ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSI*net*
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 3 (4): 237-242, 2004
ISSN 1812-5379

Tillage Effects on Soil Physical Properties and Performance of Irrigated Wheat and Clover in Semi Arid Region

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Abstract: Crop producers in the southwestern Iran traditionally use conventional tillage (moldboard plowing followed by two disc harrowing) to grow various crops. Such a tillage system requires a high energy input and may also causes long-term soil physical degradation. This field study was conducted on a silty clay loam soil (carbonatic typic torrifluvent) to determine whether reduced tillage systems alter the agronomic performance of irrigated winter wheat (*Triticum aestivum* L.) and clover (*Trifolium alexsandarum* L.). Tillage treatments consisted of conventional tillage (CT) including moldboard plowing followed by disc harrowing, reduced tillage (RT) including disc plowing followed by disc harrowing and no tillage (NT). Soil samples were collected before planting and after harvesting to a depth of 30 cm in 4 increments. Infiltration rate, mean weight diameter (MWD) of soil aggregates and soil bulk density were determined. N, P and K contents of wheat and clover crops were also determined. Soils under NT contained higher organic matter content (13.6 to 14.4 g kg^{-1}) than soil under RT (12 to 13.9 g kg^{-1}) and CT (10.2 to 11.5 g kg^{-1}). Greater infiltration rate was found in CT (11.7 to 13.0 mm h^{-1}) than either RT (7.0 to 9.1 mm h^{-1}) or NT (7.0 to 9.0 mm h^{-1}). MWD of soil aggregates in NT (1.47 to 2.11 mm) was significantly higher compared to RT (1.46 to 1.91 mm) and CT (1.36 to 1.55 mm). Wheat yield was not significantly different among different tillage systems. Clover yield was significantly higher in RT (7.35 Mg ha^{-1}) compared to CT (5.93 Mg ha^{-1}) and NT (5.12 Mg ha^{-1}). Results of this study suggested that in this semi-arid region of Iran, NT and RT were as effective as CT treatment for winter wheat. It was also shown that RT is a more suitable tillage system for clover production compared to NT and CT.

Key words: Aggregate stability, infiltration rate, tillage systems, nutrients, yield

INTRODUCTION

Irrigated wheat and clover production in arid and semi arid regions of Iran is generally practiced under conventional tillage systems. Soil physical degradations in agricultural production systems of arid and semi arid regions have always been a major concern. However, few studies have been conducted in these areas to evaluate alternative tillage systems on reducing soil degradation while obtaining similar yields compared to conventional tillage. The conventional tillage system not only needs a high energy input but also results in soil physical degradation. Given these limitations, questions about whether reduced tillage systems are effective in improving soil physical properties and the influence on crop yield should be addressed.

Increased profitability due to conserving energy and reducing soil erosion results in greater interest in using reduced and no tillage systems in many parts of the world. Conservation tillage has been shown to decrease fuel costs and soil water evaporation[1]. Reduced tillage is also effective in improving aggregate stability[2] and decreased soil mechanical impedance[3]. Griffith *et al.*[4] indicated the higher efficiency of a no tillage system in improving soil physical properties. However, the response to reduced tillage depends on the climatic conditions and soil management. A number of field studies have been carried out to evaluate the influence of different tillage systems on soil physical properties, viz. soil bulk density[5-7], water distribution and storage in soil[8], aggregate stability[2,9], soil temperature[10], infiltration rate[11], earthworm activity[11,12], and crop production such as corn (*Zea mays*)[13], barley (*Hordeum vulgare* L.), canola (*Brassica campestris* L.) and wheat[14]. Many researchers[5-7] have reported higher bulk density in no-till compared to conventional tillage. Lal *et al.*[2], however, reported a lower bulk density in no-till continuous corn systems compared to conventional tillage. Similarly,

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infiltration rate has been shown to increase in reduced tillage because of higher organic matter concentration and earthworm activity[12]. Katsvario *et al.* [11]indicated that moldboard plow tillage had the greatest infiltration rates among tillage systems.

Legumes, with symbiotic N fixation, such as clover, improve soil organic nitrogen and this is expected to benefit wheat production. Although the effects of different tillage systems on winter wheat have been studied in different climatic conditions[13-16], the influence of tillage systems on clover yield itself has rarely been studied. A few studies have examined the different varieties of clovers such as white clover (*Trifolium repens* L.), subterranean clover (*Trifolium subterraneum* L.), yellow sweet clover (*Meliotus officinalis* Lam), Persian clover (*Trifolium resupinatum* L.), strawberry clover (*Trifolium fragiferum* L.), crimson clover (*Trifolium incarnatum* L.) and berseem clover (*Trifolium alexandrinum* L.), either as a cover crop and alternative method of weed control[17] or as a leguminous crop affecting nitrogen uptake and growth of a succeeding winter wheat crop[18]. In spite of the known yield increase of crops after clover, the influence of different tillage treatments on irrigated clover yield itself is seldom studied.

In semi arid regions there exists a need to reduce rates of soil degradation without adversely affecting the yield of irrigated crops. The objectives of this study were (I) to compare the influence of different tillage systems on soil physical and chemical properties and crop performance and (ii) the feasibility of reduced tillage systems for irrigated crops in the semi arid region.

MATERIALS AND METHODS

Experimental site: The experimental site was established at Ramin Agricultural Research Station (48°53'E and 31° 35'N) 25 km northeast of Ahwaz, at an average altitude of 50 m. The soil used in this study is a silty clay loam which is representative of a large area of arable land in the Khuzestan Province in Iran. The soil is classified as a fine loamy clayey, carbonatic typic torrifluvent. Full details of the experimental site can be found in Barzegar *et al.*[19]. The average annual temperature is 23°C with the highest monthly temperature of 34°C in July and the lowest of 11°C in January (Fig. 1). The cropping sequence at the experimental site, over at least the last 25 years, was winter wheat and summer fallow. The daily rainfall during the growing stages of the crops was recorded at a meteorological station located 500 m east of the experimental site.

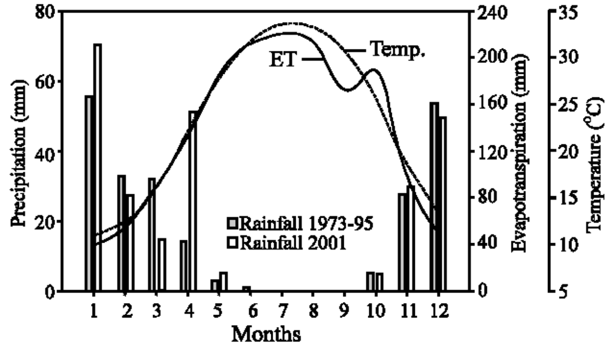

Fig. 1: Monthly mean rainfall, evapotranspiration (ET) and temperature (Temp.) of the studied area

Experimental design: In this study two separate completely randomized designs were used. Each experiment was replicated three times. Tillage treatments consisted of conventional tillage (CT), reduced tillage (RT) and no tillage (NT). In the CT treatment moldboard, plowing to the 25 cm depth was followed by two disking to a depth of 10 cm. The RT treatment consisted of disc plowing to a depth of 15 cm followed by disc harrowing to a depth of 10 cm. Experimental plots (totally 24) were 40 m long and 14 m wide and was 3 m apart.

The site was tilled and sown to winter wheat and berseem clover in December 2000. Depth of sowing was 2-3 cm. The row spacing for both crops was 18 cm. The full details of the field procedures for winter wheat can be found in Barzegar *et al.*[19]. Wheat and clover were each flood irrigated five times on February 7, 13 and 21 and on April 10 and 15.

Measurements: Prior to the experiment, composite soil samples were taken from 0-5, 5-10, 10-20 and 20-30 cm of topsoil, then air dried and sieved. Electrical conductivity of the saturation extract and pH of the saturated paste were measured. Soil texture was determined by the pipette method[20]. The concentration of organic matter was determined using the potassium dichromate oxidation method.

Wheat from three 1m^2 areas within each plot was harvested in early June 2001[19]. The clover biomass of each plot was measured four months after sowing, using a 1 m^2 wooden framework at three random locations per plot. One gram of dried ground whole crops sample was digested in nitric and perchloric acids for N, P and K analysis.

Three intact soil cores were taken from the soil layers down to the 30 cm depth with a 10-cm diameter steel coring sampler. The bulk density of the soil at three stages of wheat growth, namely tillering, flowering and after harvesting and after harvesting of clover was measured using the total weight and volume of all intact cores taken from each depth.

The wet aggregate stability of the soil layers was determined after sowing and harvesting. Wet aggregate stability was determined using the method of Kemper and Rosenaue[21]. Ten grams of air-dried aggregates (3 to 5 mm diameter) from each plot was wet sieved through a series of four sieves (2000, 1000, 500 and 53 μm). The sieving time was 10 min at 50 oscillations per minutes. Three samples were wet-sieved per treatment. The mean weight diameter (MWD) of soil aggregates was calculated, taking into account the sand content in each aggregate size fraction[21].

Infiltration rate was measured for each plot before sowing, before grain filling stage and after harvesting by using the twin-rings method.

Statistical analysis: Analysis of variance was calculated using the SAS statistical package for analysis of variance[22]. All significant differences are at the $P<0.05$ probability level unless otherwise stated. The least significant difference (LSD) was calculated only when the analysis of variance F-test was significantly different at the $P<0.05$ probability level.

RESULTS AND DISCUSSION

The precipitation for the growing months in 2001 was above average, but followed the normal distribution pattern (Fig. 1). However, the rainfall was much below the monthly evapotranspiration except in January and December. Typically then, crop production must rely on irrigation.

Soil characteristics: Selected physical and chemical properties of the experimental site just prior to the experiment are given in Table 1. The electrical conductivity ranged from 1.2 to 3.3 dS m^{-1}. The soil texture was silty clay loam with range of clay content from

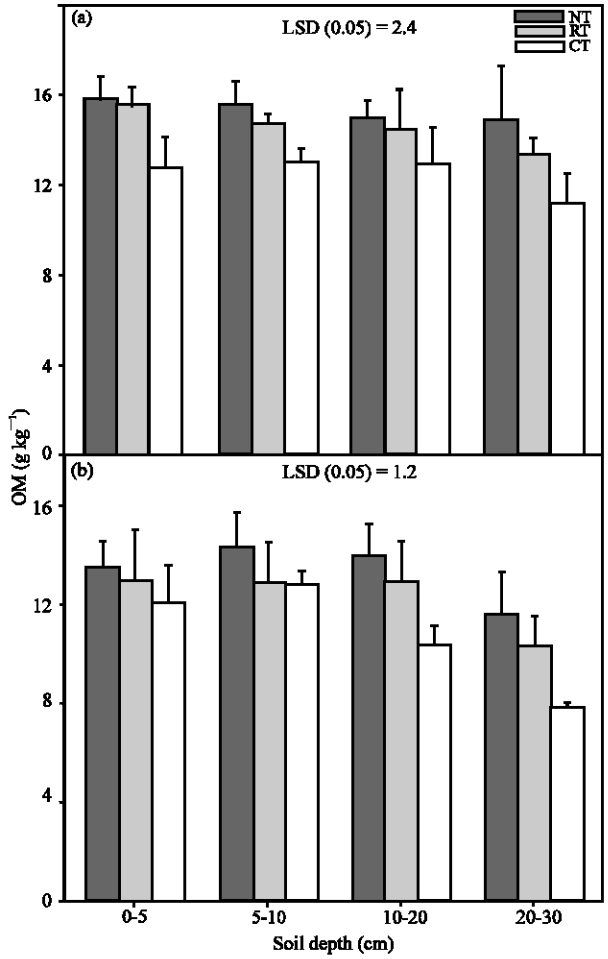

Fig. 2: Concentration of organic materials (OM) of different soil layers as influenced by tillage treatments; (a) winter wheat and (b) clover

34-35%. N, P and K contents of soil were 0.08 to 0.10%, 6.1 to 16.2 and 117 to 192 mg kg^{-1}, respectively.

Organic matter concentration for all tillage treatments for both crops measured after harvesting was generally higher than before cultivation. The organic matter concentration in different soil layers of NT, except for the upper soil layer, was significantly higher compared to RT

Table 1: Selected chemical and physical properties of soil

Soil layer (cm)	[a]O.M ($g\ kg^{-1}$)	[b]EC ($dS\ m^{-1}$)	pH	N (%)	P ($mg\ kg^{-1}$)	K	[c]BD ($Mg\ m^{-3}$)	[d]MWD (mm)	[e]IR ($mm\ h^{-1}$)	Clay ($g\ kg^{-1}$)	Silt	Sand
0-5	12.1	3.3	7.6	0.10	15.4	192	1.5	1.4	8.0	354	538	108
5-10	10.0	2.1	7.7	0.08	16.2	165	1.6	1.5		336	520	144
10-20	9.5	2.0	7.8	0.10	9.3	117	1.6	1.6		358	510	132
20-30	9.0	2.2	7.8	N/A	6.1	118	1.6	1.6		348	512	140
[f]STD	3.4	1.2	0.2	0.03	3.5	43	0.06	0.09	1.0	36	22	30

[a]OM, organic matter; [b]EC, electrical conductivity of saturated extract; [c]BD, bulk density; [d]MWD, mean weight diameter; [e]IR, infiltration rate. [f]STD, standard deviation of mean

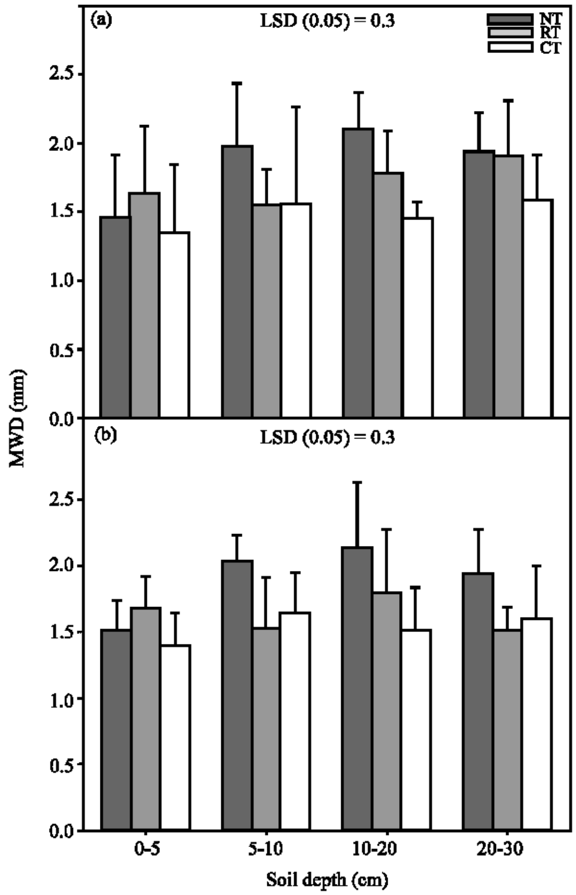

Fig. 3: Mean Weight Diameter (MWD) of soil aggregates of different soil layers as affected by tillage treatments and crops; (a) winter wheat and (b) clover

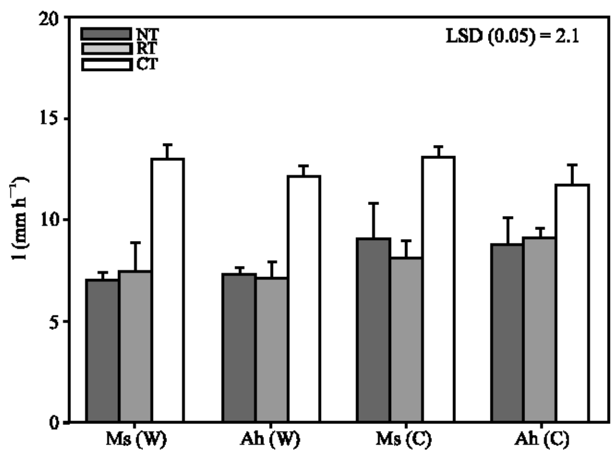

Fig. 4: Infiltration rate of different tillage treatments under winter wheat (W) and clover (C); Ms = mid season; Ah = after harvesting

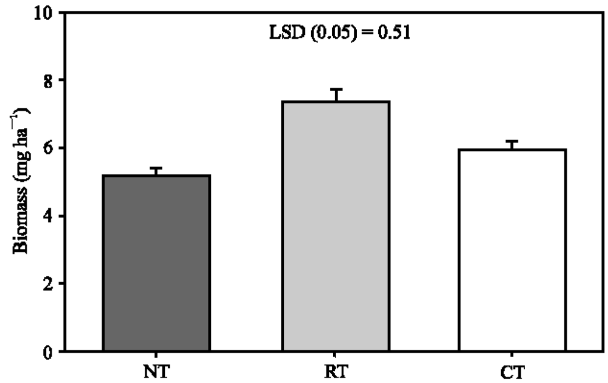

Fig. 5: Biomass yield of clover under different tillage systems

and CT (Fig. 2). Analysis of variance of data indicated that the effect of both tillage ($p<0.05$) and depth ($p<0.01$) on organic matter were significant. Our results are consistent with other reports[2] that showed a higher organic matter concentration in NT and RT compared to CT.

The MWD (measured shortly after harvesting) was used as an indication of the effect of tillage treatments on soil physical improvement or deterioration (Table 1 and Fig. 3). Aggregate stability of NT and RT treatments were relatively higher compared to that of before planting. The conventional tillage treatment, however, decreased aggregate stability compared to aggregate stability before planting. Aggregate stability of the NT treatment for both wheat and clover crops was highest except for the 0-5 cm layer (Fig. 3). Vyn and Raimbault[5] indicated higher proportions of coarse aggregates with a no-till system. On the other hand, Erbach *et al.*[23] reported that, although there was a tendency of increased MWD associated with reduced tillage intensity, differences among tillage treatments was not significant.

Soil bulk density (measured at three stages of wheat growth) was not significantly different among tillage treatments. Similar results were obtained in clover plots after harvesting (data not shown). Moldboard plow tillage treatment generally had a lower bulk density during the early stages of corn growth[2,24]. Present results are consistent with Blevins *et al.*[25] who showed no differences in bulk density among tillage systems for corn production. However, some studies reported that primary tillage operations had a transitory influence on soil physical properties because of soil setting after wetting and drying cycles occurred[26]. Wetting and drying cycles occurred during the growing months because of the rainfall pattern (Fig. 1) and also due to irrigation. Recently,

Table 2: N, P and K content of winter wheat and clover biomasses

	Wheat			Clover		
Tillage[a]	N (%)	P (g kg^{-1})	K (%)	N (%)	P (g kg^{-1})	K (%)
NT	1.5	2.7	1.4	2.8	2.4	2.4
RT	1.7	3.4	1.6	3.0	3.4	2.6
CT	1.5	3.2	1.7	2.9	2.9	2.3
$LSD_{0.05}$	0.1	0.6	0.2	0.1	0.6	0.4

[a] NT, no tillage; RT, reduced tillage; CT, conventional tillage

Katsvario *et al.*[11] reported some physical properties of a 6 year tillage, crop rotation and management systems. They indicated that tillage and crop rotation had no significant effect on soil bulk density.

Infiltration rate was greatest in the CT treatment for both wheat and clover (Fig. 4). Soil loosening in the CT treatment probably contributed to the increased infiltration rates. It is not clear why field infiltration rate was more in the CT treatment when soil bulk density did not differ among tillage systems and MWD was lower in the CT treatment. However, the results are consistent with those of Katsvario *et al.*[11].

Agronomic performance: Wheat crops under no-till had a greater yield compared to the other tillage treatments. However, the yield difference was not statistically significant[19]. Halvorson *et al.*[27] compared the grain yield of winter wheat under different tillage systems in a dryland region of United States and indicted that no-till resulted in higher grain yield compared to CT and minimum tillage. Although the dry matter of weeds, were not measured one explanation for non-significant results obtained for tillage treatments, could be due to greater incidence of weeds in the NT treatment. Young *et al.*[28] indicated that the success of reduced tillage has usually been limited largely by lack of effective weed control in NT plots. These results revealed that nitrogen content of above ground tissues of wheat crops in NT was greater than other tillage treatments (Table 2). However, the difference was not substantial and therefore no major effect on biomass and grain yield or distribution pattern of assimilates into spikes, was detected. The trend of lower wheat yield of the CT treatment compared to the NT treatment in our study was associated with lower nitrogen contents, suggesting that wheat yield might also limited by nitrogen supply. This also could be due to competition for nitrogen from weeds. Present results indicated that the RT winter wheat crops had the greatest amounts of nitrogen, phosphorus and potassium contents (Table 2), but again this surprisingly did not lead to production of higher yield. Soon *et al.*[16] reported a greater uptake of nitrogen by winter wheat in NT compared to CT. Similar results were reported by Halvorson *et al.*[15] who compared the nitrogen removal of wheat grain as influenced by different application rates of nitrogen fertilizers in CT and NT treatments.

Unlike wheat yield data[19], there was a significant tillage effect on clover yield (Fig. 5). Clover under NT treatment contained the highest nitrogen whereas RT showed the highest phosphorus content (Table 2). Potassium contents of NT and CT were less than that of RT.

Effects of tillage on soil physical properties may be useful to help explain differences in yield. The reduced tillage resulted in higher clover growth and final yield and also had generally higher organic matter concentration than the CT treatment.

Results of this experiment revealed that the no-till system increased soil aggregate stability and organic matter concentration of the soil. Although there was a tendency for bulk density to be lower with no tillage and reduced tillage, bulk density was not significantly different among tillage treatments. Clover yield was significantly higher with reduced tillage. NT and RT tillage treatments improved or maintained wheat and clover yields compared to conventional tillage, suggesting that reduced tillage systems can be considered as an appropriate tillage system for wheat and clover production in the semi arid region.

ACKNOWLEDGMENTS

We wish to thank Mr. A.H. Rajaei of Natural Resouce Center of Khuzestan Province, Ahwaz, Iran for conducting the infiltration rate measurements. The work forms a part of a larger research program and was financed by the Research Affairs of Chamran University of Ahwaz, Iran (Project no. 377).

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