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Wheat and oat yields and water use efficiency as influenced by tillage under rainfed condition

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Abstract

Long term field experiments on grain and fodder crops at Livestock Research Station, Surezai, Peshawar (rainfed area), NWFP, Pakistan, located at 33^o 45' N and 70^o 50' E at an altitude of 525 m were initiated during 2004-05 with the objective to improve/sustain soil fertility, water/soil conservation, and efficient utilization of production inputs. The treatments consisted of three rotations: i) cereal– fallow-cereal (farmers' practice) ii) cereal-legume-cereal and iii) cereal-cereal-cereal with two tillage treatments: i) Tillage (-crop residues) and tillage (+ crop residues) and ii) no-tillage (-crop residues) and no-tillage (+ crop residues). Basal dose of N_{60}: P_{60} (kg ha^{-1}) was applied to wheat and oat crops in grain and fodder rotation experiments, respectively. In this paper the result regarding the tillage effect on yield and WUE of wheat and oat are summarized. The pre sowing soil analyses of experimental field indicated that it was clay loam, non saline, calcareous and alkaline in reaction, low in O.M, deficient in N and P. The results obtained so far revealed that almost similar wheat grain, biological and oat fodder yields and water use efficiency were obtained under tillage and no-tillage system. The soil moisture contents data recorded at different growth stages of wheat indicated that similar moisture content in 0-30 cm upper soil was recorded in the tillage and no-tillage treatments. However at lower depth (30-90 cm) the zero tillage treatment at seedling, 1st tillering, 2nd tillering, booting, anthesis, milk development and maturity stages contained 30.4, 24.15, 25.73, 13.81, 44.2, 32.0, 9.65 mm more water in the soil profile than tillage treatments, respectively.

Key words: water use efficiency, tillage, wheat, oat, rain

Introduction

Pakistan is predominantly an arid and semiarid country and Agriculture is the mainstay of country economy. It provides livelihood to 70-80% of the people living in rural areas, employs 45-50 percent of the labour force and it serves as the base for major industries. Of the total cropped area of 21.85 million ha in Pakistan, about 4 m ha are rainfed. The maximum proportion of rainfed area is in North West Frontier Province (NWFP) of Pakistan where 50% of the cropped area is rainfed and over 1 million hectare of the cultivatable area is lying as wasteland (MINFAL, 2003). To meet the food and residential demand of increasing population, the rainfed lands in Pakistan have great potential for contributing to national food productions. Low productivity is the common feature of rainfed agriculture because of erratic and inadequate precipitation, very low organic matter content, erosion of soils, poor physical condition, hardpan and other undesirable environmental conditions like dry air and high soil temperatures. The nutrients losses from chemical fertilizers (because of their poor utilization) and their unavailability at proper time are also becoming the matters of serious concern in rainfed farming. Due to these reasons, the contribution of rainfed areas to national economy is minimal. However, great potential exist in these areas for increasing crop productivity, provided appropriate integrated soil, water, nutrient and crop management system are developed for improving soil fertility, water/soil conservation and efficient utilization of these inputs.

Through conservation agriculture such as minimum/zero-tillage practices, maintaining the crop residues on soil surface and involvement of legumes in crop rotation can play an important role to sustain soil fertility, improving water use efficiency, physical conditions of soils and enhance crop productivity (Dalal and Chan, 2001; Dalal *et al.*., 1998, Francis *et al.*., 1992; Gibson *et al.*., 1992; Heen and Chan, 1992; Kabir, 1999; Lampurlanes *et al.*., 2001; Mohammad *et al.*., 2003 a,b, Mason and Rowland, 1990; Nowood, 1999; Pedreno *et al.*., 1996; Shah *et al.*., 2003; Unger, 2000). The minimum/ zero tillage practices provide better physical soil condition for organic matter maintenance and conservation of moisture and thus contributing to sustainable crop productivity. In

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addition to crop production and soil fertility improvement, it also helps in reducing the erosion and environmental pollution.

Keeping in view the above facts, this project was initiated to introduce minimum/zero tillage technology to effectively utilize the crops residues and also to involve legumes in crop rotation, to keep the soil surface covered with crop and crop residue for improving soil organic fertility, crop productivity, water use efficiency and reducing the soil erosion. However, this is a long-term project and in this paper the result regarding the tillage effect on yield and WUE of wheat and oat are summarized.

Materials and methods

Two long term field experiments during 2004-05, one grain and one on fodder crop, were planed at Livestock Research Station, Surezai (rainfed area), Peshawar, Pakistan, with the objective to improve soil organic fertility, soil physical conditions and increasing water conservation in soil profile for crop production. The treatments consist of three rotations: i) cereal-fallow-cereal (farmers' practice) ii) cereal-legume-cereal and iii) cereal-cereal-cereal with two tillage treatments: i) Tillage (–crop residues) and Tillage (+ crop residues) and ii) No-tillage (–crop residues) and No-tillage (+ crop residues).

Experimental design and sowing

Experiments were laid out according to the Split split plot design, keeping the tillage and no-tillage in main plot, rotation in sub plot and residues in sub sub plot. The size of the sub sub plot was 30 m^2 and was replicated 4 times. However during 2004-05 year the data was analyzed according to RCBD, omitting the rotation and residue plots. In the next year the Split split design will be used for studying the effect of rotation and residues. Composite soil samples from the experimental field were collected before sowing and analyzed for various parameters (table-1). Neutron probe was calibrated for the experimental site. Under conventional tillage, 15-20 cm deep moldboard plough (tractor-driven) was applied and cultivator was used at sowing time followed by planking while the zero- tillage has been left undisturbed. The experiment-I and experiment-II were sown on December 9, 2004 with wheat (CV. Tatara) and oat (CV. Local), respectively, using hand drill. The row-to-row distance in both crops was 30 cm. Fertilizers were applied at N_{60}: P_{60} (kg ha^{-1}) to both wheat and oat crops in the form of urea and single super phosphate at sowing time. Weedicide (Ankalic) was sprayed at tillering stage on wheat for control of weeds while weedicide (Astarin) was sprayed on oat for control of weeds in both tillage and no-till plots; however no-weedicide was used before sowing of crops as required in most cases. Termites attacked the wheat crop at grain formation stage and oat crop after first cutting in some plots and insecticide (Furedan granule) was applied for its control. There was a visual deficiency of nitrogen and zinc in oat crop after first cutting. Through foliar application of 1% urea and 0.1% zinc sulphate solution, crop growth was improved.

Soil moisture and water use efficiency determination

To study the effect of tillage treatments on the soil water storage, Neutron access tubes down to 90cm in soil profile were installed in each treatment in three replications. Neutron probe readings along with meteorological observations were recorded regularly. A total of 395 mm rainfall was received during the whole growing season. The water use and water use efficiency was calculated according to water balance approach (Kirda, 1990).

Plant Sampling and Processing

The wheat crop was harvested on May 17, 2005 at its physiological maturity. The grain portion was removed manually. Data was recorded regarding grain and straw yield. From oat fodder crop, the first cutting was obtained on March 9, 2005. Fresh and dry weights were recorded. The second cutting was obtained on May 20, 2005 and fresh and dry weights were recorded.

Statistical Analysis

The data was analyzed statistically and the means were compared using the computer MSTAT C programme based on the principal of Steel and Torrie (1980).

Results and discussion

1. Site characterization

The experimental site is situated at Livestock Research Station, Surezai (rainfed area), $33^0 45'$ N and $70^0 50'$E, Peshawar, North West Frontier Province (NWFP), Pakistan. Soil of the experimental site is loam to clay loam and found deficient in OM, organic C, nitrogen and phosphorus. Before the establishment of experiment, composite soil samples were collected from various depths viz. 0-15, 15-30 and 30-60 cm and were analyzed for various soil physico-chemical properties (Table-1). Soil texture was determined by the Bouyocous Hydrometer method of Moodie *et al.* (1954). The soil particle size analysis indicated that the proportion of sand in the soil profile ranged between 21 and 42%, silt ranged between 32 and 42%, and clay ranged between 26 and 37%. The organic C and total N were determined according to the methods of Nelson and Sommers (1982), Bremner and Mulvaney (1982), respectively. The amount of organic C in the surface 0-15 cm was 0.52%, which gradually decreased to 0.24% in the lower 30-60 cm depth. The amount of total N was 0.05% in the 0-15 cm to 0.032% in the 30-60 cm depth. The available phosphorus was 5.33 µg P g^{-1} soil in the 0-15 cm and decreased to 2.5 µg P g^{-1} soil in the 30-60 cm depth. Soil pH was determined in soil-water suspension (1:5) with the help of pH meter (McLean, 1982). Soil EC (Electrical Conductivity) was determined in soil-water suspension (1:5) using the Electrical Conductivity Meter (Rhoades, 1982)

The soil was alkaline in reaction (pH 7.6-7.9), non-saline (EC 0.39-0.22 dSm^{-1}), moderately calcareous in nature (11.6 to 18.5% lime), having Bulk density 1.43 to 1.45 Mg/m^3. The site is located at the altitude of 525 m above sea level and has cool climate in winter and warm to hot in the summer and come under the Semi-Arid Zone. The annual rainfall during the last many years ranged between 200 mm to 1057 mm and with an average of about 435 mm. The most humid month is August (76.7mm) followed by March (73.7mm). June (11.6mm) and October (13.4mm) are the driest months.

The evapotranspiration range is narrow during December to March (36-85 mm) and highest in June (202 mm). The mean monthly maximum temperature ranged from 17.6 to 39.3 ^{o}C and the minimum temperature from 1.7 to 24.1 ^{o}C. The highest monthly temperature is around 43 ^{o}C in June and the lowest –3 ^{o}C in December. The relative humidity ranged between 54% (June) and 72.6% (August).

Table 1. Physico-chemical analyses of the experimental soil (0–60 cm)

Soil properties	Value
Clay %	26- 37
Silt %	32-42
Sand %	21-42
Textural class	Loam to clay loam
Bulk density (Mg m^{-3})	1.43-1.45
pH (Saturated soil paste)	7.6-7. 9
ECe (dsm^{-1})	0.39-0.22
Nitrogen %	0.05-0.032
Organic matter %	0.89-0.5
Total C %	0.52-0.24
Available Phosphorus (µgg^{-1})	5.33-2.5
Lime %	11.6-18.5
Water table depth (m)	45-50

2. Effect of tillage on the yield of wheat and water use efficiency

The tillage treatment effect on the crop productivity and water use efficiency are summarized as below:

i) Grain and straw yield

The results obtained regarding grain and straw yield of wheat as influenced by tillage are presented in Table 2. The results showed that almost similar grain and straw yield was obtained under till and no-till system. Generally better plant growth was observed in the initial growth stages in the tillage than in the no-tillage treatment. However, with time and after rainfall, the growth in the no-tillage treatment was also improved and the apparent difference between the tillage and no-tillage treatments was disappeared. Later on up to maturity, almost similar growth was witnessed in the both systems. Initial results indicated that tillage practice was not found beneficial under the prevailing experimental conditions. Considerable work has been done on different tillage systems from increasing productivity point of view of dry land agriculture and many workers found no difference between conventional tillage, reduced tillage or no-tillage.

Table 2. Effect of tillage on yield and water use efficiency (WUE) of wheat.

Treatment	Yield ($kg\ ha^{-1}$)		WUE ($kg\ ha^{-1}\ mm^{-1}$)	
	Straw	Grain	Straw	Grain
T0	5784.4	2679.6	11.41	5.3
T1	5785.6	2750.4	11.41	5.4

T0, No tillage; T1, Conventional tillage

Mohammad *et al.* (2003 b) reported that tillage treatment on the average did not improve the yield of wheat significantly but application of phosphorus at 60 kg ha^{-1} improved the grain yield of wheat in all growing seasons compared to 30 kg P ha^{-1}. Francis *et al.* (1992) reported that yields of wheat tended to be greater under no-tillage but yields of spring barley were greater under conventional tillage (moldboard ploughing to about 150 mm depth followed by at least 2 secondary tillage operations). Arshad *et al.*. (1994) obtained higher wheat yields from reduced tillage (one ploughing in spring) than the conventional tillage (one ploughing in autumn and two in spring) and zero tillage (harrowed + weedicide used), however, the differences were not always significant. Lafond *et al.* (1994) obtained similar yields of wheat, rape and barley under CT, ZT and MT systems. Likewise, similar wheat yields were obtained in Israel with both NT and CT in a normal year whereas in drought years, NT management increased yield relative to CT (Bonfil *et al.*, 1999). These finding support our results.

ii. Water use efficiency of wheat

The grain and straw WUE of wheat under rainfed condition as influenced by tillage are summarized in Table 2. The average WUE of wheat grain was 5.4 kg ha^{-1} mm^{-1} in the tillage compared with 5.3 kg ha^{-1} in the no-tillage treatment. These results indicated that tillage had slightly improved the WUE as compared to no-tillage treatment. These results suggest that tillage did not play any significant role in water use efficiency improvement. The effects of tillage usually depend on the growing season rainfall and soil surface conditions. The no-tillage was potentially better for semi-arid regions because it maintains greater water content in the soil and allows better root growth especially in years of low rainfall (Lampurlanes *et al.*, 2001).

iii. Soil moisture contents

The soil water content under wheat crop at different growth stage as influenced by tillage treatment is summarized in Fig-1. The no-tillage plots showed higher moisture content in the subsurface soil (30-90 cm) at all growth stages except the dough development stage. At dough development stage almost similar moisture contents were recorded under tillage and no tillage plots. Although similar moisture content in 0-30 cm upper soil was recorded in the tillage and no-tillage treatments at all growth stages, however at lower depth the zero tillage treatment at seedling, 1st tillering, 2nd tillering, booting, anthesis, milk development and maturity stages contained 30.4, 24.15, 25.73, 13.81, 44.2, 32.0, 9.65 mm more water in the soil profile than tillage treatments, respectively. These higher moisture contents at lower depth in the no-tillage treatment showed that tillage did not help to control 2^{nd} stage evaporation by breaking the capillary. These results indicated that tillage practice was not found beneficial for conservation of moisture in soil profile. The no-tillage was potentially found better for semiarid region because it maintained greater water content in the soil and greater root growth especially in years of low rainfall (Lampurlanes *et al.*, 2001).

3. Effect of tillage on the fodder yield of oat and water use efficiency

The data regarding the fodder yield and WUE of oat as influenced by tillage is summarized in Table 3. The average fresh fodder yield of oat increased by 500 kg ha^{-1} under tillage as compared zero tillage treatment. The data indicated that fresh yield was improved slightly by tillage practices. However almost similar dry yield was obtained under tillage and zero tillage systems. The data regarding water use efficiency showed that similar dry matter WUE of 14.88 and 14.86 $kgha^{-1}mm^{-1}$ were obtained under tillage and no-tillage system, respectively. The data indicated that tillage did not have significant effect on the fresh and dry yield of oat. These results also suggest that tillage did not play any significant role in water use efficiency improvement. So tillage practices should be minimized to reduce the cost of cultivation. Lafond *et al.* (1994) obtained similar yields of wheat, rape and barley under CT, ZT and MT systems. In their experiments, the effects of tillage and cropping system on spring soil moisture, which was

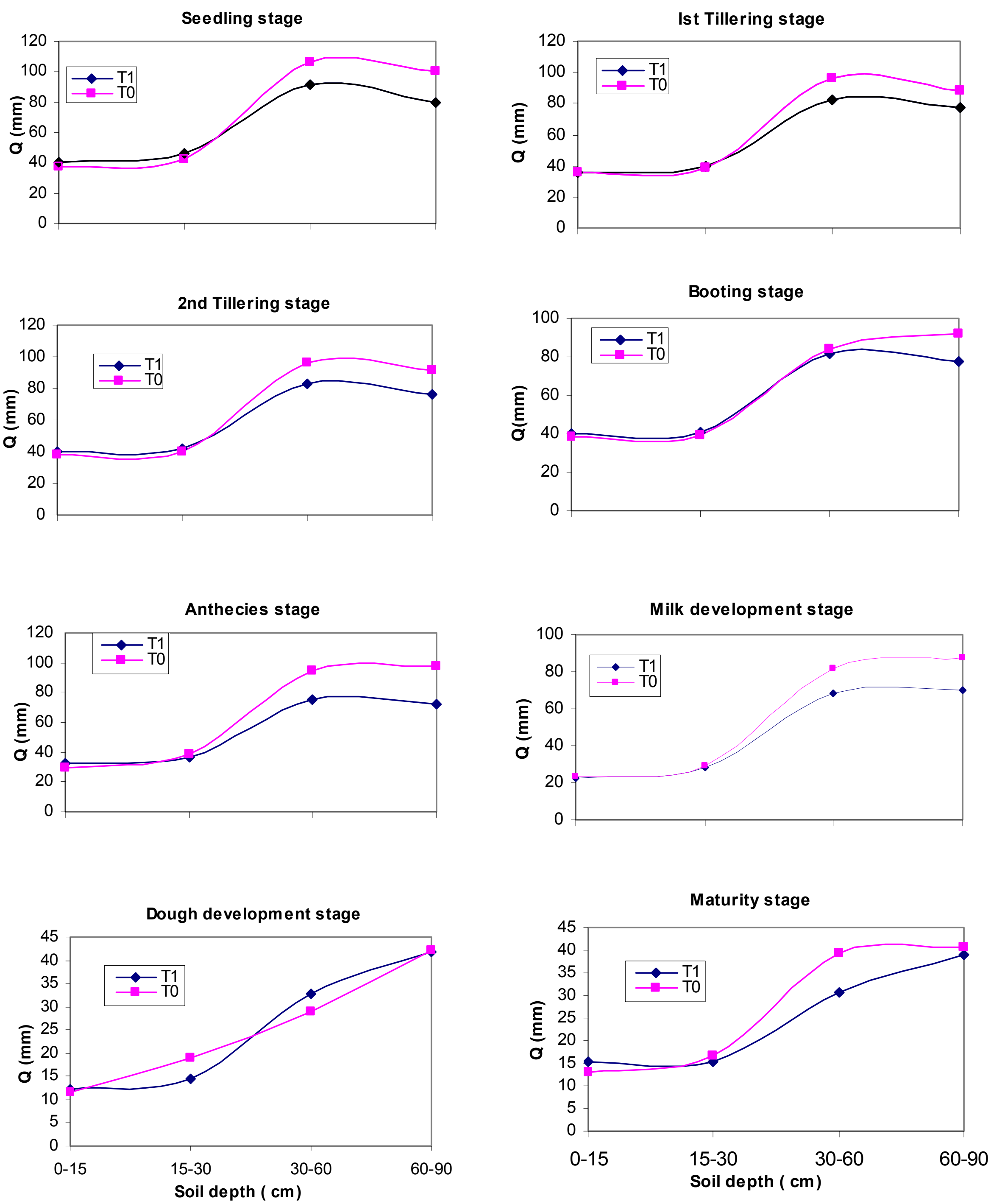

Figure1. Effect of tillage on soil moisture contents Q (mm) under wheat crop at different growth stages during 2004-2005 at Surezai Research Station (T1, Conventional tillage; T0, No tillage)

responsible for observed differences in crop water use and consequently yield, were dependent on soil type. Likewise, similar wheat yields were obtained in Israel with both NT and CT in a normal year whereas in drought years, NT management increased yield relative to CT.

Lampurlanes *et al.* (2001) resulted that the no-tillage was potentially better for semi-arid regions because it maintains greater water content in the soil and allows better root growth especially in years of low rainfall.

Table 3. Effect of tillage on fodder yield and WUE of oat.

Treatment	Yield (kg ha^{-1})		WUE, kg dry matter ha^{-1} mm^{-1}
	Fresh	Dry	
T0	37250	7536.2	14.86
T1	37750	7547.8	14.88

T0, No tillage; T1, Conventional tillage.

Conclusion

Almost similar wheat grain, biological and oat fodder yields were obtained under tillage and no-tillage system. These results indicated that tillage had slightly improved the WUE as compared to no-tillage treatment. Although similar moisture content in 0-30 cm upper soil was recorded in the tillage and no-tillage treatments at all growth stages, however at lower depth the zero tillage treatment at seedling, 1st tillering, 2nd tillering, booting, anthesis, milk development and maturity stages contained 30.4, 24.15, 25.73, 13.81, 44.2, 32.0, 9.65 mm more water in the soil profile than tillage treatments, respectively. Therefore the tillage practices can be minimized to reduce the cost of cultivation.

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