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Effects of Conservation Tillage on Soil Moisture Retention and Crop Production in Silty Loam Soil of Balochistan

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ABSTRACT

This research explores the efficacy of conservation tillage systems in comparison with farmer conventional practices in the silty loam soil of Balochistan, Pakistan, focusing on Conventional Tillage (CT), Minimum Tillage (MT), and Zero Tillage (ZT). Over two years, the study evaluated soil properties and wheat crop parameters across these systems. Results indicate initial differences in water infiltration rates, with CT and MT exhibiting 30-35% higher rates than ZT, which showed an improving trend over time. Soil moisture content favored CT initially but equalized across all systems by wheat harvest. Initial surface compaction was observed 1.6 Mg m^{-1} in ZT while CT 1.45 Mg m^{-1} and respectively in MT 1.48 Mg m^{-1}, initially reduced bulk density due to ploughing under conventional practices. Structural stability was 35% in ZT initially but improved across all systems over time. While CT resulted in higher wheat biomass in the first year due to better initial soil moisture conditions, no significant differences in grain yield were observed among systems in both experimental years, emphasizing the potential of MT as it exhibited enhanced water infiltration and comparable yields to CT. This study underscores the economic and environmental viability of reducing ploughing frequency and employing conservation tillage practices for smallholder mountainous farmers, urging further exploration of Zero Tillage for sustab agriculture.

1. INTRODUCTION

Farming in the dryland areas is a high-risk activity due to erratic rainfall and climatic patterns. Unfortunately, conventional system of excessive tillage and residue removal is further aggravating the situation by intensive natural resources mining and continuous degradation of soil fertility, causing a worsening threat to farm productivity and food security. Conventionally in dryland areas of Pakistan, wheat is grown after six-month fellow period and during this short fallow soil receives about 8-10 ploughings for weed control and moisture conservation. Excessive ploughing not only causes soil degradation by accentuating breakdown of aggregates, decomposition of organic matter and loss of nutrients (Balesdent et al., 2000) but also ruins the economic stability of small land holder farmers. There is dire need to provide the farmers with alternative soil management options that minimize soil degradation and improve soil health besides lowering input cost of the resource poor smallholder farmers of these dryland areas.

Conservation tillage is a system that involves minimum disturbance of soil while leaving at least 30% of crop residue after planting on the soil surface. The term includes minimum tillage, direct drilling, zero tillage, no-till etc. under its umbrella. The potential advantage of conservation tillage practices over conventional practices is due to leaving residue on soil surface that reduces erosion by providing barrier against rain-splash and runoff, reduces evaporation and increases infiltration (Franzluebbers, 2002). Residue also increases soil organic carbon that improves soil aggregation (Madari et al., 2005) soil water availability (Unger, 1994; Drury et al., 1999), number of biopores (Francis and Knight, 1993) that may facilitate root growth (Martino and Shaykewich, 1994) and water holding capacity. In short, conservation tillage with presence of residue on soil surface interfaces all soil ecology (Huang et al., 2008). This system also saves time and fuel cost (Baker et al., 2007) which is very important for smallholder farmers of developing countries like Pakistan. However, the benefits of conservation tillage are dependent on soil properties, climatic condition of the area and the number of the years since the tillage system has been implemented (Rhoton, 2000).

Currently world over about 117 M ha are being cultivated with conservation tillage most of which is there in North America (47%), South America (34%) and Australia (14%). Ironically Asia has only 2.2% area under conservation tillage (ICARDA, 2012). This regional comparison shows that conservation agriculture has proven most successful so far in relatively advanced countries. And that it has been slow to spread in the lower income countries, which is in fact a missed opportunity. Keeping in view the worsening climate change that threatens desertification and more frequent and severe droughts, particularly in the Indian subcontinent, it is high time to extending conservation agriculture and its benefits for dryland agriculture of these regions. In Pakistan there have been extensive research on conservation tillage in the irrigated rice-wheat system, however information in water scare mountainous areas is scarce. Therefore, the following study was conducted to evaluate different variants of conservation tillage with conventional intensive tillage system for soil water storage in profile, potential under mountainous agriculture, Balochistan.

2 MATERIALS AND METHODS

2.1 STUDY AREA

A field experiment involving conservation tillage under wheat crop was conducted in 2017-18 and 2018-19 at farmer's field at Bostan in upland of Balochistan. Pakistan.

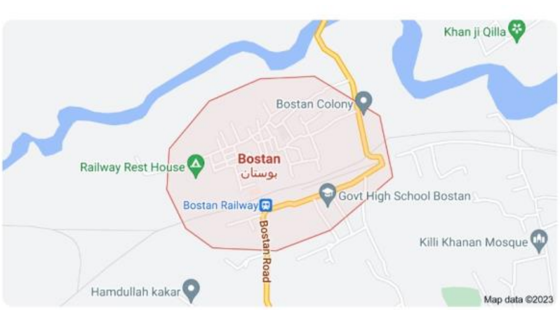

Figure 1 Location of Experimental Setup

2.2 TREATMENT DETAILS

The experiment was placed in a Randomized Complete Block Design having four replications in 16 × 25 m plots. The three tested tillage systems were Conventional Tillage (CT), Minimum Tillage (MT), and Zero Tillage (ZT). The treatment CT that has been continuously practiced over the years by farmers involves continuous plowing without retention of crop residues with a tine cultivator. The alternative MT tillage involved half the tillage operations as compared to CT while under ZT plots the soil remained undisturbed and wheat crop was planted during winter in all plots.

2.3 SOIL ANALYSIS

The soil water infiltration was measured through single ring infiltrometer methods. The ring was pressed in soil surface and infiltration rate was recorded when downward movement of water reached at steady state level. Samples for soil moisture contents in three different depth i.e 0-30, 30-60, 60-90 at three different times i.e sowing time, harvesting time were taken through king tube and moisture was calculated using gravimetric method. Sample for soil bulk density was collected through core sampler (Black, 1965). Aggregate stability was determined for each experimental plot using the wet sieving method. Soil sample for aggregate stability was taken through core sampler, air dried and the sample was prepared by passing through 2 mm sieve and retained in 1 mm sieve. Then 4-gram soil sample were placed in 0.25 mm sieve on wet sieving apparatus. The sample was mechanically agitated (vertical displacement) for 3 minutes. The soil aggregates retained in the sieve were dispersed with a 1N sodium hexametaphosphate and relocated in the same sieve to again agitate for sand separation. The soil collected in the can was oven-dried, weighed and aggregated stability was calculated (Yoder, 1936).

2.3 CROP PARAMETERS

Shoot biomass was recorded by harvesting the crop from each plot and then weighing it after oven drying. Grains at maturity were separated from spikes and average grain yield was presented in Mg ha^{-1}.

2.4 STATISTICAL ANALYSES

Finally, the data collected for various characteristics was subjected to Analysis of variance (ANOVA) and means were compared at 5% level of significance by Least Significance Difference (Steel *et al*., 1997).

3 RESULTS

3.1 WATER INFILTRATION

The infiltration rate of water in soil profile (Fig 2) was significantly lower in ZT plots than CT and MT during first year, where CT and MT had similar infiltration rates. During the second year a gradual declining trend in water infiltration rate i.e. CT > MT > ZT was observed.
The objective of infiltration rate measurement particularly during monsoon rains was to compare the capacity of different tillage treatments for intake of water during the period when most (70%) of the annual rain fall is received. The low intake of water by ZT plots was due to a relatively compacted surface layer that was indicated by numerically higher bulk density under ZT (Fig 4). The tilled plots did not have surface compacted layer and had numerically lower bulk density that made inflow of water relatively easier. It is expected that with the passage of time buildup of SOM under ZT will reduce the bulk density and improve water infiltration.

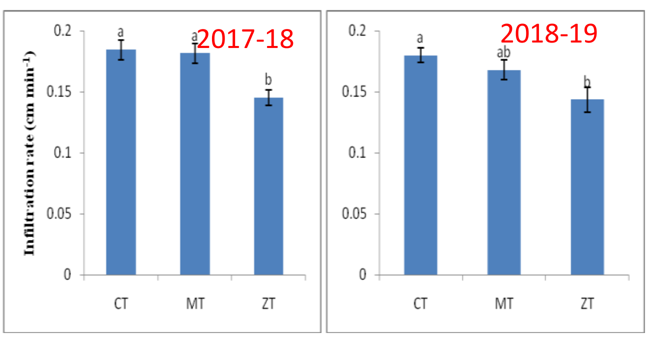

Figure 2 The infiltration of water in soil profile as influenced by different tillage systems by different tillage systems in mountanIous agriculture Balochistan: CT; Conventional tillage, MT; minimum tillage, ZT; zero tillage.

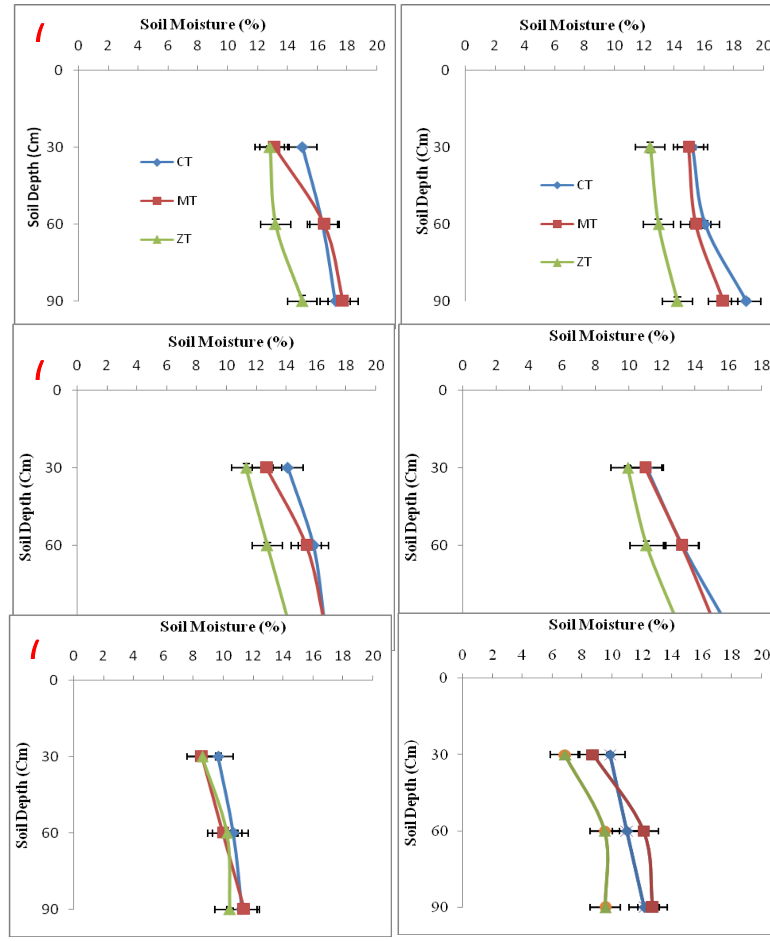

Figure 3 (a, b and c) Soil moisture contents under different depths at different stages by different tillage systems in mountainous agriculture Balochistan i.e. without crop, Wheat sowing and Harvesting, tillage systems: CT; conventional tillage, MT; minimum tillage, ZT; zero

3.2 SOIL MOISTURE CONTENTS

The soil water content upto 90 cm profile was measured at three different stages i.e. at end of monsoon, at wheat sowing and at wheat harvest (Fig. 3 a, b & c). In both the years, CT plots had collected highest moisture content by the end of monsoon, closely followed by MT plots. The ZT plots had the least water content. The same trend among water contents was carried forward to wheat sowing stage, however by the wheat harvest differences in water contents among tillage treatments had vanished. The overall water content declined significantly at each succeeding stage. The upper soil layer (0-30 cm) had lesser moisture content in all tillage systems than deeper depths (30-60 & 60-90 cm), regardless of the sampling stage.
The relatively lower soil moisture stored in ZT system at different sampling stages was result of low infiltrate rate during monsoon (Fig. 2) and easy evaporation afterwards due to insufficient residue cover.

Oicha et al. (2010) have also observed less moisture storage due to poor physical condition of soil and lack of permanent residue cover. In tilled systems, ploughing with heavy tillage breaks the capillary tubes which decrease the evaporation losses from surface layer. The lesser moisture in topsoil layer is due to rapid loss of water with weather related temperature changes. High temperatures prevailing in the area encourage evaporation especially from the soil surface.

3.3 BULK DENSITY

The bulk density measured at three different stages i.e. end of monsoon, wheat sowing, and wheat harvest (Fig. 4) showed that ZT had higher bulk density than CT and MT at end of monsoon and wheat sowing, however after wheat harvest the differences in bulk densities were statistically negligible. Overall, the bulk densities increased gradually from end of monsoon to wheat harvest. The trends were similar in both the experimental years.

The bulk density was numerically higher in ZT plots that resulted in a relatively compacted surface layer. However, ploughing with mouldboard at start of monsoon under CT and MT had broken the compacted layer which numerically decreased bulk density. Contrasting results in the literature have been reported about bulk density under conservation tillage systems. For example, Dao, 1996 agreed that there was no significant difference in bulk densities of conservation and conventional tillage systems, while some others such as (Ball-Coelho et al., 1998; Schonning & Rasmussen, 2000) found that bulk density was high in starting years of conservation tillage but decreased gradually with time. In the Pothwar area Shafiq et al. (1994) in a short duration study have also observed non significance differences in bulk density under conventional and no-till systems.

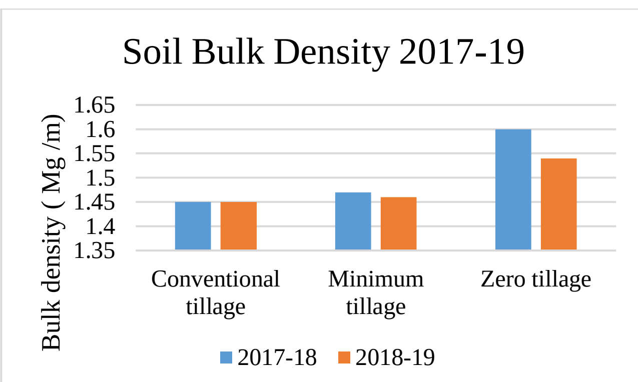

Figure 4 Bulk density at sowing time as influenced by different tillage system in mountanious agriculture Balochistan. Tillage systems; CT; conventional tillage, MT; minimum tillage, ZT; zero tillage.

3.4 STRUCTURAL STABILITY

Water stable aggregates were measured at two stages in each year i.e. wheat sowing and wheat harvesting (Fig. 5). At wheat sowing, water stable aggregates were significantly higher under ZT than CT and MT, however the differences between tillage treatments at wheat harvest were found to be statistically negligible in both the years.

The significantly higher soil aggregation under ZT at wheat sowing was due to minor physical disruption of aggregates as compared with CT and MT. By the harvesting stage an increase in aggregation in all tillage plots was observed due to absence of further disturbance and presence of crop root that encouraged aggregation. It is expected that gradually the ZT will further improve soil aggregation. Numerous researchers such as Ghuman and Sur (2001) and Shukla et al. (2003) have observed that increased organic matter content with minimum disturbance under conservation tillage systems increased soil aggregate stability in the long run.

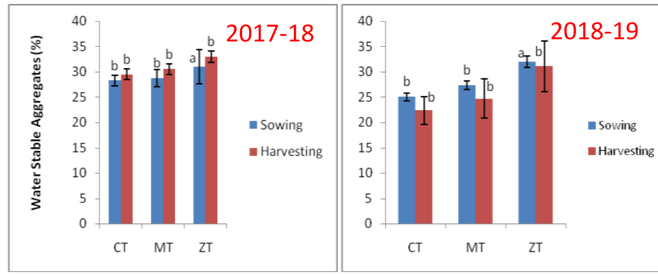

Figure 5 Soil aggregate stability at wheat sowing and harvesting stages as influenced by different tillage systems in mountainous agriculture Balochistan. Tillage systems; CT; conventional tillage, MT; minimum tillage, ZT; zero tillage

3.5 WEAT BIOMASS AND GRAIN YIELDS

The effects of tillage systems on biomass and grain yields of wheat (Fig. 6 and Fig. 7) varied in the two experimental years. During first year the treatment CT produced significantly higher wheat biomass yield than MT and ZT however during second year differences in biomass yield were insignificant. The grain yields of wheat, though numerically lower under ZT, had no statistical difference among tillage treatments in both the experimental years.

The better biomass yield during first year under CT is due to higher water content at wheat sowing and loosening of surface soil due to intensive ploughing that resulted in better seed-soil contact and hence germination. The intensive ploughing also loosened the soil which may have helped the roots to penetrate deeper and extract more water and nutrients. Gill et al. (2000) also conducted a tillage experiment in same region and concluded that mouldboard plough loosens the soil which help to increased total biomass. The ZT plots had lower water content as well as a relatively compact surface layer that not only reduced seed germination but also hindered root penetration at initial crop stages.

During the second experimental year no differences among tillage systems were observed for biomass yield because of the higher rainfall during the year. Sufficient rainfall during monsoon and during in-crop period superseded other differences as water is the main limiting factor for crop production in the dryland regions. In contrast to biomass yield the differences in grain yields under different tillage systems were statistically minor during both the experimental years. These results support the findings of Ahmed et al. (2007) who also reported non-significant differences in wheat yield of tilled and no-till plots in Pothwar region.

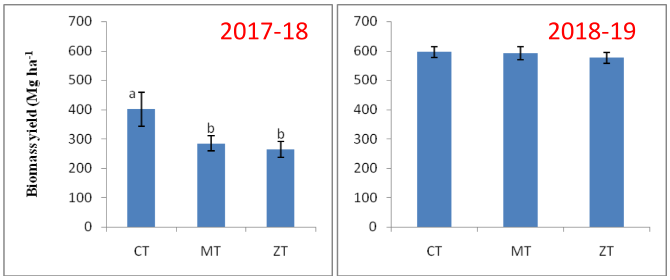

Figure 6 Wheat crop biomass as influenced by by different tillage system in mountanious agriculture Balochistan. Tillage systems; CT; conventional tillage, MT; minimum tillage, ZT; zero tillage.

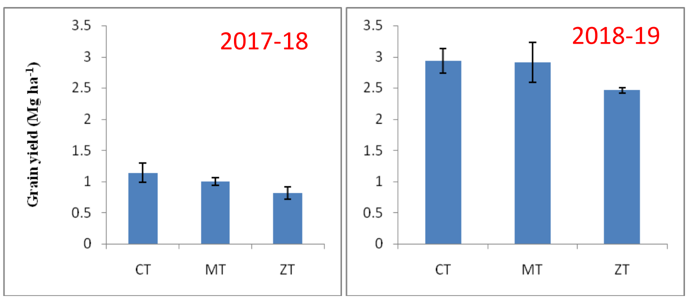

Figure 7 Wheat crop grain yields as influenced by by different tillage system in mountanious agriculture Balochistan. Tillage systems; CT; conventional tillage, MT; minimum tillage, ZT; zero tillage.

4 CONCLUSIONS

The investigation findings obviously support the effectiveness of conservation tillage, particularly the minimum tillage (MT), in boosting water infiltration and optimizing soil moisture retention. MT showed comparable wheat biomass and grain yields to the conventional tillage (CT) practiced by farmers. While acknowledging the potential of zero tillage (ZT), this succinct study emphasizes the need for extensive, long-term research to comprehensively measure its success. Ultimately, this study conclusively asserts that reducing ploughing frequency not only economic advantages for smallholder farmers but also significantly improve soil health, ensures sufficient yields, and enviornment friendly.

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