Journal of Agriculture and Veterinary Science
ISSN: 2959-1198 (Print), 2959-1201 (Online)

Research Article

Assessment of Soil Fertility and Water Dynamics under Different Tillage Practices in Loess Degraded Soil of Balochistan

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ABSTRACT

The upland of Balochistan is facing water conservation and nutrient depletion challenges in soil, with much of its highland areas relying solely on groundwater for irrigation and drinking. Effective water management and soil moisture conservation practices are imperative in arid and semi-arid regions facing water scarcity. Implementing suitable tillage systems can help alleviate the adverse impacts of water scarcity. This study, conducted from 2020 to 2021 at Balochistan Agriculture University, Quetta, aimed to assess water dynamics and nutrient concentrations under various tillage practices in Balochistan's uplands. The objectives were to quantify water content in wheat fields and assess nutrient concentrations under different management approaches. Treatments were conventional tillage (CT), zero tillage (ZT), and chisel plough (CP), replicated three times in a Randomized Complete Block Design (RCBD). Parameters assessed under different treatments included soil pH, electrical conductivity (EC), soil temperature, soil water content (SWC), organic matter (OM), available phosphorus (P), nitrate nitrogen (N), extractable potassium (K), as well as crop production such as biological yield and grain yield. Statistical analysis, employing analysis of variance (ANOVA), indicated non-significant differences among the parameters studied. However, we recommend further research to continue the conservation of tillage practices to promote sustainable agricultural practices in Balochistan.

Keywords: Soil fertility, Moisture conservation, Conservation tillage, Conventional tillage.

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Article History
Received: March 14, 2024
Accepted: April 30, 2024
Published: June 10,2024

INTRODUCTION

Balochistan located in Western Pakistan, contends with several critical challenges includes water scarcity, low contents of organic matter, desertification, nutrients depletion in soil, structural instability, excess pH, and low natural resource content. These factors contribute to a decline in crop production, exacerbated by factors such as rapid population growth, frequent droughts, climate variability, and land degradation. Addressing these challenges necessitates innovative approaches to enhance soil organic carbon (SOC) levels in these areas (ICARDA, 2012).

The role of tillage in conserving soil moisture and its subsequent positive impact on crop production has long been recognized. Conventional tillage methods effectively controlled weeds and increased crop yield but incurred significant soil loss and financial costs (Dogra *et al.*, 2020).

https://doi.org/10.55627/agrivet.003.02.575

Conventional cultivation practices resulted in soil variability and deep weed infestations, leading to a substantial reduction in weed populations (Vijaymahantesh *et al.*, 2013). Conversely, conservation agriculture, particularly no-till practices, has shown promise in improving soil structure, enhancing soil function, promoting water retention, and increasing water use efficiency (Hobbs *et al.*, 2008). Conservation agriculture has been linked to enhanced soil productivity, including improved penetration and soil moisture retention, in accordance with (FAO, 2008). Furthermore, plowing aids in soil moisture distribution and management, particularly in dry agricultural environments (Iqbal *et al.*, 2005).

The chisel plow has demonstrated a positive effect on soil moisture compared to other plowing methods (Makki and El-amin Mohamed, 2008). The chisel plow's design, with tines spaced apart, facilitates soil aeration and reduces bulk density and soil compaction, particularly in moist conditions (Shah and Khan, 2003). Studies have shown that chisel plowing and disk plowing with cultivator methods maintain better soil moisture levels compared to single plowing, especially in clay soils (Ozmerzi *et al.*, 2003). Conversely, excessive tillage, such as rotary plowing, may exacerbate soil compaction and diminish soil moisture retention (Ozmerzi *et al.*, 2003).

Conservation farming systems, including conservation tillage, are globally recognized for their role in sustainable crop production. Conservation tillage involves planting crops in residues from previous crops, both pre- and post-planting, to reduce soil erosion and runoff. To achieve conservation benefits, at least 30% of the soil surface should be covered with residue after planting the subsequent crop (Conservation Technology Information Center, 2004).

Soil cultivation significantly influences soil health and crop yields, with farming practices accounting for up to 20% of crop production and impacting land tenure decisions. Proper soil management practices are essential for overcoming agricultural challenges and preventing adverse effects such as soil erosion, nutrient loss, and soil degradation. Intensive tillage and unsustainable farming practices can lead to soil compaction, reduced soil fertility, and loss of biodiversity (Bronick and Lal, 2005).

Keeping in mind the above issues about the province, current study conducted within the area of Balochistan Agriculture, Quetta (BAC) to measure the water contents in wheat field under different tillage practices in uplands of Balochistan as well as to evaluate the nutrient concentration of under different management practices.

MATERIALS AND METHODS

Experimental Site

This research was conducted at the Balochistan Agriculture College Quetta over a one-year period from 2020 to 2021. Samples were collected from an ongoing project funded by the Punjab Agriculture Research Board (PARB) at the Balochistan Agriculture College, Quetta shed house of the Department of Earth Sciences. The study focused on evaluating different farming practices in the uplands of Balochistan. Three distinct farming methods were implemented to assess their impact on soil resources and sorghum yields. The treatments included: T1 - Conventional Tillage (CT) involving continued farming with moisture conservation and weed control, T2 - Zero Tillage (ZT) utilizing a zero tillage drill for planting and herbicide for weed control, and T3 - Chisel Plow (CP) entailing chisel plow farming at the start of the planting season and chemical weed control using a herbicide.

Soil Sampling and Preparation

Soil samples were collected at each experimental site to analyze various soil properties and nutrient status prior to implementing different treatments. Soil samples were collected using different tools for specific purposes. Samples for soil structure, pH, electrical conductivity, and Total Organic Carbon (TOC) were obtained using a soil auger. Bulk density and total stability sampling were conducted using a primary sample approach. After collection, soil samples were prepared and subjected to the following analyses.

Crop Description

Wheat (*Triticuma estivum*) was cultivated in all fields. For T2 and T3 treatments, crops were seeded using a rotating seed machine, while for T1, crops were sown using traditional propagation methods. Plant and crop spacing were set at 30 cm and 60 cm, respectively.

Soil Features and Parameters

Soil sampling was conducted to determine the physicochemical properties and nutritional status of the soil before implementing different treatments. Composite soil samples were collected from each experimental site, air-dried, crushed using a pestle and mortar, and sieved through a 2 mm filter. Soil parameters were analyzed as follows:

Soil Temperature

Soil temperature was measured using a digital thermometer installed at each experimental site, and readings were recorded accordingly.

Soil Water Content

Fresh soil samples (50 g each) from each plot were weighed and dried at 105 °C in an oven for 24 hours. Soil moisture content was calculated using the formula proposed by Hesse and Hesse (1971).

Soil pH: Soil pH was determined using a 1:2 soil-to-water solution. Soil samples (10 g each) were mixed with 20 mL of distilled water, and pH readings were taken using a pH meter following the method described by McLean (1983).

Electrical Conductivity: Electrical conductivity of soil samples was measured using the method outlined by Rhoades (1982), which involves preparing a soil-water mixture at a ratio of 1:5, followed by EC measurement using an EC meter (DDS-12DW).

Organic Matter Content

The oxidizable organic carbon content of soil samples was determined using the method described by Nelson and Sommers (1982). Soil organic matter (%) was calculated based on the oxidizable organic carbon content and adjusted using a conversion factor.

Available Phosphorus (P)

The AB-DTPA method proposed by Soltanpour and Workman (1979) was employed to determine available phosphorus in soil samples. Soil extracts were prepared using AB-DTPA solution, followed by spectrophotometric analysis to measure P concentrations.

Nitrate Nitrogen

Nitrate nitrogen content in soil samples was determined using the AB-DTPA method described by Soltanpour and Workman (1979), with spectrophotometric analysis at 540 nm wavelength.

Extractable Potassium (K): Potassium extraction from soil samples was performed using the method proposed by Soltanpour and Workman (1979). Soil extracts were analyzed using flame photometry to determine potassium concentrations.

Crop Data

During harvest, the following crop data were recorded:

Biological yield (kg/ha)

Grain yield (kg/ha)

Meteorological Data

Temperature, rainfall, and evaporation pan data were obtained from the Balochistan Agriculture Research and Development Center, Quetta.

Statistical Analysis

The collected data underwent variance analysis, and the LSD test was conducted at a significance level of 0.05 to detect differences among treatments across all parameters. Statistical analyses were performed using Statistic 8.1 software (MathSoft Inc., Cambridge, MA, USA).

RESULTS

Soil reaction

The findings reveal that the soil pH of the Zero Tillage (ZT) treatment decreased to 7.6 at the time of sowing and increased to 7.8 after harvesting. Similarly, the Conventional Tillage (CT) treatment showed a pH of 8.1 at sowing, which increased to 8.2 after harvesting, while the Chisel Plow (CP) treatment exhibited a pH of 8.2 at sowing, rising to 8.4 after harvesting (Figure 1). Consequently, the differences observed among the three tillage treatments were deemed non-significant.

EC concentration (dSm^{-1})

Soil electrical conductivity (EC) levels under various tillage practices are illustrated in figure 2. The data revealed that different tillage practices significantly influenced soil EC levels at both sowing and harvesting times. The highest mean EC value (0.78 dS/m) was observed in conventional tillage at sowing, followed by Chisel Plow (EC 0.72 dS/m) and zero tillage (EC 0.69 dS/m), respectively. Conversely, the highest mean soil EC value (0.6 dS/m) was recorded in Zero Tillage, followed by conventional tillage (EC 0.55 dS/m) and Chisel Plow (EC 0.52 dS/m) after harvesting.

Soil Organic Matter (%)

The study revealed significant variations in soil organic matter content among three tillage practices at both sowing and harvesting stages. The findings indicate that soil organic matter content was higher in Zero Tillage (ZT) at

https://doi.org/10.55627/agrivet.003.02.575

sowing, reaching 0.71%, while it decreased to 0.62% after harvesting. Similarly, at sowing, Conventional Tillage (CT) showed 0.69% organic matter, decreasing to 0.60% after harvesting, and Chisel Plow (CP) had 0.70% organic matter at sowing, declining to 0.58% after harvesting (Figure 3). Consequently, the differences among the three tillage treatments appeared to be statistically non-significant.

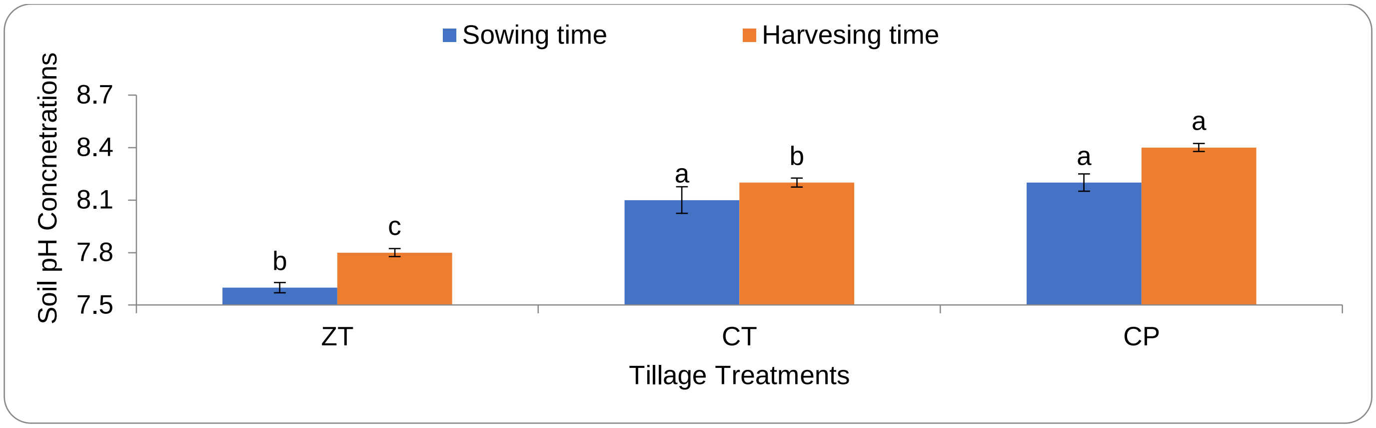

Figure 1: Soil pH under Different tillage practices during 2019-20 under wheat crop in upland of Balochistan

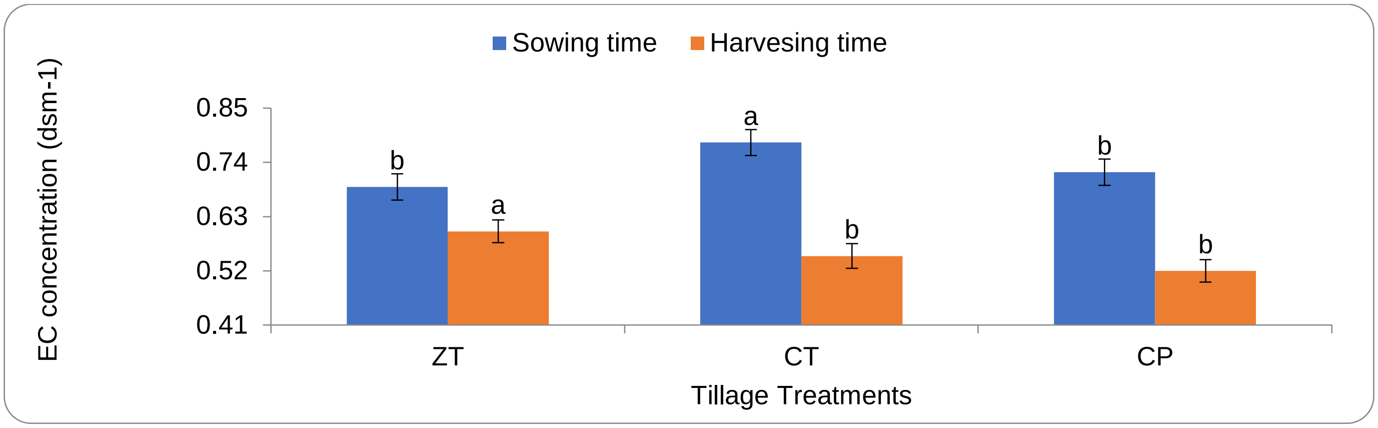

Figure 2: Soil EC concentration (dsm^{-1}) under different tillage practices during 2019-20 under wheat crop in upland of Balochistan.

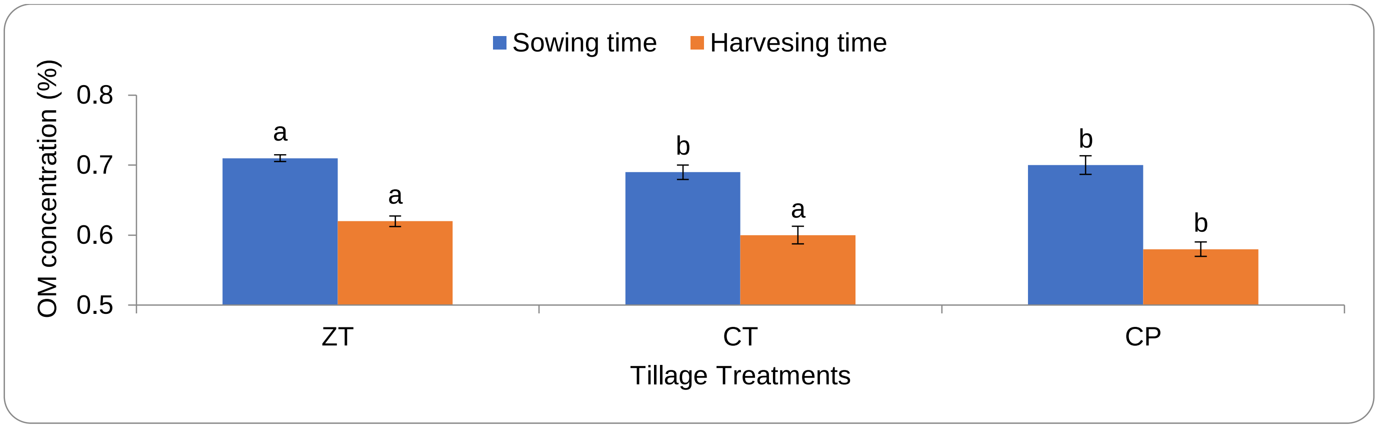

Figure 3: Soil OM concentration (%) under Different tillage practices during 2019-20 under wheat crop in upland of Balochistan.

Soil Moisture (%)

Soil moisture levels under various tillage methods are depicted in figure 4. The data reveal significant variations in soil moisture content at different stages of sowing, mid-growth, and harvesting. The highest mean soil moisture

https://doi.org/10.55627/agrivet.003.02.575

value, at 9%, was observed in Chisel Plow during the mid-growth stage, followed by conventional tillage at 8.8% and zero tillage at 8.9%. Conversely, the highest mean soil moisture value, at 8.6%, was observed in zero tillage at the time of sowing, followed by conventional tillage at 8.6% and Chisel Plough at 8.2%. After harvesting, the highest mean soil moisture value, at 8.4%, was recorded in Chisel Plough, followed by zero tillage at 8.2% and conventional tillage at 7.3%. HE (2009) also reported a 6.3% higher water content in ZT treatment compared to CT up to a depth of 0-20 cm, with an even greater difference of 10.9% from 20-30 cm, favoring ZT plots over CT.

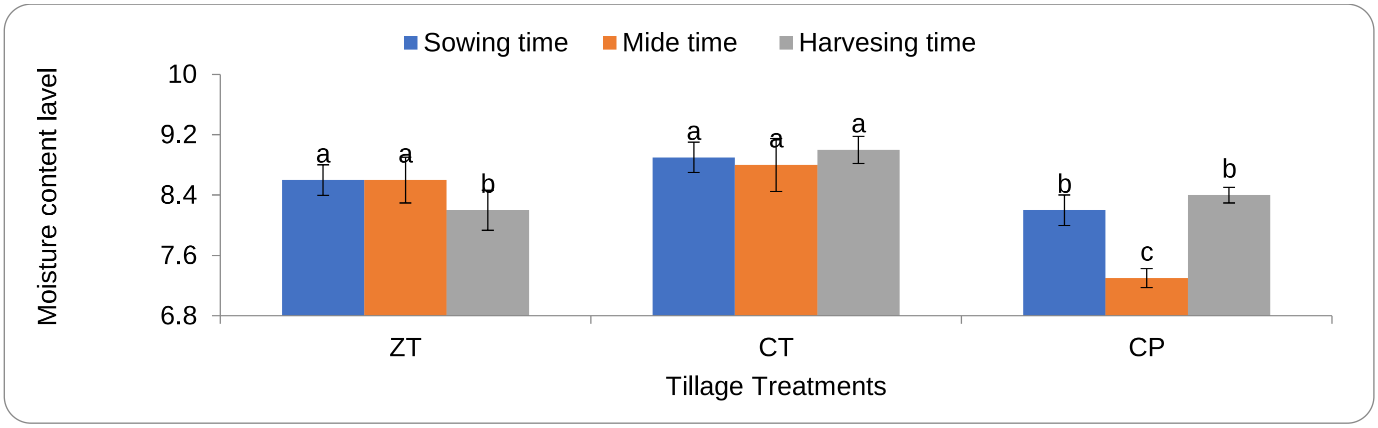

Figure 4: Soil moisture contents (%) under Different tillage practices during 2019-20 under wheat crop in upland of Balochistan.

Soil Temperature (^{0}C)

During the experiment, the soil temperature in ZT was recorded as 25.6°C at the time of sowing and increased to 30.1°C after harvesting (Figure 5). The findings also reveal that soil temperature is significantly influenced by three different tillage practices. At the time of sowing, the soil temperature in CT was 25.6°C, and it increased to 30.1°C at the time of harvesting. Similarly, the temperature of Chisel Plough was 25.5°C at the time of sowing and 27.7°C at the time of harvesting. There was a statistically non-significant difference in soil temperature among different tillage practices, indicating minimal temperature variations within the experimental plots.

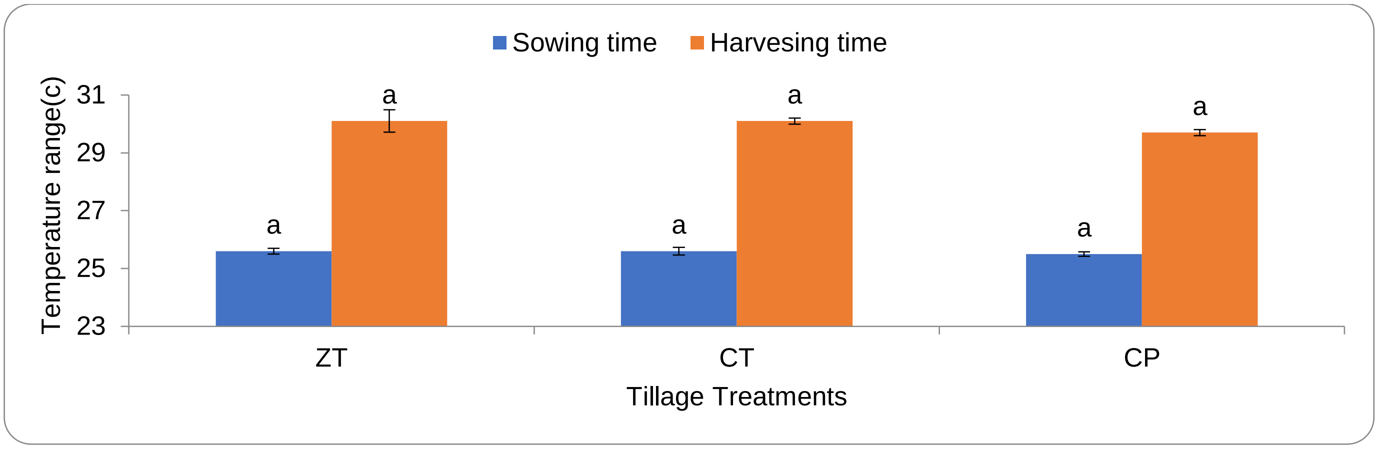

Figure 5: Soil temperature (^{o}C) under Different tillage practices during 2019-20 under wheat crop in upland of Balochistan.

Soil Nitrate Nitrogen (ppm)

Soil nitrate nitrogen concentrations under various tillage practices are depicted in figure 6. The data indicate that different tillage methods significantly influence soil nitrate nitrogen concentrations at different sowing and harvesting times. The highest mean value of soil nitrate nitrogen (8.5) was observed in conventional tillage at the time of sowing, followed by Chisel Plough (nitrogen 8.4) and zero tillage (nitrogen 8.3), respectively. Similarly, the maximum mean value of soil nitrogen (9.3) was recorded in zero tillage, followed by conventional tillage (nitrogen 9) and Chisel Plough (nitrogen 9), respectively, after harvesting.

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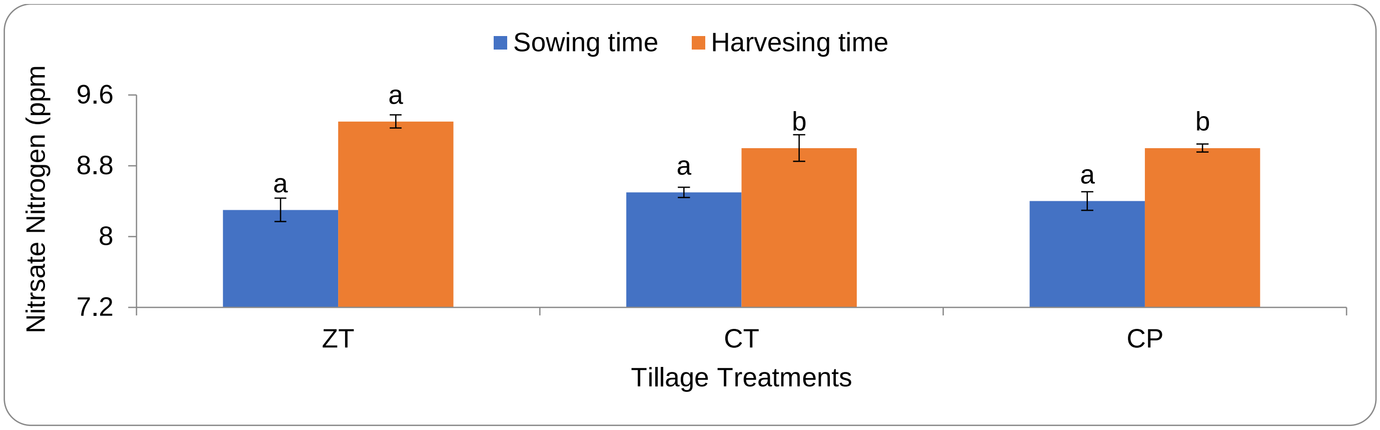

Figure 6: Soil Nitrate Nitrogen (ppm) under different tillage practices during 2019-20 under wheat crop in upland Balochistan.

Soil available Phosphorus (ppm)

Soil available phosphorus concentrations under various tillage practices are depicted in figure 7. The data reveal that different tillage methods significantly affect soil available phosphorus concentrations at various sowing and harvesting times. The highest mean value of soil available phosphorus (5.3) was observed in conventional tillage at the time of sowing, followed by zero tillage (phosphorus 5.3) and Chisel Plough (phosphorus 4.8), respectively. Similarly, the maximum mean value of soil available phosphorus (6.5) was recorded in conventional tillage, followed by zero tillage (phosphorus 6.5) and Chisel Plough (phosphorus 6.0), respectively, after harvesting.

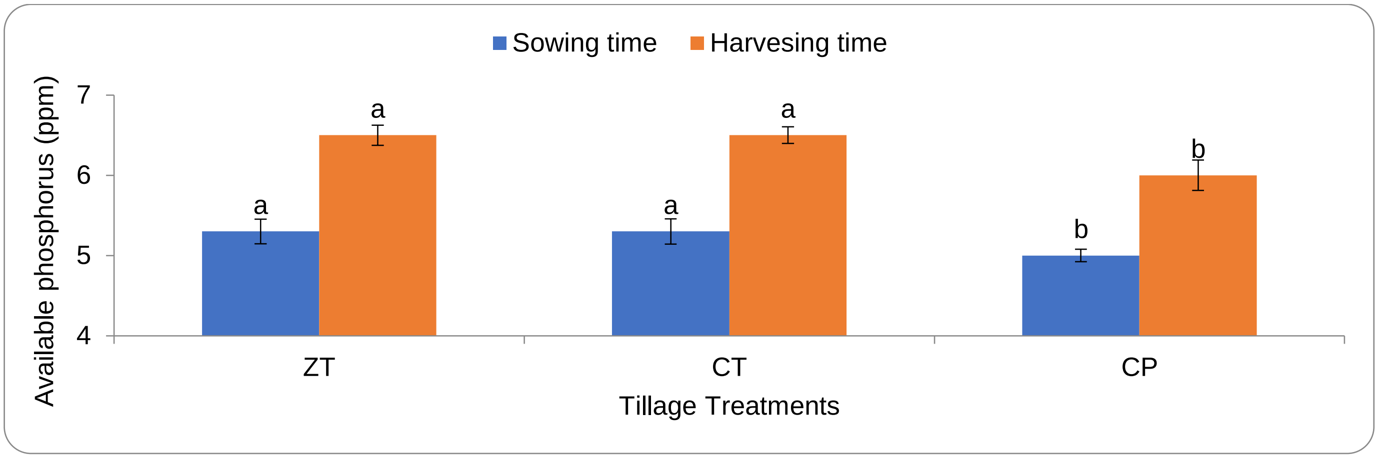

Figure 7: Soil available Phosphorus (ppm) under different tillage practices during 2019-20 under wheat crop in upland Balochistan.

Soil Extractable Potassium (ppm)

The concentration of soil extractable potassium under different tillage practices is depicted in figure 8. The data reveal that the various tillage practices significantly influence soil extractable potassium concentrations at different sowing and harvesting times. The highest mean value of soil extractable potassium (91.3) was observed in conventional tillage at the time of sowing, followed by zero tillage (potassium 91.2) and Chisel Plough (potassium 91.2), respectively. Similarly, the maximum mean value of soil potassium (92.1) was recorded in zero tillage, followed by conventional tillage (potassium 92) and Chisel Plough (potassium 91.9), respectively, after harvesting.

Biological Yield (Mg ha^{-1})

This study investigated the impact of three tillage practices on biological yield, revealing that conventional tillage (CT) resulted in the highest biological yield at 4.8 Mg ha^{-1}. In contrast, the biological yield was 1.4 Mg ha^{-1} in zero tillage (ZT) and 1.4 kg/ha in chisel plow (CP) treatments.

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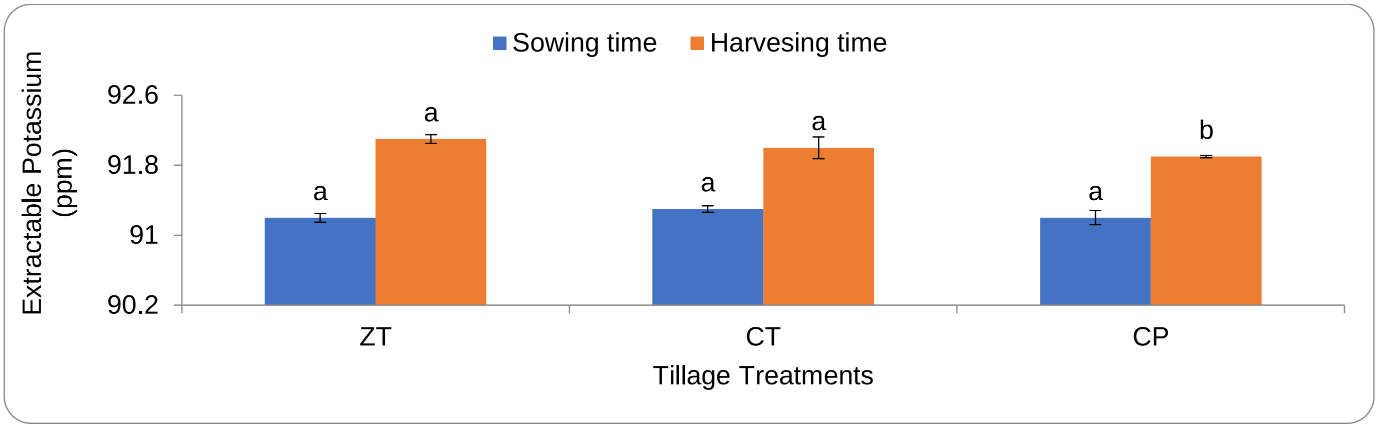

Figure 8: Soil extractable potassium (ppm) under different tillage practices during 2019-20 under wheat crop in upland Balochistan.

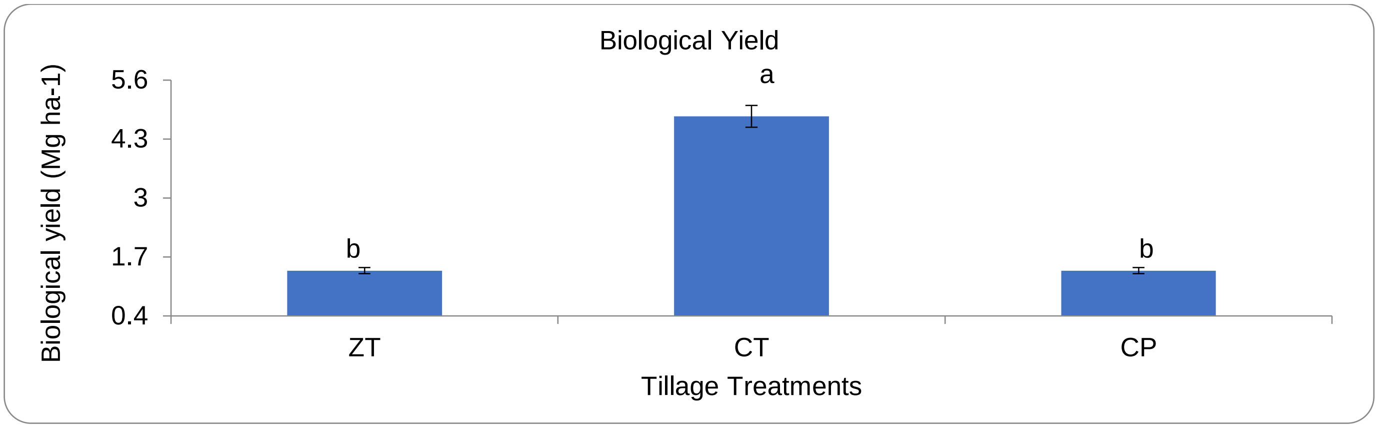

Figure 9: biological yield (Mg ha^{-1}) under different tillage practices during 2019-20 under wheat crop in upland Balochistan.

Grain yield (Mg ha-1)

Grain yield was assessed under various tillage practices (Figure 10), revealing no significant impact of different tillage methods on grain yield. The highest mean grain yield (2.8 Mgha-1) was recorded in fields under conventional tillage, followed by zero tillage (grain yield 2.7 Mgha^{-1}) and chisel plough (grain yield 2.6 Mgha^{-1}) treatments, respectively.

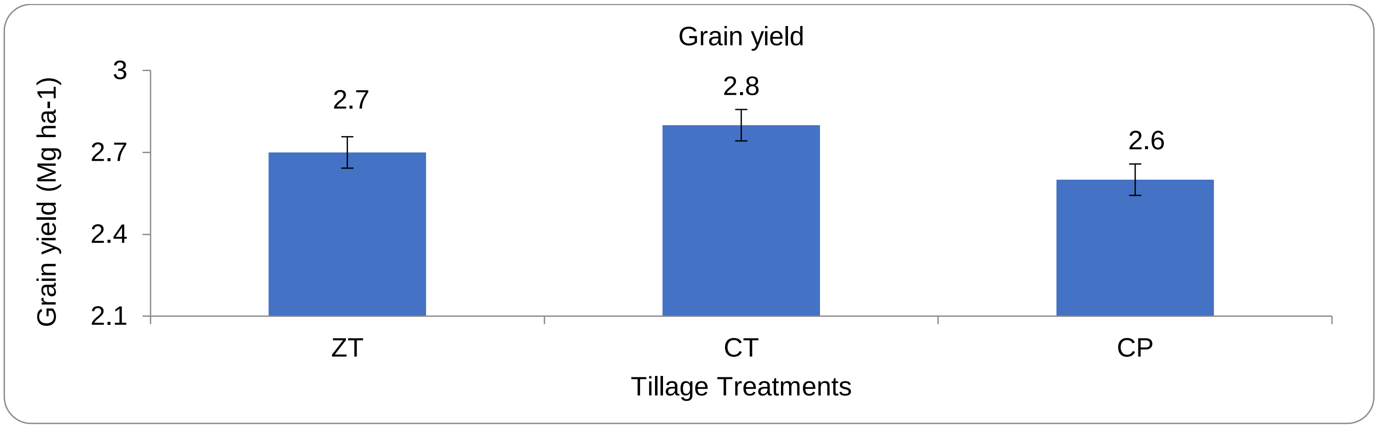

Figure 10. Grain yield (Mg ha^{-1}) under different tillage practices during 2019-20 under wheat crop in upland Balochistan.

DISCUSSION

The decline in pH observed in the ZT treatment could be attributed to soil disturbance, leading to increased microbial

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activity and subsequent release of carbonic acid into the soil, resulting in pH reduction. These results align with those of Tarkalson *et al.* (2006), who reported a nine percent decrease in soil pH under No-Till (NT) compared to CT due to enhanced acidification. Kahlon and Gurpreet (2014) also observed lower pH values in ZT (7.19) compared to CT (7.27) in sandy loam (SL) soils, as well as in low-density sandy loam soils, with ZT (7.34) exhibiting lower pH compared to CT (7.43). However, did not find a significant difference in pH levels between NT and CT practices.

Figure 2 depicts a gradual decrease in EC under Zero Tillage (ZT) attributed to soil compaction, which reduced evaporation rates and mitigated soil salinity. Additionally, the ZT system enhanced soil permeability by mixing saline soil with clear water, thereby lowering soil EC levels. Kahlon and Gurpreet (2014) also observed higher EC levels in conventionally tilled soil (CT) compared to ZT in different soil types (SL and LS).

The lower soil pH observed in zero tillage indicates an increased content of dissolved organic matter, whereas conventional tillage exhibited lower levels of dissolved organic matter. This disparity may be attributed to higher levels of organic material, whose decomposition releases various organic acids, thereby reducing the pH of the soil under zero tillage. Changes in soil organic carbon (SOC) can significantly affect soil fertility and crop production in agricultural environments. Soil organic carbon is a crucial indicator of soil quality. Soil depth generally influences the accumulation of SOC under different tillage systems. Results obtained from surface analysis of 0-6 cm soil depth indicated significant changes under ZT treatment.

Under different tillage systems, soil temperature remained lower during the summer season due to the retention of crop residues, while during the winter season, soil temperature was relatively higher across all treatments. The presence of crop residues acted as a surface cover, reducing heat conductivity and consequently lowering soil temperature during the summer. During the winter season, the reduced impact of solar energy leads to a decline in soil temperature, while ground cover provided by crop residues helps protect against heat loss. Abu-Hamdeh *et al.* (2001) also observed lower soil temperatures during hotter seasons and higher temperatures during colder seasons.

The increasing trend in total soil nitrate nitrogen with residue retention in all tillage systems can be attributed to the incorporation of crop residues into the soil, which increases organic matter content and enhances soil nitrogen fertility. The breakdown of organic matter contributes to increased nitrogen levels in the soil. Crop residues play a crucial role in enhancing soil organic carbon. Our findings are consistent with the results of Shah and Khan (2003).

The increase in phosphorus content in the soil under different cultivation systems and crop residue storage is attributed to organic matter development. It could be due to the release of carbonic acid during the decomposition of plant residues, ultimately leading to an increase in soil phosphorus content. Plant residues also serve as a significant source of microorganisms and can aid in phosphorus extraction. These findings align with (Gangwar *et al.*, 2006), they reported that an increase in biological content enhances soil available phosphorus. Specific growth factors associated with phosphorus include enhanced root development, stem growth, flower improvement, seed production, uniform maturation, early crop maturity, increased nitrogen fixation capacity, crop growth, and disease resistance in plants.

The potassium content was higher in water flow from uncultivated soil compared to the digestive tract, which may be associated with and explained similarly to phosphorus loss. These findings are consistent with previous reports by (Sagervanshi *et al.*, 2014).

The increased biological yield observed in conventional farming may be attributed to favorable soil conditions, including a well-prepared seed bed, improved soil aeration, enhanced water infiltration, and increased nutrient availability and moisture retention. The use of a rotary tiller effectively eliminated weeds, creating an optimal environment for plant growth by maximizing soil moisture and nutrient uptake. Additionally, the application of herbicides suppressed weed emergence, further promoting robust plant growth. Similar effects of achieving high biological yields through effective weed control using various herbicides have been observed in previous studies by D. *et al.* (2007).

CONCLUSION

The soil in Pakistan, including Balochistan, faces significant challenges such as low organic matter, high temperatures, erosion, instability, and alkalinity, leading to stagnation in agricultural productivity and soil fertility. Water scarcity and nutrient depletion also constrain agricultural production. To address these issues, a study was conducted to assess water content and nutrient levels under different tillage systems with various organic amendments. The study involved three treatments: Conventional Tillage (CT), Zero Tillage (ZT), and Chisel Plough (CP), following a Completely Randomized Design (CRD) replicated three times. The findings revealed that variations in organic amendments did not enhance nutrient availability or soil organic matter, affecting chemical properties like pH. The study also observed a negative correlation between soil properties, water content, and nutrients. Based on these results, it is recommended to continue research on water content and nutrient concentration under various tillage systems to improve tillage practices. Expanding studies to cover all areas of Balochistan and extensively using zero tillage and chisel plow systems are also suggested.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this research.

COMPETING OF INTEREST

The authors declare no competing interests.

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