organic matter content of soils (Odell ve ark., 1960 Farrar ve Coleman, 1967; Munsuz, 1985).

Plasticity and Workability

Plasticity behavior of the soil samples taken from 0 - 30 cm were determined from plasticity chart (Figure 1). At this study 64% of soil samples positioned between 30%-50% of liquid limit scale and upper A-line which are medium plasticty zone, 24% of soil samples positioned between 30%-50% of liquid limit scale and bottom A-line. The soil samples 12% positioned high plasticty zone of the plasticity chart. Based upon these results, about 75 % of the soils studied could be tilled without causing any

structural deformation at placticity moisture content. Petelkau (1984), reported that water content for optimum workability was related to the water content at a tension of -5 kPa. According to these findings, clay soils were workable in the range of 50–65%, loam soils in the range of 40–75% and loamy sands in the range of 20–85% of the water content at -5 kPa. The soil workability status is clearly related to the moisture content at the plastic limit according to Atterberg (Canbolat ve Oztas, 1997; Mueller and Schindler, 1998b and Dexter and Bird, 2001).

Table 2. Regression coeficients (a, b) and correlation coeficients (r) determined for the relationships between liquid limit, plasticity index and activity values and soil properties.

Independent variables	Dependent variables	0-30 cm			30-60 cm		
		r	**a**	**b**	**r**	**a**	**b**
Clay	LL (CM)	0,64**	28,89	0,47	0,56**	32,11	0,46
	LL (COPM)	0,63**	26,65	0,57	0,50*	30	0,62
	LL (CPM)	0,64**	30,37	0,45	0,52**	32,39	0,50
	LL (COPM)	0,64**	28,37	0,54	0,47*	32,04	0,54
	PI (CM)	$0,39^{NS}$	10,38	0,23	0,43*	11,58	0,29
	PI (COPM)	0,44*	8,13	0,33	0,42*	9,47	0,44
	PI (CPM)	$0,37^{NS}$	11,86	0,20	0,41*	11,86	0,32
	PI (COPM)	0,44*	9,86	0,30	$0,39^{NS}$	11,51	0,36
	A (CM)	-0.61**	1,12	0,016	-0,64**	1,24	0,017
	A (COPM)	-0.51**	1,08	0,014	-0,40*	1,19	0,013
	A (CPM)	-0.68**	1,22	0,018	-0,62**	1,32	0,018
	A (CPOPM)	-0.61**	1,20	0,017	-0,55**	1,34	0,018
CEC	LL (CM)	0,67**	28,44	0,55	0,56**	31,51	0,56
	LL (COPM)	0,65**	26,28	0,67	0,50*	29,14	0,74
	LL (CP)	0,66**	30,02	0,52	0,52**	31,73	0,60
	LL (COPM)	0,66**	28,16	0,63	0,48*	31,19	0,65
	PI (CM)	0,47*	9,12	0,31	0,42*	11,41	0,33
	PI (COPM)	0,50*	6,95	0,43	0,48*	9,04	0,52
	PI (CPM)	0,45*	10,69	0,28	0,40*	11,63	0,38
	PI (COPM)	0,50*	8,83	0,39	$0,39^{NS}$	11,09	0,43
	A (CM)	-0,46*	1.00	-0,014	-0,64**	1,27	-0,020
	A (COPM)	$-0,37^{NS}$	0,96	-0,011	-0,41*	1,21	-0,016
	A (CPM)	-0,53**	1,10	-0,016	-0,62**	1,35	-0,022
	A (CPOPM)	-0,46*	1,08	-0,014	-0,54**	1,36	-0,021

Signicant at * $P < 0.05$, ** $P < 0.01$, NS: no significant.

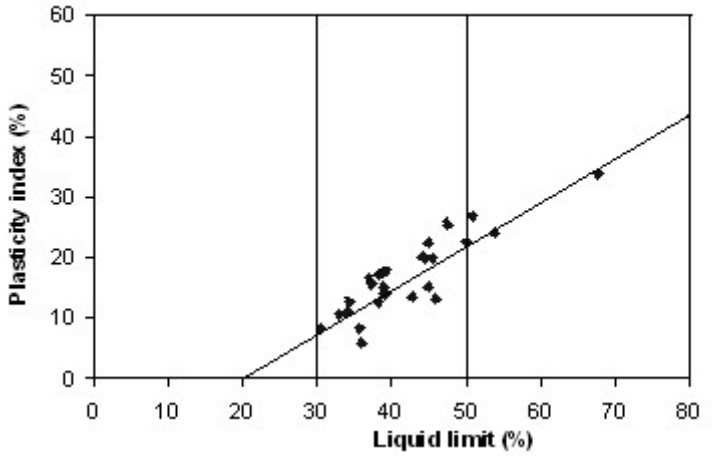


Figure 1. Distribution of soil samples on plasticity chart.

CONCLUSION

In the present study, liquid limit, plasticity index and activity values were obtained for all soil samples by different four methods. The liquid limit methods were compared with each other. According to t-test results there were no significant differences in liquid limit, plasticity index and activity values between Casagrande, cone penetrometer, Casagrande one-point and one-point cone penetrometer methods. Significant correlation coefficients between the methods were obtained. Tillage operations without causing any damage in soil structure could be succeded at 25 % optimal moisture content levels of the soils studied.

REFERENCES

Boden, A.G. 1994. Bodenkundliche Kartieranleitung, 4th ed. Hannover, 392 pp.

Budhu, M., 1985, The Effect of clay content on liquid limit from a fall cone and the British cup device, Geotechnical Testing Journal, GT JODJ, 8(2): 91–95.

Canbolat, M.Y.and Oztas T. 1997. Factor affecting consistency limits of soil and evaluation of consistency limits for agricultural purposes. Ataturk Univ. Agric. Fac. Journal. 28(1): 120-129.

Dexter, A. and Bird N.R.A., 2001. Methods for predicting the optimum and the range of soil water contents for tillage based on the water retention curve. Soil Till. Res. 57: 203–212.

Dowdy, S., Wearden S.,1983. Statistics for Research. John Wiley and Sons, Inc. USA.

Farrar, D.M. and. Coleman J.D, 1967. The Correlation of Surface Area With Other Properties of Nineteen Brithish Clay soils. J. Soil Sci., 18: 118-124.

Feng, T.W. 2001. A linear log d – log w model for the determination of consistency limits of soils. Can. J. Geotech./Rev. Can. Geotech. 38(6): 1335-1342

Gee, G. W. and Bauder J.W. 1986, Partical-Size Analysis. p. 383-411. In A. Klute (ed.) Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI. USA.

Head, K.H. 1984. Manual of Soil Laboratory Testing. Volum1: Soil Classification and Compaction Tests. ISBN, 0-7273-1302-9. Biddles Ltd,Guildford.

McLean E.O. 1982. Soil pH and lime requirement. In Page A L Miller R H and 45Keeney D R (Eds.) Methods of Soil Analysis Part 2.Chemical and M46icrobiological Properties. 2nd Edition 9,199-224 American Society of A47gronomy Madison WI.

Mithchell, J.K. 1976. Fundamentals of Soil Behavior. ISBN, 0-471-61168-9 John Willey and Sons Inc., New York.

Mueller, L. and Schindler U.1998b. Wetness criteria for modelling trafficability and workability of cohesive arable soils. In: Proceedings of the Seventh Annual Drainage Symposium on Drainage in the 21st Century: Food Production and the Environment, Orlando, FL, March 8–10, 1998, pp. 472–479

Munsuz, N. 1985. Toprak Mekanigi ve Teknolojisi. Ankara Uni. Ziraat Fak. Yayinlari, 922. Ders Kitabi, 260.s, 248.

Nelson, D.W.and Sommers L.E. 1982. Total carbon, organic carbon and organic matter. In Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties (Ed. A, Klute). American Society of Agronomy, Madison, Wisconsin, USA.

Odell, R.T., Thornburn T.H. and McKenzie L.J. 1960. Relationships of Atterberg Limits to Some Other Properties of Illinois Soils. Soil Sci. Soc. Amer. Proc., 24: 297-300.

Rhoades, J.D. 1982. Cation exchange capacity. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.), Methods of Soil Analysis. Part 2: Chemical and Microbiological Properties. 2nd ed. American Society of Agronomy, Madison, WI, pp. 149-158.

Schmitz, R.M., Schroeder C. and Charlier R. 2004. Chemo–mechanical interactions in clay: a correlation between clay mineralogy and Atterberg limits. Applied Clay Science (http://www.sciencedirect.com/science)

Skempton, A.W. 1953. The colloidal "activity" of clays. In: Proceedings of the 3rd International Conference on Soil Mechanics and Foundation Engineering vol. 1, pp. 57–61.

Soil Survey Division Staff. 1993. Soil Survey Manual. United States Department of Agriculture.Handbook No:18.USDA, Washington, D.C.

Sridharan, A. and Prakash K. 2000. Percussion and Cone Methods of Determining the Liquid Limit of Soils. Geotechnical Testing Journal, GTJODJ, 23 (2): 242–250.

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THE EFFECT OF TILLAGE AND ROTATION SYSTEMS IN WHEAT

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ABSTRACT
The effects of different rotation systems (wheat-wheat, vetch-wheat, fallow-wheat, chemical fallow-wheat and vetch-fallow-wheat) and soil tillage methods (plough, chisel, anatolian plough and no tillage) on the grain/hay yield and some yield components in wheat and vetch were studied. no tillage with vetch-fallow-wheat and chemical fallow-wheat were found to be the most profitable combinations. Agricultural activities are based on animal production in Eastern Anatolia, for that reason no tillage and vetch-fallow-wheat seem to be advisable to the region.
Key Words: Wheat, vetch, tillage, rotation, fallow, no tillage, yield, soil.

INTRODUCTION
Wheat is the dominant crop in the Eastern Anatolia as in Turkey where rainfall is low (< 500 mm) and variable. Cropping systems in the region are diverse and are dependent on the annual precipitation. Due to large seasonal fluctuations in precipitation, low yields or crop failures due to drought stress (intermittent and terminal) are common. At least more than 50 % of the total rainfall comes during winter (November to February) and the summer is virtually dry. The wheat- fallow system typical of cereal production in the region where wheat is rotated with fallow every other year. Yield is so low and it is under the effect of many factors including lack of favourable rotation and soil tillage systems. It has been declared that in the long run, wheat yield in favourable rotation is much more higher than monoculture wheat production (Black and Siddoway, 1977). Rotation offers producers easier control of diseases, insects, weeds, allows for increased yields and helps ensure crop stability. It also reduce erosion, improve chemical and physical properties and increase bioactivity in soil. (Willis, 1976; Stiegler, 1987). Toth and Kismanyoky (2001) determined that vetch was the best preceding crop for wheat in rotation system and it is . The yield of winter wheat was significantly higher in rotation system than monoculture. Some studies concluded that removing fallow from wheat-fallow system is impossible but placing vetch- fallow- wheat system is more suitable and profitable in areas that receive less than about 500 mm rainfall. Fallow increases soil water capacity, grain yield and water- use efficiency, controls weeds more efficiently (Tosun et al., 1987; Sayadian and Taliee, 2001).
Majority of wheat in Eastern Anatolia is grown on land that has been fallowed ant tilled some time before or at the time of seeing. Tillage time and type are important for keeping soil water capacity, improving soil properties, reducing erosion (Black and Power, 1965; Black and Siddoway, 1977). One of major trends in dryland farming towards reduced tillage. In different countries, use of chemical fallow, reduced and no tillage is becoming more widespread (Hamblin, 1987; Fischer, 1987; McDonald and Fischer, 1991). Reduced or no tillage enable better soil water storage, decreases costs of inputs, pressure and erosion of soil (Fischer, 1987). Triplett et al. (2002) revealed that applying no tillage has advantage than plough tillage. They found that though there was no statistically difference between plough tillage and no tillage, no tillage seemed as

more profitable and it increase more organic matter in soil. The purpose of this study was to determine the effects of different rotation systems (wheat- wheat, vetch-wheat, fallow-wheat, chemical fallow-wheat and vetch-fallow-wheat) and soil tillage methods (plough, chisel, anatolian plough and no tillage) on wheat yield, some yield components, and some soil characters.

MATERIALS AND METHODS

This study was carried out in the Ilica location of Eastern Anatolia Research Institute, Erzurum, Turkey from 1999-2001. Precipitation was 277.5 mm in 1998-1999, 235.4 mm in 1999-2000 and 343.4 mm in 2000-2001. Soil properties were; soil: sandy-loam, E.C.(mmhos cm^{-1}): 2.60, pH: 7.63, lime ($CaCO_3$, %): 0.33, phosphorus (P_2O_5, kg/ha): 174, potassium K_2O, kg/ha): 2408, Organic matter (%): 2.09. Palandoken-97 (*Triticum aestivum* L.) wheat genotype was used. It is winter-habit wheat genotype, released for irrigated conditions, white and 41 g 1000 seed weight, tall (102 cm), resistant to lodging, cold and stripe rust. Hungarian vetch (*Vicia panonica* L.*)* was used. Ammonium sulphate (21% N) and triple super phosphate (46 %) were used as fertilisers in the study. Experimental design was split-split plot design (Little and Hills, 1978; Mead et al., 1994). Plot size was 5 m x 30 m (150m²).

Rotation systems were wheat- wheat, vetch-wheat, fallow-wheat, chemical fallow-wheat and vetch-fallow-wheat. Total herbicide in chemical fallow was used. Selective herbicide as a weed control in wheat plots was used. Tillage systems were plough, chisel, anatolian plough and no tillage. Wheat was sown in 1-15 September with 36 cm between rows (Ozcan and Acar, 1990) and seed rate was 475 seed /m² (Akkaya, 1994). 60 kg N/ha (½ at sowing stage and ½ at tillering stage) and 60 kg P_2O_5 (at sowing) were applied (Akkaya, 1993; Kiral and Ozcan, 1990). Vetch was sown (Celik, 1980), 50 kg N (Tan and Serin, 1995) 30 kg P_2O_5 (Serin et al., 1999) were applied at sowing.

Yield, seed number per spike, spike number per m² (Kiral and Ozcan, 1990; Akkaya, 1994), soil moisture content, soil volume weight, organic matter content, aggregate stability soil porosity (Demiralay, 1993) were evaluated in wheat. In vetch, yield (Celik, 1980; Tan and Serin, 1995) soil moisture content, soil volume weight, organic matter content, aggregate stability soil porozity (Demiralay, 1993) were evaluated.

RESULTS AND DISCUSSION

Yield

The effect of years, rotation systems on yield and interaction of year and rotation system were found to be significant at 1% in wheat (Table 1). The highest yield was taken from 1st year. There were no statistically difference in tillage systems (1537.6-1690.1 kg/ha). besides, the highest yield was obtained from chemical fallow- wheat (1771.2 kg/ha), fallow- wheat (1689.5 kg/ha) and vetch- fallow- wheat (1654.5 kg/ha). Wheat- wheat (1393.2 kg/ha) gave lowest yield (Table 2). Effect of years on yield was significant at 1% (Table 3) in vetch. The highest vetch yield (4876.5 kg/ha) was obtained from 1st year (Table 4). No differences were determined in rotation (2757.1- 2919.2 kg/ha) and tillage systems (2675.3- 3052.7 kg/ha). These results assign that no difference occurred among tillage systems. Having advantages in terms of lower fuel consumption, erosion rate no tillage could be profitable and safely used. Similar findings were found in some studies that differences among tillage systems an no tillage has advantage for lowed inputs and is more effective to improve soil conditions (Ambika et al., 1971; Pot and Ouwerkerk, 1980; Lindswall and Anderson, 1981). Moreover, chemical fallow-

wheat, fallow- wheat and vetch- fallow- wheat could be used for high yield. vetch-fallow- wheat rotation system in other word placing vetch in fallow- wheat system improves soil properties and contribute fodder crop production. Tosun et al. (1987) found that vetch- fallow- wheat rotation system is the most profitable system and it gives the highest yield. Table 5 showed that no significant differences occurred with reducing tillage; by applying fallow- wheat (21%), chemical fallow- wheat (27%) and vetch- fallow- wheat (19%) significant increase occurred. In vetch, Differences on rate in tillage abnd rotation systems were insignificant.

Seed Number per Spike

In wheat, the effect of years and rotation systems on seed number per spike, interactions of year and tillage system, year and rotation system were determined as significant at 1%. Besides, differences among rotation systems were significant at 5% (Table 1). Only 3rd year gave the highest see number per spike (23.8). Tillage with plough, no tillage and tillage with chisel gave higher seed number (23.6, 22.9 and 22.6, respectively) than tillage with Anatolian plough. Seed numbers per spike in vetch-fallow- wheat (23.5), Chemical fallow- wheat (23.1), wheat-wheat (22.4) were so higher than vetch wheat (Table 2). Studies related to this subject pointed out that highest seed numbers per spike were obtained from tillage with plough (Debruck, 1971; Abbas and Al Rawi, 1989) and vetch- fallow- wheat (Sadowski., 1992). Reducing tillage decreased (Table 5) but placing fallow in rotation system increased seed number per spike (-10% in no tillage and 27% in chemical fallow- wheat).

Spike Number per M²

As seen in Table 1, differences among tillage systems an rotation systems were determined as significant at 1%. Interactions of year and tillage system, year and rotation system, tillage system and rotation system, year and tillage system and rotation system were determined as significant at 1% (Table 1). Seed numbers per m² in tillage with plough, tillage with chisel and no tillage were higher (309.7, 304.2 and 299.9, respectively) than tillage with Anatolian plough (290.2). Highest seed number per m² (Table 2) was taken from fallow- wheat (320.1) and vetch- fallow- wheat (309.2). Abbas and Al Rawi, (1989) and D'Antuono et al., (1992) found similar results that highest seed number per m² was obtained from tillage with plough, nevertheless, fallow-wheat application gave highest seed number (Sadowski., 1992). Reduce in tillage systems decreased (Table 5), fallow based rotation systems increased spike number per m² (-7% in tillage with anatolian plought and 12% in fallow- wheat).

Soil Moisture Content

Soil moisture content is one of the most effective components in high yield and depends on rotation systems, tillage systems and rainfall. In wheat, effects of years, tillage and rotation systems on soil moisture content, interactions of year and tillage system, year and rotation system were found as significant at 1% (Table 1). Soil moisture contents in first (11.4%) and second (11.2%) years were evidently higher than last year. The highest value was taken from no tillage (11.4%) and fallow included applications (chemical fallow- wheat 11.3%, fallow- wheat 11.1% and vetch- fallow- wheat 10.9%) gave higher soil moisture (Table 2). In vetch, differences among years and tillage systems were significant at 1% and tillage system x rotation system interaction was significant at 5% (Table 3). Soil moisture contents in first year (10.4%) and second year (10.1%) were so higher. No tillage gave highest value (10.8%) than the other tillage systems (Table 4). Keeping sufficient soil moisture content and obtaining high yield is impossible excluding fallow in rotation (Tosun et al., 1987). Our findings were similar

to other studies that the highest soil moisture contents were obtained from no tillage (Faroogi, 1983; Yushkovich and Ershov, 1985) and fallow- wheat system (Black and Siddoway, 1979; Abu Kreshe et al., 1996). With 14% no tillage and with 18% chemical fallow system made increase in soil miosture content than tillage with plough in wheat. No tillage made 0.3% increase than tillage with plough in vetch (Table 5).

Soil Volume Weight

Effects of years, tillage systems on soil volume weight were determined as significant at 1% and differences among rotation systems were significant at 1% in wheat (Table 1). Third year gave highest soil volume weight (1.18 g/cm³). The highest values were obtained from tillage with plough (1.16 g/cm³) and no tillage (1.15 g/cm³) in tillage systems. Fallow- wheat (1.15 g/cm³), chemical fallow-wheat (1.14 g/cm³) and wetch-fallow- wheat (1.14 g/cm³) gave highest soil volume weight in rotation systems (Table 2). In vetch, effect of years was significant at 5% (Table 3) and soil volume weights in third (1.22 g/cm³) and second (1.12 g/cm³) years were higher than the first year (Table 4). In some studies tillage with plough (Modetus et al., 1992; Norwood, 1992) and fallow- wheat (Norwood, 1992) gave highest soil volume weight. Table 5 showed that no significant differences took place among tllage and rotation systems in vetch. Fallow- wheat system made 2% increase in soil volume weight and reducing tillage decreased soil volume weight.

Soil Organic Matter Content

In wheat, effect of rotation systems on soil organic matter content and tillage system x rotation system interaction were significant at 1%. Besides, effect of years and tillage systems on soil organic matter content were found as significant at 5% (Table 1). Organic matter content in 2nd year (2.18%) was lower than the other years. More organic matter content in no tillage (2.37%), tillage with chisel (2.28%) and tillage with anatolian plough (2.31%) were taken. In the same way, fallow- wheat (2.38%), chemical fallow- wheat (2.35%) and vetch- fallow- wheat (2.32%) gave more organic matter (Table 2). As seen in Table 5, applying no tillage and fallow- wheat made 12% and 16% increase in organic matter than tillage with plough and wheat- wheat systems; with decreased tillage rate, organic matter increased in soil.

In vetch, effects of years, tillage and rotation systems on soil organic matter content, and year x tillage system x rotation system interaction were significant at 5% (Table 3). Organic matter content in 2nd and 3rd years (2.32% and 2.30%, respectively) were more than the fist year. More organic matter content in no tillage (2.41%) was taken. Vetch-fallow- wheat (2.21%) provided more organic matter (Table 4). Applying no tillage (25%) and vetch- fallow- wheat (6%) increased organic matter than tillage with plough an vetch- wheat systems; Decreased tillage rate increase organic matter in soil (Table 5). It was declared that decrease on tillage systems (Pryczkova and Jurencak, 1976; Hernanz et al., 1986) and placing fallow on rotation systems (Muzilli, 1983) in dry farming significantly increased organic matter content in soil. No tillage (Allmaras et al., 1982; Klein and Wicks, 1987) and fallow- wheat systems gave the highest organic matter in soil.

Soil Aggregate Stability

Effects of years, tillage and rotation systems on soil aggregate stability were significant at 1% in wheat (Table1). Soil aggregate stability in 1st year (1.50%) and no tillage system (2.31%) were highest than the other year's tillage systems. Monoculture (wheat-wheat system) showed lowest soil organic aggregate stability (Table2). As seen in Table 5, decreasing tillage system (270% in no tillage) a placing fallow (128 in vetch-fallow-

wheat) in rotation made clearly enhance in soil aggregate stability than tillage with plough and wheat-wheat systems. In vetch, effects of years, and tillage systems on soil aggregate stability were significant at 5% and 1%, respectively (Table 3). Aggregate stability in 3rdyear (1.11%) and in tillage with plough (0.62%) was lowest (Table 4). No tillage (233%) and vetch- fallow- wheat (1%) increased aggregate stability than tillage with plough a vetch-wheat systems (Table 5). Similar results found in various studies no tillage (Schneider and Gupta, 1985; Unger, 1984) and fallow including rotation systems (Aina, 1982; Doran et al., 1999) increased soil aggregate stability.

Soil Porosity

Only difference in tillage systems was significant at 1% in wheat (Table 1) and tillage with anatolian plough (57.2%) gave highest soil porosity (Table 2). Effects of years and tillage systems on soil porosity were significant at1% and 5%, respectively in vetch (Table 3). While soil porosity in 1st year (57.9%) was higher; with 54.7%, tillage with plough gave lowest value (Table 4). Tillage with chisel and anatolian plough (1-3%) provided more increase in wheat and vetch. No tremendous increase or decrease occurred in rotation systems (Table 5). Studies related to this subject showed that no statistically difference was recorded in roration systems (Norwood, 1992; Abu Kreshe et al., 1996); however, significant differences were obtained from tillage systems and tillage with plough gave the highest soil porosity (Abu Kreshe et al., 1996).

So, results in this study showed that no tillage with vetch- fallow- wheat and chemical fallow-wheat were found to be not only the most profitable combinations but this combination is best method for improvement of soil chemical and physical properties. Agricultural activities are based on animal production in Eastern Anatolia, for that reason no tillage and vetch-fallow-wheat seem to be advisable to the region.

LITERATURES

Abbas, M. K. and Al Rawi, K. A., 1989, Effect of tillage practices on growth and yield components of wheat under dry farming. Mesopotamia J. Agric., 21, 4: 73-85.

Abu Kreshe, M. A., Farghly, B. S. and Zohry, A. A., 1996, Effect of tillage systems, preceding crops and nitrogen fertilizer on grain yield of sorghum under upper Egypt condition. Assiut J. Agr. Sci., 27, (4): 77-89.

Aina, P.O., 1982. Soil and crop responses to tillage and seedbed configuration in southwestern Nigeria. Proceedings of the 9th Conference of the Soil Tillage Research Organization: 72-78.

Akkaya, A., 1993. Effect of amount and time of phosphorus fertilisers on wheat yield and yield components in wheat. Ataturk Univ. J. of Agr. Col., 24: 36-50.

Akkaya, A., 1994. Effect of different seed rate on yield and yield components in wheat. Nature, 18: 161-168.

Allmaras, R. R.,Ward, K., Douglas, C. L., Ekin, L. G., 1982. Long-term cultivation effects on hydraulic properties of a Walla Walla silt loam. Soil and Tillage Res., 2 ,(3): 265-279.

Ambika, S., Bhan, V. M., Singh, K. N., Singh, A., 1971. Possibilities of minimum tillage practices in vetch-wheat rotation. Indian J. Agric. Sci., 41, (6): 539-543.

Black, A.L., Power J.F., 1965. Effect of chemical and mechanical mechanisation fallow methods on moisture storage, wheat yields, and soil erodibility. Soil Sci. Soc. Am. Proc., 29: 465-468.

Black, A.L., Siddoway, F.H., 1977. Winter wheat recropping on dryland as affected by stubble height and nitrogen fertilization. Soil. Sci. Soc. Am. J., 41: 1186-1190.

Black, A. L., Siddoway, F. H., 1979. Influence of tillage and wheat straw residue management on soil properties in the Great Plains. J. Soil and Water Conservation, 34, (5): 220-223.

Celik, N., 1980. Effect of Different Between Row, Harvesting Time and Fertilisers on Hay and Seed Yield and Quality in (*Vicia sativa* L. var. 147) (PhD Thesis), Ataturk Univ. Agr. Col. Field Dept., Erzurum.

D' Antuono, L. F., Venezia, G., Lo Cascio, B., 1992. Effect of reduced tillage in dryland cereal systems in Alto Lazio. Rivista di Agronomia, 25, (1): 3-13.

Debruck, J., 1971. Soil cultivation and direct-sowing on weak pseudovergley para brown earth. Landwirtschaftliche Forschung, Sonderheft, 26, (1): 230-244.

Demiralay, I., 1993. Soil Physical Analysis. Ataturk Univ. Agr. Col. Soil Dept., Pub. No: 143, Erzurum, p: 132.

Doran, J.W.,Elliott,E.T.,Paustian,K., 1999. Soil microbial activity, nitrogen cycling, and long-term changes in organic carbon pools as related to fallow tillage management. Soil and Tillage Research,49(1-2): 3-18.

Faroogi, M. A. R., 1983. Moisture and nitrogen management in dryland wheat. Dissertation Abstracts International, 44, (4): 972.

Fischer, R.A., 1987. Responses of soil an crop water relations to tillage. In P.S. Cornish & J.E. Pratley, eds. Tillage. New Directions in Australian Agriculture, Melbourne, Australia, Inkata, Press.

Hamblin, A., 1987. The effect of tillage on soil physical conditions. In P.S. Cornish & J.E. Pratley, eds. Tillage. New Directions in Australian Agriculture, Melbourne, Australia, Inkata, Press.

Hernanz, J. L., Fernandez, Q. C., Sanchez, G. V., Navarrete, L., 1986. Results obtained in experiments with direct drilling and minimum cultivation in the Central Zone. Conservar el suelo.I.Simposium Sobre Minimo Laboreo En Cultivos Herbaceos. Universidad Politecnica de Madrid: 145-158.

Kiral, A. S. ve Ozcan, H., 1990. Determination of Amout of Seed, Nitrogen and Phosphorus Fertilisers on Wheat in Erzurum Dry Conditions Eastern Anatolia Agr. Res. Inst. Pub. No: 5, Erzurum.

Klein, R. N., Wicks, G. A., 1987. Ecofarming - an integrated crop protection system. Optimum erosion control at least cost. Proceedings of the National Symposium on Conservation Systems, December 14-15, 1987, Chicago, IL, USA: 318-326.

Lindwall, C. W., Anderson, D. T., 1981. Agronomic evaluation of minimum tillage systems for summer fallow in southern Alberta. Canadian J. Plant Sci., 61, (2): 247-253.

Little, T. M., Hills,F. J., 1978. Agricultural Experimentation Design and Analysis, John Wiley & Sons, Inc., USA, (2nd ed.) p 298.

McDonald, G.K., Fischer, R.A., 1991. Soil management to maimtain crop production in semi-arid environments. In E. Acevedo, E. Fereres, C. Gimenez, J.P. Srivastava, eds. Improvement of Winter Cereals under Temperature, Drought and Salinity Stresses. Marid, Ministerio de Agricultura, Pesca y Alimentation, Instituto Nacional de Investigaciones Agrirarias.

Mead, R., Curnow, R.N., Hasted, A.M., 1994. Statistical Methods in Agriculture and Experimental Biology, Second Edition, Chapman & Hall, p 412.

Modestus, W. K., Tanner, D. G., Mwangi, W., 1992. The effect of zero and conventional tillage on wheat yield in northern Tanzania. Seventh Regional Wheat Workshop For Eastern, Central and Southern Africa: 489-493.

Muzilli, O., 1983. Effects of no-tillage, compared to conventional tillage, on the fertility of the arable layer of the soil. Revista Brasileira de Ciencia do Solo, 7,(1): 95-102.

Norwood,C.A., 1992. Tillage and cropping system effects on winter wheat and grain sorghum. J. Production Agric., 5, (1): 120-126.

Ozcan, H., Acar, A., 1990. Effect of Different Planting Time and Genotypes on Wheat Yield in Erzurum Conditions. Eastern Anatolia Agr. Res.Inst.Pub.No: 3, Erzurum.

Pot, M., Ouwerkerk, C., 1980. Conventional tillage and minimum tillage in a wide crop rotation. Annual report 1977 of the soil tillage experiment IB 0011 on the Dr. H.J. Lovinkhoeve [Crop Husbandry Farm] at Marknesse. Rapport, Instituut voor Bodemvruchtbaarheid, No, 3-80, p 51.

Pryczkova,L., Jurencak,J.,1976. Effect of progressive arable techniques on the dynamics of soil chemical properties and cereal yields. Rostlinna Vyroba, 22, (5): 547-556.

Sadowski, T., 1992. Winter and spring wheat in specialized crop rotations. II. Morphometry and yields. Acta Academiae Agriculturae ac Technicae Olstenensis, Agricultura, 54: 173-181.

Sayadian, K., Taliee, A.A., 2001. Investigationtermine a suitable rotation for rain-fed wheat in Kermanshah. Seed and Plant, 16 (4): 495-508.

Schneider,E.C., Gupta,S.C., 1985. Plant emergence as influenced by soil temperature, matric potential, and aggregate size distribution. Soil-Science-Society-of-America-Journal. 1985, 49: 2: 415-422;

Serin, Y., Tan, M., Ozturk, D., 1999. Fertilisation of vetch + barley mixtures. Turkey 3rd Field Crop Congress, 15-18 Nov. 1999, Adana: 47-52.

Stiegler, J.H., 1987. Cropping Systems and Rotations. In E.G. Heyne(ed.) Wheat and Wheat Imrovement,am. Soc. of Agronomy, Madison, Wisconsin, USA.

Tan, M, Serin, Y., 1995. Effect of Rhizobium inoculation and different fertiliser rates on hay and seed yield, nodule number and protein rate in common vetch (*Vicia sativa* L.) in Erzurum irrigated conditions.Nature, 19: 137-144.

Tosun, F., Akkaya, A., Akten, S., Serin, Y., 1987. Effect of some rotation systems on wheat yield in Erzurum. Turkey Cereal Symposium, TUBITAK and Uludag University, Agricultural College, Bursa: 123-133,.

Toth, Z., Kismanyoky, T., 2001. Study of the grain yield of maize (Zea mays L.) and winter wheat (Triticum aestivum L.) in different crop rotations and in continuous maize cropping. Novenytermeles, 50 (1): 123-134.

Triplett, G.B., Robinson, J.R.C., Dabney, S.M., Santen, E., 2002. A whole-farm economic analysis of no-tillage and tilled cropping systems. Making conservation tillage conventional: building a future on 25 years of research. Proceedings of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture, Auburn, AL, USA, 24- 26 June, 2002: 48-52.

Unger,P.W., 1984. Tillage and residue effects on wheat, sorghum, and sunflower grown in rotation. Soil Science Society of America Journal,48(4): 885-891.

Willis, W.O., 1976. Dryland agriculture. In R.E. Moreng (ed.) Western resource conference on food production and resources in the West. 15-16 July 1976. Fort Collins, CO.

Yushkovich, L. V. Ershov, V. L., 1985. Technological improvement of the primary cultivation under durum wheat in the southern forest steppe of Western Siberia. Sibirskii Vestnik Sel'skokhozyaistvennoi Nauki, (6): 1-5.

Table 1. Variance Analysis of Tillage and Rotation Systems for Characters in Wheat.

Variables	Yield (kg ha^{-1})	Seed Number per Spike	Spike Number per M²	Soil Moisture Content (%)	Soil Volume Weight (g/cm³)	Organic Matter Content (%)	Aggregate Stability (%)	Soil Porosity (%)
Year	330.15**	45.55**	1.88	61.30**	252.31**	8.10*	12.31**	1.05
Error$_1$	-	-	-	-	-	-	-	-
Tillage Systems	2.21	10.66**	5.25**	19.73**	6.06**	4.88*	33.12**	38.81**
Year x Till. Sys.	1.35	4.63**	7.27**	4.34**	1.93	1.25	1.85	1.72
Error$_2$	-	-	-			-	-	-
Rotation Sys.	16.30**	3.13*	10.55**	25.64**	2.49*	7.62**	13.40**	1.67
Year x Rot. Sys.	6.72**	3.05**	3.04**	5.49**	0.98	1.52	1.92	1.53
Til. Sys. x Rot. Sys.	1.22	0.99	3.34**	1.07	1.35	3.57**	1.61	1.65
Y. x T. S. x R.S.	1.08	1.00	1.93**	1.39		0.40	0.69	0.82
Error$_3$	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-
C.V. (%)	9.23	14.00	11.79	16.22	4.45	12.57	14.51	4.46

Table 2. Yield and Yield Components and Soil Characteristics Related to Tillage and Rotation Systems in Wheat.

Variables	Yield (kg ha^{-1})	Seed Number per Spike	Spike Number per M²	Soil Moisture Content (%)	Soil Volume weight (g/cm³)	Organic Matter Content (%)	Aggregate Stability (%)	Soil Porosity (%)
1998-1999	1366.6 B	21.7 B	294.8	11.4 A	1.11 B	2.31 a	1.50 A	58.7
1999-2000	1154.3 B	22.3 B	301.2	11.2 A	1.12 B	2.18 b	1.37 C	58.4
2000-2001	2336.7 A	23.8 A	306.9	8.9 B	1.18 A	2.30 a	1.44 B	56.2
Mean	1619.2	22.6	300.9	10.5	1.14	2.26	1.44	57.7
Tillage Systems								
Tillage with Plough	1690.1	23.6 A	309.7 A	10.0 C	1.16 A	2.11 b	0.62 C	55.5 C
Tillage with Chisel	1641.2	22.6 A	304.2 A	10.0 C	1.14 B	2.28 a	1.21 B	56.4 B
Tillage with Anatolian Plough	1607.8	21.2 B	290.2 B	10.8 B	1.12 C	2.31 a	1.61 B	57.2 A
No Tillage	1537.6	22.9 A	299.9 AB	11.4 A	1.15 AB	2.37 a	2.31 A	56.0 BC
Mean	1619.2	22.6	301	10.6	1.14	2.27	1.43	56.3
Rotation Systems								
Vetch- Wheat	1587.7 B	21.3 B	300.9 BC	9.8 B	1.13 b	2.24 B	1.44 A	56.4
Fallow- Wheat	1689.5 AB	22.7 A	320.1 A	11.1 A	1.15 a	2.38 A	1.55 A	56.1
Wheat- Wheat	1393.2 C	22.4 AB	285.5 D	9.6 B	1.13 b	2.05 C	0.76 B	56.6
Chemical Fallow- Wheat	1771.2 A	23.1 A	289.2 CD	11.3 A	1.14 ab	2.35 AB	1.69 A	55.9
Vetch- Fallow- Wheat	1654.5 B	23.5 A	309.2 AB	10.9 A	1.14 ab	2.32 AB	1.74 A	56.1
Mean	1619.2	22.6	301.1	10.6	1.13	2.27	1.43	56,2

Table 3. Variance Analysis of Tillage and Rotation Systems for Characters in Vetch.

Variables	Yield (kg ha^{-1})	Soil Moisture Content (%)	Soil Volume Weight (g/cm^3)	Organic Matter Content (%)	Aggregate Stability (%)	Soil Porosity (%)
Year	1329.64**	100.28**	7.26*	13.62*	3.23*	47.56**
Error$_1$	-	-	-	-		-
Tillage Systems	1.46	12.80**	0.32	12.46*	10.95**	3.90*
Year x Till. Sys.	2.14	0.13	1.42	1.15	1.02	1.92
Error$_2$	-	-	-	-	-	-
Rotation Sys.	1.71	0.99	0.34	4.90*	2.11	2.04
Year x Rot. Sys.	0.46	0.06	1.34	2.20	1.84	1.56
Til. Sys. x Rot. Sys.	0.45	3.27*	0.52	0.48	1.31	1.34
Y. x T. S. x R.S.	0.42	1.73	1.20	2.56*	0.98	1.03
Error$_3$	-	-	-	-	-	-
Total	-	-	-	-	-	-
C.V. (%)	12.21	11.87	12.13	12.87	10.21	11.35

Table 4. Yield and Yield Components and Soil Characteristics Related to Tillage and Rotation Systems in Vetch.

Variables	Yield (kg ha^{-1})	Soil Moisture Content (%)	Soil Volume weight (g/cm^3)	Organic Matter Content (%)	Aggregate Stability (%)	Soil Porosity (%)
1998-1999	2307.1 B	10.4 A	1.08 b	2.01 b	1.35 ab	57.9 A
1999-2000	1930.2 C	10.1 AB	1.12 ab	2.32 a	1.66 a	56.4 B
2000-2001	4876.5 A	9.3 B	1.22 a	2.30 a	1.11 c	52.9 C
Mean	3097.9	9.9	1.14	2.21	1.37	55.7
Tillage Systems						
Tillage with Plough	2919.2	9.5 B	1.12	1.92 c	0.62 C	54.7 b
Tillage with Chisel	2884.4	9.7 B	1.14	2.17 b	1.37 B	56.4 a
Tillage with Anatolian Plough	2757.1	9.6 B	1.12	2.12 b	1.44 AB	56.5 a
No Tillage	2893.6	10.8 A	1.16	2.41 a	2.07 A	55.3 ab
Mean	2863.6	9.9	1.13	2.15	1.35	55.7
Rotation Systems						
Vetch- Wheat	3052.7	9.8	1.14	2.09 b	1.38	57.2
Vetch- Fallow- Wheat	2675.3	9.9	1.13	2.21 a	1.40	56.3
Mean	2864.0	9.8	1.13	2.15	1.39	56.7

Table 5. Increase in Yield and Yield Components and Soil Characteristics with Application of Tillage and Rotation Systems in Wheat.

Wheat								
Variables	Yield	Seed Number per Spike	Spike Number per M²	Soil Moisture Content	Soil Volume weight	Organic Matter Content	Aggregate Stability	Soil Porosity
Tillage Systems								
Tillage with Plough	0	0	0	0	-	0	0	0
Tillage with Chisel	-3	-4	-2	0	-2	8	95	1
Tillage with Anatolian Plough	-5	-10	-7	8	-4	7	160	3
No Tillage	-10	-3	-6	14	-1	12	270	0.9
Rotation Systems								
Wheat- Wheat	0	0	0	0	0	0	0	0
Vetch- Wheat	14	-5	5	2	0	9	89	-1
Fallow- Wheat	21	1	12	16	2	16	103	-1
Chemical Fallow- Wheat	27	3	1	18	0.1	15	122	-2
Vetch- Fallow- Wheat	19	5	8	13	0.1	13	128	-1

Vetch						
Variables	Yield	Soil Moisture Content	Soil Volume Weight	Organic Matter Content	Aggregate Stability	Soil Porosity
Tillage Systems						
Tillage with Plough	0	0	0	0	0	0
Tillage with Chisel	-2	2	0.2	13	120	3
Tillage with Anatolian Plough	-6	1	0	10	132	3
No Tillage	-1	13	0.3	25	233	1
Rotation Systems						
Vetch- Wheat	0	0	0	0	0	0
Vetch- Fallow- Wheat	-13	1	-1	6	1	-2