Effect of long term tillage and soil moisture regime on the chemical properties of soil under mung bean-wheat and sorghum-wheat cropping system

Abstract

The field experiment entitled "Effect of long term tillage and soil moisture regime on the chemical properties of soil under mung bean-wheat and sorghum-wheat cropping system" was conducted during 2021-22 on an on-going long term experiment which was started since 2006-07 at Soil Research Farm, Department of Soil Science, CCS HAU, Hisar. The field experiment consisted of three tillage treatments i.e. CT-CT (Conventional tillage in both *kharif* and *rabi* season), ZT-CT (Zero tillage in *kharif* and conventional tillage in *rabi*) and ZT-ZT (Zero tillage in both *kharif* and *rabi* season). The experiment also consisted of two cropping system MW and SW (Mung bean-wheat and sorghum-wheat) and three soil moisture regimes (IW/CPE= 0.60, 0.75 and 0.90) with three replications. The results of the experiments revealed that the chemical properties of the soil were better under MW than SW cropping system. The adoption of long term zero tillage and soil moisture regimes improves the physical, chemical and biological properties of the soil under mung bean and sorghum crop. The pH and electrical conductivity of the soil was highest under CT-CT followed by ZT-CT and the lowest were under ZT-ZT under both the cropping system. The soil organic carbon, nitrogen, phosphorus and potassium content was highest under ZT-ZT followed by ZT-CT and the lowest were under CT-CT under both cropping system. Also, the pH and electrical conductivity of the soil were highest under $M_{0.60}$ followed by $M_{0.75}$ and the lowest were under $M_{0.90}$ under both the cropping system. Similarly, the highest value of soil organic carbon, nitrogen, phosphorus, potassium content in soil was under $M_{0.90}$ followed by $M_{0.75}$ whereas the lowest value was under $M_{0.60}$ under both the cropping system.

Keywords:zero tillage, cropping system, chemical properties, soil moisture regimes, etc.

INTRODUCTION

Tillage is defined as the mechanical manipulation of the soil for the purpose of crop production affecting significantly the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes. Soil is tilled to change soil structure, to kill weed and to manage crop residue. Soil-structure modification is often necessary to facilitate the intake, storage, and transmission of water and to provide a good environment for seeds and roots. Crop residues on the surface must be managed in order to provide conditions suitable for seeding and cultivating a crop (Shah *et al.,* 2011). Tillage operation used to prepare seed beds can be divided into two categories: Primary tillage and Secondary tillage. Tillage that is deeper and more thorough is classified as primary, and tillage that is shallower and sometimes more selective of location is secondary. Primary tillage loosens the soil and mixes in fertilizer or plant material, resulting in soil with a rough texture. Secondary tillage produces finer soil and sometimes shapes the rows, preparing the seed bed. In reduced tillage 15 to 30% of crop residue was left on the soil during the critical erosion period. Whereas in intensive tillage, less than 15% crop residue was left on the soil. This type of tillage is often referred to as conventional tillage, but as conservational tillage is now more widely used than intensive tillage (Walter and Jasa, 2000) it is often not appropriate to refer to this type of tillage as conventional. Another form of tillage is conservation tillage in which at least 30% of crop residue was left on the soil surface during the critical soil erosion period. This slows water movement, which reduces the amount of soil erosion. Conservation tillage, especially no-tillage, results in accumulation of crop residues on the soil surface and reduces nutrient distribution in the soil profile (Jakab *et al.,* 2017). Soil tillage is one of the important factor which affects the physio-chemical as well as biological properties of the soil. Changes in chemical properties are dependent mainly on the organic matter content of the soils (Sokolowski *et al.*, 2020). Tillage affects aeration and thus the rate of organic matter decomposition. Bravo *et al.* (2007) reported that in no till system, the contact between the P fertilizer and soil is decreased, which result in lower P fixation and an increase in P liability in the surface soil. This fact can also be favoured by the greater organic matter content found in the no-till soil surface, because the organic compounds are able to bind to the soil colloids, decreasing P fixation, especially in the oxide rich soils, such as the Oxisols and Plinthosols, which have high capacity to retain P (Pinto *et al.,* 2013). Khattak *et al.* (2004) reported that tilled plot have lower bulk density, high soil moisture and high cumulative infiltration rate which enhance the crop yield by 15%. Soil moisture regime refers to the presence or absence either of ground water or of water held at a tension of less than 1500 kPa in the soil or in specific horizons during periods of the year. Water held at a tension of 1500 kPa or more is not available to most mesophytic plants. The availability of water is also affected by dissolved salts. If a soil is saturated with water that is too salty, it is considered salty rather than dry. Water is an excellent solvent for most of the plant nutrients. It serves major four functions in plant: it is the major component of plant protoplasm, it is essential for photosynthesis; it is the solvent in which nutrients moves and it provide turgidity to plant (Chadha *et al.*, 2019). In fact, the soil water is a great regulator of physical, chemical and biological activities in the soil. The immobilization and mineralization of nitrogen and phosphorus in the soil is controlled by microorganism which required an optimum amount of soil moisture (Cookson *et al.,* 2002). The urea which applied to the soil is hydrolysed by the urease enzyme whose activity is depends on the soil moisture (Agehara and Warncke, 2005). The activity of urease is generally higher at field capacity and decrease as moisture decreases. The availability of phosphorus is higher at optimum moisture range and decrease as soil moisture decreases and increases. Phosphorus in soil moves primarily by diffusion through pores filled with water. Thus, when soil moisture content is low, P mobility also decreases (Osakabe *et al.*, 2014). (Cantarella *et al.,* 2018) The quantity of moisture present in soil also affects the decomposition rate soil organic matter. Soil moisture also affects soil K availability and diffusive flux, as well as K+ uptake via its effects on root growth and activity (Zeng and Brown, 2000). Increasing soil moisture increased the diffusive K+ flux in the soil and the efficiency of applied K. Low soil moisture restricted K+ diffusion and K+ uptake as a result of increased impedance at low soil moisture. Therefore, keeping the above facts in mind the present experiment was conducted .

MATERIAL AND METHODS

Experiment site characteristics

The field experiment was conducted from the on-going experiment, which was started since 2006-07 at Soil Research Farm, Department of Soil Science, CCS HAU, Hisar. Hisar is the administrative headquarters of Hisar district in the state of Haryana in northwestern India. Hisar is located at 29.09°N 75.43°E in western Haryana. It has an average elevation of 215 m above mean sea level. The soil of the experimental site was sandy loam in texture, slightly alkaline, low in organic carbon, low in available nitrogen, medium in available phosphorus and high in available potassium (Phogat, 2019). The main characteristics of climate of experiment site are dryness, extremes of temperature, and scanty rainfall. The maximum daytime temperature during the summer varies between 40 and 46 °C. During winter, its ranges between 1.5 °C and 4 °C. Relative humidity varies from 5 to 100%. The average annual rainfall is around 429 mm, most of which occurs during July and August. Dew is observed in December and January. Hot winds, locally known as loo, are strong and frequent from May to July.

Treatments and experimental design

The experiment was carried out in two main plots treatments viz. (i) Mungbean-wheat and (ii) Sorghum-wheat cropping system. These main plots were split in to sub plots receiving three different tillage practices i.e (i) Conventional tillage in both *kharif*&*rabi* seasons (CT-CT), (ii) conventional tillage in *kharif*& zero tillage in *rabi* seasons (CT-ZT) and, (iii) zero tillage in both *kharif*&*rabi* seasons (ZT-ZT). These sub-plots were further split into sub-sub plots receiving different soil moisture regimes viz. IW/CPE =0.60, 0.75 and 0.90 to each sub-plots. The experiment was layout in split plot design and size of each plot was 35m x 8m. Replications were three of each treatments and in conventional tillage field was ploughed during both the season. In second treatment plots, the fields were ploughed during *kharif* only and no tillage was done during *rabi* season. In zero tillage plots, no tillage was done during both the seasons. The residues of the preceding crop were removed in conventional tillage. In zero tillage practice plots, the crop was harvested and no tillage was done for preparation of seed bed for the succeeding crop, and zero till machine was used for sowing the crop.

Soil sampling and measurement

The soil sample were collected from 0-15 cm depth after the harvest of the crop in the end of the *kharif* season. Three samples from each of the plots were collected with the help of augur and khurpi and made a composite sample by mixing these samples. These composite sample were brought to the laboratory in the sampling bag, dried in shade, grind, sieved (2mm) and finally stored in the sampling bag with proper labeling. Soil pH was determined using a pH meter (Jackson 1967) fitted with a calomel glass electrode after equilibrating the soil with distilled water for half an hour using appropriate buffer. The electrical conductivity (EC) of soil samples was determined in 1:2 soil : water suspension using an electrical conductivity meter after equilibrating the samples with intermittent mixing. Total soil organic carbon was determined using Walkley and Black (1934) wet digestion method. Available nitrogen in soil was determined by micro-kjeldahl method (Subbiah and Asija, 1956) using alkaline $KMnO_4$. The available phosphorus was determined using Olsen‟s P method (Olsen *et al.*, 1954) using 0.5 M $NaHCO_3$ pH 8.5. The available potassium was extracted with neutral 1N ammonium acetate and determined by flame-photometer.

STATISTICAL ANALYSIS

The data generated in both laboratory and field experiments were statistical analysed as per the design of experiment. Treatment effects were compared with CD (0.05). Statstical analysis was done in consultation with Department of Mathematics and Statistics, CCS Haryana Agricultural University, Hisar.

RESULTS

Soil pH

The pH of soil was lowest under zero tillage and highest under conventional tillage under both cropping system (Table. 1). The pH of the soil was non-significantly affected by the cropping system as well as tillage practices. The soil under ZT-ZT had mean pH of 7.40 and 7.97 whereas under CT-CThad 8.10 and 8.08 under mung bean-wheat and sorghum-wheat cropping system respectively. Also, the soil under ZT-CT resulted the pH of 8.05 and 8.04 under mung bean-wheat and sorghum-wheat. Similarly, the effect of moisture regimes on the pH of soil was also found non-significant in both cropping pattern. However it was observed the pH of the soil was decreased as the moisture regimes increased. The moisture regimes $M_{0.60}$ had highest mean pH value of 8.03 and 8.04 whereas lowest mean pH of 7.45 and 8.00 was observed in $M_{0.90}$ under mung bean-wheat and sorghum-wheat cropping system respectively. The soil which was under $M_{0.75}$ soil moisture regimes had the mean pH value of 7.91 and 8.02. Also, the combined effect of cropping system and tillage; cropping system and moisture regimes; and cropping pattern, tillage and moisture regime on the pH of soil was found to be non-significant.

Electrical conductivity

The EC of the soil was significantly affected by the tillage practice under both the cropping system (Table. 2). The value of EC was observed highest under CT-CT in both the season. The mean value of EC was 0.580 and 0.551 dSm^{-1} under CT-CT which was significantly higher than which was under ZT-CT and ZT-ZT. Also the soil under ZT-CT had mean value of EC 0.527 and 0.563 dSm^{-1} which was significantly higher than ZT-ZT under both cropping pattern. The lowest (0.512 and 0.540 dSm^{-1}) mean value of EC was under ZT-ZT in both the cropping system respectively. Similarly, the moisture regimes significantly affect the EC of soil under both cropping system. The lowest mean value of EC (0.485 and 0.530 dSm^{-1}) was observed under $M_{0.90}$ under both cropping system respectively. It was observed that the EC of the soil decreased as the moisture regime increased.

$M_{0.75}$have mean value of EC 0.539 and 0.572 dSm^{-1} which was found to be significantly higher than $M_{0.90}$ in both cropping system. The highest value (0.565 and 0.581 dSm^{-1}) of EC was observed in $M_{0.60}$ under both cropping system which was statistically at par with $M_{0.75}$. However, the overall effect of cropping system; cropping system and moisture regimes; tillage and moisture regimes; cropping system, tillage and moisture regimes on EC was found non-significant.

Soil organic carbon

The organic carbon was reported significantly higher under mung bean-wheat than sorghum-wheat cropping system (Table. 3). However, the soil under ZT-ZT recorded highest (0.77 and 0.75 %) mean value of organic carbon which was significantly higher than ZT-CT and ZT-ZT under both cropping system. The lowest (0.69 and 0.67 %) mean value of organic carbon was observed under CT-CT under both cropping system. Also, the soil under ZT-CT mean value of organic carbon was 0.74 and 0.72 % under both cropping system respectively which was significantly higher than CT-CT. Similarly, long term effect of moisture regime also significantly effect the organic carbon of soil. It was observed that the organic carbon of soil increased as soil moisture regimes increased. The highest mean value of organic carbon was observed under under $M_{0.90}$ (0.76 and 0.74 %) under both system respectively. The organic carbon in the soil under $M_{0.90}$ was found significantly higher than $M_{0.75}$ and $M_{0.60}$. Also, the soil under $M_{0.75}$ moisture regimes have mean value of soil organic carbon 0.73 and 0.71 % in both cropping system which was significantly higher than $M_{0.60}$ whereas the lowest mean value of soil organic carbon (0.71 and 0.69 %) was observed under $M_{0.60}$. However, the combined effect of cropping system and tillage; cropping system and soil moisture regimes; cropping system, tillage and soil moisture regimes was found non-significant.

Available nitrogen

The available nitrogen content was significantly affected by the cropping system, tillage and soil moisture regimes (Table. 4). The nitrogen content in the soil under mung bean-wheat cropping system was reported higher than sorghum-wheat. The mean value of available nitrogen was reported highest (168.12 and 154.21 kg ha^{-1}) under ZT-ZT under both cropping system. This value of available nitrogen was significantly higher than available nitrogen which was under ZT-CT and ZT-ZT. The lowest mean value of available nitrogen content (134.53 and 129.86 kg ha^{-1}) was observed under CT-CT which was also significantly lower than ZT-CT whereas it was 151.72 and 140.89 kg ha^{-1} in the plots which was under ZT-CT. However, among soil moisture regimes it was observed that the available nitrogen content was significantly increased as the soil moisture regimes increased. Soil moisture regime $M_{0.90}$ recorded the highest (173.85 and 164.75 kg ha^{-1}) mean value of available nitrogen in both cropping system whereas lowest (132.52 and 125.00 kg ha^{-1}) mean value was reported under $M_{0.60}$. The available nitrogen in the soil which were under $M_{0.90}$ was found to be significantly higher than $M_{0.75}$ and $M_{0.60}$. Also, the soil under soil moisture regime $M_{0.75}$ gave available nitrogen mean value of 147.99 and 138.20 kg ha^{-1} in mung bean-wheat and sorghum-wheat cropping system respectively which was significantly higher than mean value of available nitrogen of the soil which was under $M_{0.60}$. The combined effect of cropping system and soil moisture regime; tillage and soil moisture regimes was reported non-significant whereas the effect of cropping system, tillage and soil moisture regimes was significant. In both cropping system, the soil under ZT-ZT and $M_{0.90}$ had the highest value of available nitrogen was 194.30 kg ha^{-1} which was significantly higher than rest of the treatment whereas the lowest (112.97 kg ha^{-1}) value was in CT-CT and $M_{0.60}$ which was also significantly lower than rest of the treatment.

Available phosphorus

The cropping system and tillage significantly affect the available phosphorus status of soil (Table. 5). The mean value of available phosphors status was highest (23.9 and 20.7 kg ha^{-1}) in the under ZT-ZT which was found to be significantly higher than ZT-CT and CT-CT followed by ZT-CT i.e. 21.6 and 18.3 kg ha^{-1} and it was lowest (20.3 and 16.3 kg ha^{-1}) in CT-CT in both the cropping system. The available phosphorus status under ZT-CT was also found significantly higher than the CT-CT. However, it was reported that the available phosphorus status was significantly higher in mung bean-wheat cropping system as compared to sorghum-wheat. Similarly, the effect of soil moisture regimes was also found significant on the available phosphorus status of soil. The available phosphorus content of soil increased as the soil moisture regime increased. The mean value of available phosphorus (23.5 and 19.3 kg ha^{-1}) was found highest in $M_{0.90}$ which was significantly higher than $M_{0.75}$ and $M_{0.60}$ and lowest in $M_{0.60}$ (20.8 and 17.6 kg ha^{-1}). The mean value of available phosphorus reported under $M_{0.75}$ was 21.5 and 18.5 kg ha^{-1} which was found to be significantly higher than the $M_{0.60}$ under both cropping system. The interactive effect of cropping system and tillage was found to be non-significant whereas the interactive effect of cropping system and soil moisture regimes; tillage and soil moisture regimes; cropping system, tillage and soil moisture regimes was significant. In both cropping system, the soil under ZT-ZT and $M_{0.90}$ had the highest value of available phosphorus which was 26.4 kg ha^{-1} that was significantly higher than rest of the treatment except CT-CT and $M_{0.75}$ whereas the lowest (15.5 kg ha^{-1}) value was in plot CT-CT and $M_{0.60}$ which was also significantly lower than rest of the treatment except CT-CT and $M_{0.75}$.

Available potassium

The available potassium was significantly affected by the cropping pattern and tillage practices (Table. 6). The highest mean value of available potassium was (398.23 and 357.90 kg ha^{-1}) reported under ZT-ZT which was significantly higher than ZT-CT and CT-CT. Also, the mean value of available potassium (322.69 and 283.22 kg ha^{-1}) which under ZT-CT was also found significantly higher than CT-CT. The lowest value of available potassium was 281.32 and 275.18 kg ha^{-1} under CT-CT. Similarly, the soil moisture regimes also affects the available potassium of the plots under both cropping system. The available potassium content was significantly increased as the soil moisture regimes increased. The highest mean value of available potassium (339.50 and 301.29 kg ha^{-1}) was under soil moisture regime $M_{0.90}$ which was significantly higher than $M_{0.75}$ and $M_{0.60}$. The lowest mean value of available potassium was 325.88 and 290.60 kg ha^{-1} under $M_{0.60}$. The soil under $M_{0.75}$ have available potassium 334.00 and 297.89 kg ha^{-1} which was significantly higher than the mean value of available potassium under $M_{0.60}$. However, the combine effect of cropping system and tillage; cropping system and soil moisture regimes on the available potassium was non-significant while the effect of tillage and soil moisture regimes; cropping system, tillage and soil moisture regimes was found significant.The highest available potassium value was 405.98 kg ha^{-1} which was under ZT-ZT and $M_{0.90}$ which was found statistically at par with treatment ZT-ZT and $M_{0.75}$; ZT-ZT and $M_{0.60}$ and significantly different with the rest of treatment whereas the lowest value of available potassium was 223.66 kg ha^{-1} in the plot which was under CT-CT and $M_{0.60}$ treatment which significantly different from rest all the treatment.

Table 1. Effect ofmoisture regimes and tillage on the pH of soil under mung bean-wheat and sorghum-wheat cropping system.

Moisture Regime (IW/CPE)	Mung bean-Wheat			Mean	Sorghum-Wheat			Mean
	ZT-ZT	ZT-CT	CT-CT		ZT-ZT	ZT-CT	CT-CT	
$M_{0.60}$	7.89	8.01	8.27	8.03	8.07	8.04	7.94	8.04
$M_{0.75}$	7.73	8.09	7.99	7.91	7.94	8.07	8.13	8.02
$M_{0.90}$	7.05	8.05	8.09	7.45	7.92	8.03	8.12	8.00
Mean	7.40	8.05	8.10		7.97	8.04	8.08	
CD (p=0.05)	A = NS, B = NS, C = NS, AXB = NS, AXC= NS, BXC= NS, AXBXC = NS							

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

Table 2. Effect of moisture regimes and tillage on the EC (dSm^{-1}) of soil under mung bean-wheat and sorghum-wheat cropping system.

Moisture Regime (IW/CPE)	Mung bean-Wheat			Mean	Sorghum-Wheat			Mean
	ZT-ZT	ZT-CT	CT-CT		ZT-ZT	ZT-CT	CT-CT	
$M_{0.60}$	0.550	0.553	0.593	0.565	0.537	0.587	0.620	0.581
$M_{0.75}$	0.513	0.547	0.557	0.539	0.570	0.570	0.577	0.572
$M_{0.90}$	0.473	0.480	0.503	0.485	0.513	0.533	0.543	0.530
Mean	0.512	0.527	0.551		0.540	0.563	0.580	
CD (p=0.05)	A = NS, B = 0.008, C = 0.035, AXB = NS, AXC= NS, BXC= NS, AXBXC = NS							

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

Table 3. Effect of moisture regimes and tillage on the soil organic carbon (%) of soil under mung bean-wheat and sorghum-wheat cropping system.

Moisture Regime	Mung bean-Wheat			Mean	Sorghum-Wheat			Mean
	ZT-ZT	ZT-CT	CT-CT		ZT-ZT	ZT-CT	CT-CT	

(IW/CPE)								
$M_{0.60}$	0.74	0.71	0.68	0.71	0.72	0.68	0.64	0.69
$M_{0.75}$	0.77	0.74	0.69	0.73	0.75	0.71	0.67	0.71
$M_{0.90}$	0.79	0.77	0.71	0.76	0.77	0.74	0.70	0.74
Mean	0.77	0.74	0.69		0.75	0.72	0.67	
CD (p=0.05)	A = 0.010, B = 0.015, AXB = NS, C = 0.015, AXC= NS, BXC= NS, AXBXC=NS							

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

Table 4. Effect of moisture regimes and tillage on the available nitrogen (kg ha^{-1}) of soil under mung bean-wheat and sorghum-wheat cropping system.

Moisture Regime (IW/CPE)	Mung bean-Wheat			Mean	Sorghum-Wheat			Mean
	ZT-ZT	ZT-CT	CT-CT		ZT-ZT	ZT-CT	CT-CT	
$M_{0.60}$	146.58	131.08	119.91	132.52	139.22	122.83	112.97	125.00
$M_{0.75}$	163.47	149.70	130.80	147.99	151.83	137.32	125.44	138.20
$M_{0.90}$	194.30	174.37	152.88	173.85	171.57	162.53	151.16	161.75
Mean	168.12	151.72	134.53		154.21	140.89	129.86	
CD (p=0.05)	A = 5.32, B = 2.13, C = 2.31, AXB = 3.01, AXC= NS, BXC= NS, AXBXC=5.66							

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

Table 5. Effect of moisture regimes and tillage on the available phosphorus (kg ha^{-1}) of soil under mung bean-wheat and sorghum-wheat cropping system.

Moisture Regime (IW/CPE)	Mung bean-Wheat			Mean	Sorghum-Wheat			Mean
	ZT-ZT	ZT-CT	CT-CT		ZT-ZT	ZT-CT	CT-CT	
$M_{0.60}$	21.8	20.9	19.8	20.8	19.9	17.4	15.5	17.6
$M_{0.75}$	23.3	21.2	20.0	21.5	20.9	18.2	16.3	18.5
$M_{0.90}$	26.4	22.6	21.1	23.5	21.3	19.4	17.1	19.3
Mean	23.9	21.6	20.3		20.7	18.3	16.3	
CD (p=0.05)	A = 0.65, B = 0.51, C = 0.39, AXB = NS, AXC= 0.56, BXC= 0.69, AXBXC=0.92							

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

Table 6. Effect of moisture regimes and tillage on the available potassium (kg ha^{-1}) of soil under mung bean-wheat and sorghum-wheat cropping system.

Moisture Regime (IW/CPE)	Mung bean-Wheat			Mean	Sorghum-Wheat			Mean
	ZT-ZT	ZT-CT	CT-CT		ZT-ZT	ZT-CT	CT-CT	
$M_{0.60}$	390.48	312.65	274.52	325.88	365.50	282.65	223.66	290.60
$M_{0.75}$	398.22	324.66	279.12	334.00	368.00	278.51	247.15	297.89
$M_{0.90}$	405.98	330.75	281.32	339.50	340.21	288.49	275.18	301.29
Mean	398.23	322.69	278.32		357.90	283.22	248.66	
CD (p=0.05)	A = 6.09, B = 5.32, C = 5.96, AXB = NS, AXC= NS, BXC= 10.33, AXBXC = 14.61							

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

DISCUSSION

Soil pH

The pH of the soil was higher under sorghum-wheat cropping system as compared to mung bean-wheat cropping system. This might be due to low C:N ratio of the mung bean residue which decompose easily and release more acid which decrease the pH of the soil under mung bean-wheat cropping system. Kumar *et al.* (2022) also reported decrease in the pH of soil under maize-chickpea cropping system as compared to maize-wheat. The mean value of pH was highest under ZT-ZT followed by ZT-CT and the lowest was under CT-CT. This might be due to accumulation of organic matter in soil which release organic acids on decompositionthat ultimately lowers the pH of the soil in zero tillage. Neugschwandtner *et al.* (2014) and Kumar *et al.* (2022) also reported higher pH value under conventional tillage in field experiments over zero tillage. Also, the mean value of pH was higher under $M_{0.90}$ followed by $M_{0.75}$ and lowest under $M_{0.60}$. The mean value of pH decreased as the value of soil moisture regimes increased which may be due to more favourable conditions for decomposition of organic matter which reduced the pH value. Punita and Sagar (2011) and Vogel *et al.* (2023) also found decrease in the pH of the soil with increased moisture content under different soil moisture regimes in their field experiments.

Electrical conductivity

The EC of the soil was higher under sorghum-wheat cropping system as compared to mung bean-wheat cropping system. The highest mean value of EC was observed under CT-CT followed by ZT-CT and the lowest mean value was under ZT-ZT under both cropping system. The lower value of EC under zero tillage might be due to downward movement of the salt to the deeper layer with water infiltration. Chatterjee and Lal (2009), Gholami *et al.* (2014) and Kahlon and Gurpreet (2014) also reported lower value of EC in the soil under zero tillage in their experiments. Also, the effect of soil moisture regimes on the EC of soil in the plots was significant and the value of EC increased as the soil moisture regimes increased. The highest mean value of EC was under $M_{0.60}$ followed by $M_{0.75}$ and the lowest mean value was under $M_{0.90}$ under both the cropping system. The decrease in the EC of soil with increasing soil moisture regime might be due to dilution of the salt with increasing moisture and which leach down to deeper layer with downward moment of water. Chang *et al.* (2019) and Yang *et al.* (2019) also reported decrease in the EC of soil with increase in the soil water content.

Soil organic carbon

The organic carbon content of the soil was significantly higher under mung bean-wheat cropping system than sorghum-wheat which might be due to narrow C:N ratio of the legumes which decompose easily and increase the SOC content of the soil. Cogreves *et al.* (2015) also reported higher value of SOC under legumes crop under different cropping systems in their findings. The highest mean value of organic carbon was under ZT-ZT followed by ZT-CT whereas the lowest mean value was under CT-CT under both the cropping system. The value of organic carbon was significantly higher under ZT-ZT might be due to less disturbance of soil which increase the organic matter content as well as root mass of the soil. The lower value of organic carbon under CT-CT was due to fast oxidation of the organic matter of the soil which decrease the organic carbon of the soil. Kahlon and Gurpreet *et al.* (2014) and Neugschwandtner (2014) reported higher value of organic carbon of the soil under zero tillage as compared to conventional tillage in their field experiments. Also, under different soil moisture moisture regimes the organic carbon was highest under $M_{0.90}$ whereas the lowest value was under $M_{0.60}$ under both the cropping system. The increase in the soil organic carbon with increase in soil moisture regimes might be due to favourable conditions for the microbes to decompose the organic matter which increase the soil organic carbon. Yun *et al.* (2019), and Fang *et al.* (2022) also noticed an increase in the soil organic carbon with increase in the soil moisture content in their field experiments.

Available nitrogen

The available nitrogen content was significantly higher under mung bean-wheat cropping system as compared to sorghum-wheat which was might be due to biological nitrogen fixation done the the nodules present on the roots of mung bean crop which increase the nitrogen content of the soil. Mohammad *et al*. (2012) reported higher nitrogen content under legume crop cropping system over cereals cropping system in their experiments. Also, higher number of N-fixing bacteria were recorded by Kumar *et al.* (2023) under zero tillage mung bean as compared to zero tillage wheat in their experiment. The highest mean value of available nitrogen was under ZT-ZT followed by ZT-CT whereas the lowest mean value was under CT-CT under both the cropping system. This was might be due to higher organic matter and less disturbance of soil which increase the soil aggregation and increase the amount of nitrogen and carbon storage in soil. The higher amount of available nitrogen under zero tillage was also reported by Alam *et al.* (2014), Kahlon and Gurpreet *et al.* (2014) and Neugschwandtner *et al.* (2014) in their field experiments. Similarly, the available nitrogen content of the soil increases significantly with the increase in the soil moisture regimes. This might be due to more favourable condition for the microorganism which enhance the mineralization of the organic nitrogen and increase the available nitrogen of the soil. The highest mean value was under $M_{0.90}$ followed by $M_{0.75}$ and lowest was under $M_{0.60}$ under both the cropping system. Zhang and Wienhold (2002), Abera *et al.* (2012) and Uddin *et al.* (2021) also noticed an increase in the available nitrogen status of soil with increasing moisture in their findings.

Available phosphorus

The available phosphorus content of the soil under mung bean-wheat cropping system was significantly higher than sorghum-wheat cropping system. The roots of legumes secrets the exudates that increase the available phosphorus content of the soil was one of the reason for higher phosphorus content under mung bean-wheat cropping system (Li *et al*, 2015). Also, higher organic matter was observed under mung bean crop as compared to sorghum crop which increase available phosphorus under mung bean-wheat cropping system. The mean value available phosphorus was highest under ZT-ZT followed by ZT-CT and lowest mean value was under CT-CT under both the cropping system. Higher organic matter content under the zero tillage which decompose and release the inorganic phosphorus might be the reason for higher phosphorus under zero tillage. Higher value of available phosphorus under zero tillage was also found by Gholami *et al.* (2014), Kahlon and Gurpreet *et al.* (2014) and Neugschwandtner *et al*. (2014). Similarly, the mean value of available phosphorus was highest under $M_{0.90}$ followed by $M_{0.75}$ and lowest mean value was under $M_{0.60}$ under both the cropping system. The available phosphorus content of the soil increased with the increase in the soil moisture regimes. This might be due to more conducive environment which increase the microbial activities which mineralized the organic phosphorus to inorganic and increase the available phosphorus. He *et al.* (2005), Song *et al.* (2012) and Suriyagoda *et al.* (2014) also observed higher available phosphorus under higher soil moisture.

Available potassium

The available phosphorus content of the soil was significantly higher under mung bean-wheat cropping system than sorghum-wheat. The highest mean value of available potassium was observed under ZT-ZT followed by ZT-CT and the lowest mean value was under CT-CT under both the cropping system. Also, the available potassium content increased significantly with the increase in the soil moisture regimes. The highest mean value of available potassium was observed under $M_{0.90}$ followed by $M_{0.75}$ and the lowest mean value was in the plots that was under $M_{0.60}$ under both the cropping system. Similar to nitrogen and phosphorus, the higher availability of potassium under zero tillage may be due to addition of more organic matter in the form of crop residue which is a source of potassium. Lopez-fando and Pardo (2009) and Neugschwandtner *et al.* (2014) also found higher available potassium under zero tillage treatments. The available potassium content of the soil in the plots increased significantly with the increase in the soil moisture regimes. This might be due to the increase in the tortuosity and impedance factor with high soil moisture. Gholami *et al.* (2014) and Kahlon and Gurpreet (2014) and Villamil and Nafziger (2015) observed significantly higher exchangeable potassium under zero tillage than conventional tillage in continuous corn cropping system.

CONCLUSION

The results of the present experiment concluded that the long term zero tillage and optimum soil moisture regimes improves the chemical properties of the soil as compared to conventional tillage under mung bean-wheat and sorghum-wheat cropping system. The results also show that the legume based cropping system is better than non-legume based cropping system. The results also concluded that long term zero tillage and optimum soil moisture regime decreases the pH and electrical conductivity of the soil whereas the soil organic carbon and available nutrient status were increased than conventional tillage under mung bean-wheat and sorghum-wheat cropping system.

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