INFLUENCE OF TILLAGE INTENSITY AND IRRIGATION ON SOIL PROPERTIES, WATER CONSERVATION AND YIELD OF WHEAT

ABSTRACT

An experiment was conducted at during winter season, from 26 November 2019 to 23 March 2020 to evaluate the influence of tillage intensity and irrigation on soil properties, water conservation and yield of wheat (cv. Prodip). The experiment was laid out in a split-plot design with three tillage practices arranged as main plots and four irrigation practices in the sub-plots and replicated thrice. The tillage operations were: T_1 = 1 passing of a power tiller, T_2= 2 passing of a power tiller and T_3= 3 passing of a power tiller and the irrigation treatments were: I_0= No irrigation, I_1=1 irrigation at crown root initiation (CRI) stage i.e., at 17 days after sowing (DAS), I_2= 2 irrigation, at crown root initiation (CRI) stage and another at jointing stage i.e., at 54 days after sowing (DAS) and I_3= 3 irrigation, at crown root initiation (CRI) stage, another at jointing stage and the final irrigation at booting stage i.e. at65 days after sowing (DAS). The unit plot size was 4m×2.5 m. Fertilizers were applied @ 100 kg N ha^{-1}, 18 kg P ha^{-1}, 50 kg K ha^{-1}, 20 kg S ha^{-1}, 3 kg Zn ha^{-1} and 1 kg B ha^{-1}. The highest soil moisture (35.52%) was observed with T_3 and lowest (33.32%) with T_1 treatments over the growth period. In case of irrigation, I_3 recorded the highest soil moisture (38.40%) and I_0 showed the lowest (28.44%). The maximum (1.51 g cm^{-3}) and minimum (1.32 g cm^{-3}) bulk densities were obtained from T_1 and T_3 treatments, respectively and for irrigation treatments bulk densities were 1.50 g cm^{-3} (I_0) and 1.30 g cm^{-3} (I_3), respectively. The highest air filled porosity (76.94%) was recorded under T_3 treatment and lowest values ofair filled porosity (76.86%) and (74.68%) were recorded in I_0 treatment. The highest and lowest soil organic matter contents (1.87% and 1.09%) were found respectively in T_1 and T_3 under tillage treatments and in I_0 (1.84%) and I_3 (1.18%) under irrigation treatments. The total N content of soil exactly followed the organic matter result. The plant height, effective tillers $hill^{-1}$, spike length and 1000grain weight, the highest result was measured with T_3 and I_3 treatments and the minimum with T_1 and I_0 treatments. These plant parameters had reflected the grain yield showing the highest yield by T_3 (3.74 t ha^{-1}) and I_3 (4.26 t ha^{-1}) treatments and the lowest yield by T_1 (3.32 t ha^{-1}) and I_0 (2.68 t ha^{-1}). The maximum and minimum straw yields (6.98 t ha^{-1} and 6.29 t ha^{-1}) were found in $T_3$and T_1 treatments. Considering the irrigation, the highest (7.29 t ha^{-1}) and lowest (5.78 t h^{-1}) straw yield were obtained in I_3 and I_0 treatments. Overall results indicate that tillage and irrigation helped in improving soil aeration, soil moisture, bulk density, organic matter decomposition and nutrient availability, which in turn had impacted the increased wheat yield.

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CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's leading cereal crops. Wheat ranks first both in acreage and production of the world FAO and UNDP, 1988). About one-third of the total population of the world live on it (Honsan *et al.* 1982). In some countries, it is the main food item. In Bangladesh, wheat is the second most important staple food crop next to rice (Razzaque and Hossain, 1991). Bangladesh produces 9, 72, 085 metric ton of wheat per annum from 923000 acres of land. Human get more nutrients from wheat than from any other cereal crops. As compared to rice, wheat grains are richer in food value with 14.7% protein, 2.1% fat, 2.1% mineral matter and 78.11% starch (Peterson, 1965). Wheat has grained much popularity in Bangladesh for its nutritive value and diversified use especially in bakery purpose. It plays a vital role in the national economy to reduce the gap between food production and import of food.

Bangladesh is an over populated country and the food production of this country is not increasing that much to keep pace with that of population growth. In order to meet the demand for the increasing that much population, wheat production need to be increased. In Bangladesh, wheat yield is low compared to the other wheat growing countries of the world. In Holland, United Kingdom (UK), France and Norway the average yield of wheat is 7.5, 6.2, 5.9 and 4.8 t ha^{-1}, respectively. But in Bangladesh, it is only 2.1 t ha^{-1} (FAO, 1999). Wheat yield can be increased up to 6.4 t ha^{-1} in our country. The scope of increasing cultivated area is limited in Bangladesh due to occupation of land for accommodating ever- growing population. The only option to increase total production of wheat is to find out the ways and means to increase the yield on unit area basis.

The low yield of wheat in Bangladesh is attributed to a number of reasons, viz. the traditional cultural practices, poor field management, lack of using proper plant densities, late planting, unavailability of quality seed, use of local cultivars, climatic hazards, intensive cropping and non-replenishment of soil nutrients, inadequate fertilizer use, irregular irrigation and fertilizer management including splitting of N application. Further, the yield of wheat in the farmar's field is much lower than that of the research managed plots (Anon 1990 a).

Yield of wheat is influenced by the interaction of a number of the other factors including soil fertility, climatic condition, variety, tillage, intercultural operations etc. Tillage is considered to be the oldest, most fundamental farm activity and first step for crop production. Tillage is the mechanical manipulation of soil, to optimize the condition for seed germination, emergence and seedling establishment (Abodorrahmani *et al.,* 2005). The magnitude of tillage effect varies with use of tillage implements. Power tiller is used for deep ploughing, sub soiling and rotating the soil to make the soil better than the country plough. Different tillage operations may influence the physical properties of soil such as soil bulk density, soil moisture, soil porosity and air filled porosity (Vulloid *et al.,* 2006, Ozpnar and Clay, 2005). Tillage also affects the physical and chemical properties of the soil by affecting the aggregates size distribution which is turn affect plant growth (Dexter, 1999). Tillage operations are necessary to remove the weeds and prevent crust formation. Different tillage operations incorporate organic matter into soil which creates improved physical condition of soil that brings out better nutrients and water relations and has a key role in growth and development of roots by controlling air and water movement to a certain extent and nutrient supply of the roots of the growing plants. Tillage intensity decreases the bulk density and increases the soil porosity and infiltration rate. So, soil becomes permeable, aerated and have a good physical condition for crop production. Moreover, power tiller is used to deep tillage practices which help to make easy uptake of nutrients and water by the root system from the deeper soil depths efficiency and consequently increased root growth and density. Thus, the more tillage intensity favors root growths as well as crop yield compared to less tillage intensity. Moreover, the advantages of different tillage systems are moisture conservation, reduced soil erosion, less labour and energy requirement, more timely planting of crops and increased intensity of land use.

The climate of Bangladesh is favorable for wheat production during Rabi season and the duration extends from the month of November to March. The rainfall during Rabi season is characteristically scanty and uncertain. So, the Rabi season in Bangladesh is dry and as such, the inadequate soil moisture in this season limits the area of fertilizer, especially results in decreased grain yield. About 24.84% of the total yield cultivated area in the country is irrigated and rest of the area is cultivated under rainfed condition (BBS, 2007). Irrigation at optimum level is one of the most important tools for boosting up the yield of wheat (Razzaque *et al.*. 1992). Irrigation frequency has a significant influence on growth and yield of wheat. Yields of irrigated and non-irrigated wheat lie between 1.75 to 2.75 and 3.50 to 6.60t ha^{-1}, respectively (Ahmed Haque, 1987). But as a matter of fact, irrigation water in Bangladesh is a limited resource and hence irrigation practices must be rationalized for high water use efficiency. Irrigation water plays a vital role in growth and development of wheat. Insufficient water affects the germination of seeds and uptake of nutrients from the soil. Nutrients from soil reach the root zone by mass flow and diffusion process which are related with the moisture content of the soil. Moreover, movement of nutrients through the plant body by physiological activities is also associated with soil water (Tisdale *et al.,* 1985). Irrigation influences dry matter production, plant height, duration of grain filling and grain protein content of wheat. The application of irrigation water at different stages of growth is one of the approaches of irrigation scheduling in wheat cultivation. When water supply is limited, it is necessary to take into account the critical stages of crop growth with respect to soil moisture level. The farmer's usually select the time of irrigation in wheat fields primarily on the basis of growth stages, rather than the soil water condition (Rahman *et al.,* 19996). The economy use of irrigation water is necessary for maximizing yield of wheat.

Considering the above fact, the present investigation was undertaken involving the influence of tillage intensity and irrigation with the following objectives:-

1. To find out the best treatment responsible for the highest yield.

2. To investigate the changes in the soil physical properties such as bulk density, moisture content and chemical properties such as organic carbon, total N due to tillage and irrigation.

3. To assess the yield and yield contributing characteristics of wheat under different tillage intensity and irrigation.

4. To examine the relationship between the soil properties and the yield of wheat.

CHAPTER 2

REVIEW OF LITERATURE

Literature reviewed in this study was taken from different sources. This section presents the most common and relevant research works which have been conducted both at home and abroad on various aspects of wheat cultivation. Still now more modern and sophisticated researches on improving soil properties and yields are in progress. Some of the pertinent reviews with regard to soil physical and chemical properties and yield of wheat as influenced by tillage and irrigation intensity have been reviewed, are presented in this chapter.

Effect of tillage on some properties of soil

Effect of tillage on soil bulk density

Simanskaite *et al.* (2007) suggested that different soil tillage methods had significant effects on structure, bulk density, total and air-filled porosity and moisture content of soil.

Ranjan *et al.* (2006) studied the conventional and zero tillage operation and observed that soil bulk density decreased significantly with conventional tillage at 0-15 and 15-30 cm soil depths than zero tillage.

Bhattacharyya et al. (2006) stated that the soil bulk density decreased with the degree of soil manipulation during tillage practices. Significantly lower soil bulk density in conventional tillage system could be due to the incorporation of crop residues by tillage to the surface soil depth.

Dam *et al.* (2005) reported that soil bulk density was 10% higher in no tillage compared to conventional tillage , at particularly at the 0-10 cm in soil depth.

Islam *et al.* (2005) Indicated that bulk density was significantly altered by different tillage practices whenever the lowest bulk density was observed in the disc ploughing at 0-10 cm soil depth.

Lipice *et al.* (2005) Observed that the tillage treatments significantly affected pore size distribution. Conventional tillage had greater percentage of pore volume for large pore diameter ((>100micrometer) Lower pore volume of smaller pores (<6 micrometer) compared to all others tillage treatments.

Lampurlanes and Martinez (2003) reported that the effect of tillage on bulk density was significant in the three strips. Bulk density was greater in general, for no tillage, medium for minimum tillage and lower for subsoil tillage, according to tillage intensity.

Huk and Muler (2003) found that the decreased of bulk density in the compact layer of light soil is due to deep ploughing up to the depth of 15-40 cm.

Molla et al. (2000) carried out an experiment in BRRI farm in boro rice season1996-97 and found that up to 65 cm depth soil was clay loam as well as bulk density was 1.5 g cm-3. Bulk den sity gradually increased with the increase ofdepth.

Maecka and Blecharezyk (2002) indicated that capillary porosity was decreased when reduced tillage but increased with conventional tillage.

Matin and Hossain (2000) indicated that the highest bulk density of 1.5 g cm-3 was found under single tillage and lowest bulk density of 0.09 g cm-3 was found in deep tillage at 0-10 cm depth.

Chan *et al.* (1999) indicated that air filled porosity of soil would be decreased and soil organic carbon would be increased in the minimum tillage instead of intensive tillage. They also found decreasing Na from soil at minimum tillage, would increase the chemical quality of soil.

Ahuja *et al.* (1998) reported that the porosity was greater in tilled layer than in the untilled layer and the dry bulk density is reduced in the tilled layer, which are the general characteristics of the effects of tillage.

Benegas and Kokuban (1998) showed that the effect of no tillage system has a greater bulk density of surface sample.

Rahmqn et al. (1997) observed that the highest soil bulk density under no tillage treatment and lowest value of soil bulk density measured by deep tillage treatment.

Singh and Singh (1996) stated that bulk density was generally higher in no tillage than other tillage treatments.

Hur *et al.* (1996) conducted that the soil bulk density ranged from 1.22 g cm-3 with tractor tillage to 1.40 g cm-3 with no tillage.

Matin and Uddin (1994) observed that soil bulk density was higher to tilling soil by country plough than power tiller. Soil bulk density was increased significantly with progress of soil depth.

Effect of tillage intensity on soil moisture content

Vita *et al.* (2007) observed that soil water content was significantly lower under no tillage than conventional tillage, at the beginning of the wheat cycle, during each of the two growing seasons, but differences declined towards the end of the crop cycle.

Khan *et al.* (2006) noted that the mean higher soil moisture content were found in intensive tillage treatment and lower soil moisture content was recorded in no tillage.

Vulloid *et al.* (2006) mentioned that water storage capacity was related to tillage intensity. Highest storage capacity was characterized in minimum tillage and lowest in no tillage.

Jamal *et al.* (2004) found the lower soil moisture content in the 15-30 cm depth due to existence of hard plough pan.

Rahman *et al.* (2003) studied that puddled soil showed highest moisture retention capacities between 1.5 and 7.0 than zero tillage and conventional tillage.

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Rathor *et al.* (2001) reported that minimum tillage with or without straw enhanced soil moisture conservation and moisture availability during crop growth.

Bonfil *et al.* (1999) reported that greater bulk density under no tillage would have decreased soil water capacity, which in association with reduced water evaporation from the soil surface due to residue, would have enhanced available water for the crop.

Wang and Guang (1999) stated that full tillage preserved the soil moisture better than that of no tillage and interval tillage.

IRRI (1995) conducted an experiment that reduced tillage in tropical regions had higher moisture (45%) that did medium tillage (39%) and complete tillage (36%) during seedling.

Negi *et al.* (1995) reported that the magnitude of time rate of change of soil water content was smaller in zero tilled plots as compared to the conventionally tilled plots.

Sharma *et al.* (1995) showed that the soil moisture content was significantly lower in zero or in minimum tilled plots than the puddle plots.

Salton and Mielnizuk (1995) reported that the highest and the lowest moisture content were found under conventional tillage and no tillage respectively.

Cullum *et al.* (1993) observed general trends of increasing soil water content depth, probably due to the presence of frigipan layer.

Chowdhury and Joshi (1992) suggested that water absorption enhanced in sandy soil by compaction. Deep tillage increased the water storage in layered soils which are different in texture and structure.

Effect of tillage on air filled porosity

Chan *et al.* (1999) indicated that air filled porosity of soil would be decreased and soil organic matter would be increased in the minimum tillage instead of intensive tillage. They also found decreasing Na from soil at minimum tillage, would increase the chemical quality of soil.

Rahman *et al.* (1996) conducted an experiment at the Bangladesh Agricultural University Farm and found that air filled porosity was the highest at 10-20 cm depth and lowest value was 0-10 cm depth under different tillage treatments.

Sehjnning *et al.* (1996) found the lower air filled porosity in loamy soil ploughed at 25-30 cm as compared the shallow cultivated soil, which was the indicative of plough pan, but he did not find significant differences in the coarse sandy soil.

Sharma and Datta (1995) found the aeration porosity was 15% at the plough layer and the 2% at the plough pan layer.

Matin and Uddin (1994) found that power tiller tillage operations result the highest air filled porosity (1.34%) and country plough operations result the lowest air filled porosity (0.92%).

Effect of tillage on chemical properties of soil

Conception *et al.* (2007) reported that no tillage resulted in enhanced organic matter, Olsen P, organic P and total P contents relative to conventional tillage and minimum tillage in the top 5 cm of soil.

Onless *et al.* (2007) observed both positive and negative effects of tillage on nitrogen accumulation rates. Most of the nitrogen accumulation occurred over a 30- day period and time of nitrogen accumulation was not affected by tillage. Tilled profiles tend to contain greater NO3-N, greater aeration and lower moisture contents than untilled profiles, and these characteristics interact to affect plant nitrogen accumulation.

Vullioud *et al.* (2006) stated that conservation tillage, (strip tillage, minimum tillage and some extent no tillage) slightly influenced soil pH, preserved soil organic matter level on upper soil layer.

Singh *et al.* (2006) observed that no tillage applied to wheat field positively influenced the organic carbon content in soil. Conventionally-tilled soil contained higher amount of available P compared to that under bed-planted soil.

Roldan *et al.* (2005) in the surface 0-5 cm, organic matter decreased with increasing tillage. The no tilled soil had increased values of water soluble C, organic matter and phosphate contents.

Rahim and Sharif *et al.* (2005) reported that the application of N and P increased the concentration of total N, available P, exchangeable k and organic matter content of soil under conventional tillage, but continuous cropping decreased their status.

Kruger *et al.* (2004) found minute difference in soil pH among no tillage, surface tillage and mould board ploughing. The author also observed in another experiment conducted in sandy loam entice haplustoll of the semi arid pampa region of Argentina and stated that significantly more organic carbon present in the 7.5 cm soil layer under no tillage than other tillage systems.

Rahman *et al.* (2003) stated that the soil pH and electrical conductivity were significantly lower under no tillage than other practices.

Ishuq *et al.* (2002) tillage rates and methods affected soil N, K, P and S concentrations and the concentration of soil organic carbon were less in the ploughed layer than sub soil.

Ishaq *et al.* (2001) reported that the increasing rates of N, P and K cause a corresponding increase in tissue contents of N, P and K of wheat. Tillage and fertilizer treatments had a positive effect on nutrient uptake by wheat. Conventional tillage and deep tillage increased N, P, and K uptake compared to minimum tillage treatment.

Basunia *et al.* (2000) revealed that soil pH, organic carbon, total N, available P, exchangeable K and available S did not differ significantly due to tillage practices.

Bayer *et al.* (2000) concluded that no till cropping system with addition of crop residue increased total N in soil at 0-17.5 cm depth.

Thompson and Whitney (2000) stated that soil organic matter was not changed significantly over the 30 years in wheat sorghum follow rotation system and tillage system. They also observed that organic matter was highest in the 2-5 cm increment for the no tillage among clean till, reduced till and no till.

Blecharezyk *et al.* (1999) mentioned that direct sowing and reduced tillage systems used on the same field decreased soil pH and increased total N and organic C in the top layer (0-5 cm) compared to conventional tillage.

Demaria *et al.* (1999) showed that higher amount of organic matter at the depth of 0-0.5 m under no tillage practices than chisel plough and conventional tillage.

Mazid *et al.* (1999) revealed that tillage intensity decreased organic carbon, total N and increased soil pH.

Alvarez *et al.* (1998) reported that under no tillage nitrogen in light and heavy fractions and minimized in weak soil, diminished markedly with depth. Mean while, in ploughed soil these variables remained constant up to 20 cm depth. In the first 20 cm no tillage accumulated more nitrogen in light and medium fractions.

Singh *et al.* (1998) reported that organic matter, total N and exchangeable K distribution decreased with the increase of depths and were higher in the soils subjected to minimum tillage.

Lal *et al.* (1998) and Dick (1983) reported that soil organic carbon at Foggia was greater with no tillage than conventional tillage at 0-15 cm and 15-30 cm depths.

Gupta *et al.* (1997) stated that ammonium nitrogen and nitrate nitrogen concentrations were lower in run off generated from disc tillage, compared to that from the no tillage plots.

Nico et al. (1997) noticed that the highest value organic matter was obtained under no tillage condition at 10-15 cm layer and the lowest range was obtained in conventional tillage at 0-5 cm depth.

Miglierina *et al. (1995)* conducted an experiment and concluded that organic matter increased under zero tillage and it decreased under conventional tillage in an Entice Haplusol of the South- West sub-humid region of the province of Buenos Aires.

Chowdhury *et al.* (1992) found that organic matter values of Old Brahmaputra Floodplain soil ranged from 0.64 to 1.77% and that of Madhupur tract from 0.28 to 1.70% under different cropping patterns and tillage.

Unger *et al.* (1991) observed that the no tillage fields tended to have higher organic matter at surface than stubble mulch tillage field, but all differences are not significant. In general, more differences with depth were significant on no tillage fields than on the stubble mulch field.

Effect of tillage on yield and yield contributing characters of wheat Vita *et al.* (2007) stated that higher yield of wheat was obtained with CT (Conventional tillage) than NT (No tillage) in the first two years at Foggia. In contrast, mean yield and quality parameters at Vasto were similar for the two treatments.

Grove *et al.* (2006) stated that the tillage management had significant effects on the average yield of wheat following soybean residues. The more recent the chisel tillage, the greater the wheat yield. Wheat yields were reduced with greater duration of no- tillage.

Albrecht *et al.* (2005) reported that tillage, nitrogen fertilization, and precipitation all affected wheat yield. Based on the 7- year averages from 1998 to 2004, yields of wheat with no N fertilizer were 57 percent higher under conventional till than under direct seed.

Roozbeh and pooskani *et al.* (2003) conducted a field experiment to study the effects of four tillage methods on grain yield of wheat. Treatments included conventional tillage, mould board plough and disc harrow chisel plough and disc harrow and use of maize stalk shredder before the first and second treatment operations. In all the tillage methods yield and yield components were measured. The results showed that the different tillage methods had a significant effect on crop yield.

Fischer *et al.* (2002) reported that cropping system in the sub humid tropical highlands is characterized by continuous cultivated cereal monoculture, leading to serious erosion and fertility and decline. To over this problem crop residues application and reduced tillage more effectively helped to increase the yield and yield component of wheat.

Siritanu *et al.* (2002) stated that the different treatments of tillage operation (no, one two, and three) significantly affect soil properties, weed infestation and composition, crop yield.

Basunia *et al.* (2000) investigated the maximum plant height found by plough with 4 passes.

Blecharchzyk *et al.* (1999) mentioned that wheat yield was greater for conventional tillage compared to direct sowing.

Kadir *et al. (*1999) conducted a field experiment on a clay loam soil at Kazirshimla, Mymensingh, Bangladesh to study the performance of tillage implements. Two types of tillage namely country plough and power tiller were used. They found that the use of power tiller ensured better grain and straw yield of wheat.

Ghosh *et al.* (1998) from a field experiment with rape seed in rice fields during the winter seasons of 1988-92 in West-Bangla showed that yields were affected by increasing the number ploughing from 2 to 4 or 6.

Panjab *et al.* (1998) concluded that conventional tillage resulted in tiller plants, longer and heavier spikes and more grains spike^{-1} and higher grain yield than no tillage. Conventional tillage also decreased the population of monocot weeds, while soil fertility was generally not significantly affected by tillage.

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Rezaul Ahmed *et al.* (1997) found that highest grain yield was produced when the land was prepared with two ploughings followed by two laddering and the lowest yield was obtained in the plots with no preparations.

Matin and Uddin (1994) obtained significantly highest grain and straw yield of rice in power tiller treatment over country plough treatments.

Modestus *et al.* (1994) carried out an experiment with different tillage treatment for wheat production. They found that wheat yields under minimum tillage practices and conventional tillage did not differ significantly. The result indicated that minimum tillage practices are available option for wheat production.

Negussie *et al.* (1994) carried out an experiment to study the effect of minimum tillage on yield of durum wheat. The grain yield obtained with minimum tillage was less than that of conventional tillage.

Razzaq *et al.* (1993) stated that yield increase of 16.91% in wheat yield was obtained with the use of disc harrow once, followed chisel plow twice and moldboard plow once followed by disc harrow once the conventional practice.

Gill and Aulakh *et al.* (1990) stated that tillage system influenced the grain yield of wheat. They further reported the tillage systems affected 1000- grain weight and plant height of wheat.

Effect of irrigation on some properties of soil

Effect of irrigation on some physical and chemical properties of soil

Ganbari *et al.* (2007) stated that a field experiment was conducted to investigate the effect of irrigation on some soil properties. The treatments included, T,- irrigation with well water during entire growing season, T_2irrigation with well water during flowering stage, T_3- at booting stage, T_4-at tillering stage with waste water, T_5-with waste water during entire growing season. Organic carbon and

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total nitrogen in T_4 and T_5 were statistically reduced than that of control treatment.

Hati *et al.* (2007) conducted an experiment on soybean-wheat system for 3 constructive years in Vertisol of central India to evaluate the effect of distillery effluent as an amendment on soil properties. The organic carbon, microbial biomass carbon, and electrical conductivity of the surface (0-10 cm) soil increased significantly but soil pH was not affected.

Karim *et al.* (2007) stated that the pH values of the ground water collected from Sirajgonj Sadar and Shahzapur thana under Sirajgonj district varied from 6.37 to 7.82.

Lozovitskii *et al.* (2005) stated that changes occurred in some physical and chemical properties of dark chestnut soils irrigated for 27 years with fresh water from the Kakhovka irrigational canal. The long term soil irrigation has resulted in a rise of ground water level. The increase of $CaC0_3$ beyond the soil profile also increase the alkalinity of soil.

Uddin *et al.* (2005) conducted an experiment and stated that the pH value of the ground water collected from Lakshmpur and Noakhali district ranged from 6.24 to 7.6 and 0.07 to 0.80 mg $L^{-'}$.

Stevens *et al.* (2003) conducted an experiment and stated that, data suggested that changes in soil salinity and B concentration from reclaimed water use would not decrease yields. Changes in soil SAR increase salinity and restrict drainage consequently.

Taha and Nanda (2003) observed the morphological, physical, and chemical characteristics of 6 typical pedons of Hirakud Command area in Orissa, India, both under irrigated and non irrigated conditions were studied. A compact plough sole layer developed below the surface of horizon under continuous rice cultivation. Organic matter decomposition increased under irrigated rice farming.

Al-Solaimani *et al.* (2002) stated that an experiment was conducted during the period 1996/1997 to study the effects of three irrigation regimes of Saudi. Soil pH value increased with irrigation rates not with soil depth.

Hulugalle *et al.* (2002) observed that the effect of replacing furrow irrigation with subsurface trickle irrigation on some soil physical and chemical properties of hardsetting red alfisols. The soil properties evaluated were soil structural stability, soil porosity and bulk density increased faster with furrow irrigation compared with trickle irrigation.

Wanas *et al.* (2001) conducted an experiment to study the effect of surge irrigation on some physical properties and stated that the increase in soil bulk density amounted to 4.07, 3.25, and 3.15% for continuous irrigation.

The increase in total porosity reached 3.14, 3.15 and 3.24% for the different irrigation techniques compared to initial values for the depths of 0-30 cm.

Hoque *et al.* (2000) observed that water collected from Sherpur sadar under Old Brahmaputtra Floodplain, had pH in the range 7.64 to 8.90.

Nizam *et al.* (2000) stated that the pH values of 103 water samples collected from 11 unions of Bhaluka upazila under Mymensingh district were within the range of 2.80 to 10.30.

Costa *et al.* (1999) observed that increase in EC, SAR, and exchangeable K of saturated soil extract from the soil cores collected to a depth of 0.6 cm from 1996 to 1998. When irrigation is discontinued for a year the increased value tends to decreasing trends.

Speir *et al.* (1999) stated that irrigation significantly decreased total - and Olsen - P status of the soils and greatly enhanced nitrification potential. Soil and surface water $N0_3$-N concentrations decreased markedly especially in the second half of the trial when soil nitrification rates were also high.

Grigorov and Kirpo *et al.* (1998) observed that irrigation results in both positive and negative effects and requires an extremely competent approach to the irrigated land. The chemical and physical properties of sediments, as well as the volume of the irrigation water considered to the change in the properties.

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Effect of irrigation on moisture content of soil

Pathan *et al.* (2007) Mentioned that, the cumulative volume of water applied during summer to the field plots of turfgrass, the moisture content in the sensor-controlled system was 25% less than that of applied plots with conventional irrigation scheduling.

Sarkar *et al.* (2005) stated that, the magnitudes of soil moisture content and AE (Active Evaporation) declined temporarily with the decrease in both irrigation frequency and fertilizer level. The water storage capacity of soil increased with the increase in the frequency of irrigation.

Abid *et al.* (2004) Observed that three irrigation levels; 3 (I_1), 4.5 (I_2) and 6 inches (I_3) were applied in permanently constructed cemented lysimeters having dimensions of 4 x 4x 4 feet. Soil samples were collected before each of irrigation to determine the actual moisture content. Soil analysis data showed that moisture content in profiles increased with the increase of irrigation and soil depths.

The possibility to choose a wished percentage of the Soil Moisture Deficit (SMD) to take it into account at the lower end of the run-off area is also considered in the irrigation simulation. In this way, several conditions about application and storage efficiencies and process uniformity are established, depending on the application at the end of the irrigated area of the combination flow rate-percentage of the SMD. (Tafur *et al.* 2004)

Shao *et al.* (2000) mentioned that, the results showed that soil water content in profiles calculated by in situ measurements. The field water logging situations could be determined at different irrigation rates of the subsurface water table under any meteorological boundary condition. More water content determined under more irrigation in the crop growing period.

Amir and Wallach (2001) stated that, the range of moisture content variations and moisture depletion rates between subsequent irrigation events were higher in the shallow than in the deeper layer. Irrigation non-uniformity and spatial variability of soil hydraulic properties contributed to the unevenness of the moisture distribution in the soil profile.

At different irrigation interval of 0, 24 and 48 hr after irrigation. The vertical and radial movement of moisture decreased with increase in discharge rate and decrease in irrigation interval. The radial storage and movement of moisture was maximum after 24 hr of irrigation (Powar *et al.*1999).

Effect of irrigation on yield and yield contributing characteristics of wheat

Yield of wheat may be influenced by the irrigation regimes and application of appropriate critical stages. Some of the research findings relevant to the present study have been reviewed here.

Tomic *et al.* (2007) stated that the irrigation and drainage are essential for grain yield. Grain yield increase with the increase of irrigation levels at different critical levels. On the other hands process of drying kernels to the storage humidity value look the shortest time with drainage. It contributes to energy saving on the process of drying wheat and maize crop.

Shuquin *et al.* (2006) expressed that the influence of irrigation on yield and quality of different gluten wheat cultivars. Results showed that increasing the number of irrigation steadily raised yield and quality as well as water use efficiency, with the minimum number of irrigation yield and quality decreased.

Rahman *et al.* (2006) stated that a field experiment was conducted to evaluate effect of irrigation on plant growth and yield of wheat. Total dry matter (TDM), LAI and CGR and grain yield increased with the increased number of irrigation. Three irrigations at CRI, tillering and heading stages produced the highest TDM, LAI, CGR and grain yield and the lowest values found in control.

Kanwar *et al.* (2006) conducted that irrigation 5 times (21, 45, 65, 85 and 105 DAS) resulted in greater density, dry weight and nutrient uptake by wheat compared to twice or three times. Increases in grain yield of wheat due to irrigation % and 3 times over irrigation twice were 23.9% and 118.9% during 1999-2000.

Rafiq *et al.* (2005) stated that the wheat cultivars showed differential response to moisture stress with regards to the yield contributing factors. Overall, a sigmoid trend in the growth pattern of wheat yield contributing factors was observed. Leaf dry matter increased up to the start of earing and decreased steadily in the later part of the crop growth. Moisture supplied in the form of shallow grain growth and consequently, grain weight. Dry weight of the stem, ear and grain increased up to the physiological maturity.

Jaiamin *et al.* (2005) reported that three irrigation schedules, pre-sowing irrigation only, pre-sowing irrigation and irrigation at booting stages and also pre sowing irrigation, irrigation at booting stage and flowering stages were identified. Pre-sowing irrigation, irrigation at booting stage and flowering stages was recommended for physical winter wheat production in the North China Basin.

Hussain *et al.* (2005) stated that four or five irrigation treatments, based on soil moisture, deficit, were applied to each cultivar in the 2 seasons. Irrigation treatments were designed to induce a range of treatments from full irrigation to no irrigation between emergence and harvest. The highest yields were obtained from fully irrigated treatments, yield variations among the treatments were caused affecting by real uptake of water.

Level of irrigation and their timing of application in wheat significantly influenced 1000 grain weight which finally played a vital role in increasing grain yield.

Guizio et al. (2005) conducted a study with heard wheat cultivars Ofranto and Simeto, frequent rains in autumn in 1999-2000 and in spring 2001-2002 made irrigation unnecessary but lack of rain in 2000-2001 made it necessary to irrigate at the booting stage again at the heading stages. Simeto generally produced higher yields than Ofranto.

Aboddorrahmani *et al.* (2005) stated that draught stress reduced dry matter production, crop growth rate and relative growth rate. All traits except the number of grains per ear and harvest index were affected by water deficit. The green cover percentage, plant height, crop growth rate, biological yield and productivity were significantly correlated with grain yield.

Rajput and Pandey (2004) observed the grain yield, ear length, number of grains per year, 1000 grain weight, water use efficiency, leaf area index, crop growth rate, relative growth rate, net assimilation rate were highest with 55% soil moisture.

Zai and Li (2003) carried out a plot experiment with winter wheat and showed that water stress significantly inhibited the yield of wheat.

Pal *et al.* (2002) stated that the treatments comprised different irrigation frequency (2, 3 or 4 times) carried out during growth stages. Wheat plants which received 4 irrigations recorded the highest yield.

Wang *et al.* (2001) stated that as four irrigation compared with irrigating twice in spring. Four irrigations increased 1000- grain weight. Water consumption for four irrigations is more than two irrigations.

Ottman *et al.* (2000) conducted a field experiment in which the treatments consisted of 3 levels of N (0, 3.4 and 6.6 g N/m^2) until anthesis and irrigation based on 30, 50 and 70% depletion of plant available soil water. It was observed that irrigation frequently during grain filling increased 1000- grain weight.

Rahman *et al.* (2000) conducted a field experiment on Shallow Red Brown Terrace Soil of Madhupur tract of Bangladesh in robi season. The experiment comprised with five levels of irrigation. The treatment having three irrigations gave highest yield of 4.94 t/ha, using 206 mm of water was considered to be optimum levels of irrigation in this soil.

Lidder *et al.* (1999) observed that wheat grown on a vertisol at Powarkheda in winter was given 1, 2, 3 or 6 irrigations and grain yield were 2.79, 3.18, 3.28 and 3.53 t ha^{-1} with increasing number of irrigations.

Rahman *et al.* (1999) conducted an experiment to find out the optimum scheduling of irrigation for getting maximum yield of wheat (cv. Protiva) and water use of wheat. The highest yield of wheat was obtained under three irrigation treatment with optimum amount of nitrogen application. Singh *et al.* (1991) conducted an experiment on tall wheat and found that number of effective tillers hill^{-1} was significantly better in irrigation than no irrigation treatment.

Singh and Singh (1991) conducted a field experiment at Lakhaoti, Uttar Pradesh, India during 1983-84 and 1984-1985 with irrigation at 20, 27, 34 and 41 DAS and reported that spike length increased significantly when irrigation applied at 20 and 27 DAS.

Islam *et al.* (1995) stated the effects of different levels of irrigation (no, one, two, three irrigation) on the performance of Shourav variety of wheat. Irrigation application was found to be better than control on the crop characters and contributed to maximum grain and straw yield.

BARI (1993) reported that maximum grain and straw yields were reported with three irrigations applied at CRI, maximum tillering and grain filling stages of wheat.

Singh and Singh (1991) conducted a field experiment at Lakhaoti , Uttar Pradesh, India during 1983 -84 and 1984 -85 with irrigation at 20, 27, 34 and 41 DAS and reported that spike length increased significantly when irrigation applied at 20 amd 27 DAS.

Singh *et al.* (1991) reported that plant height was significantly higher at 3 irrigations than single irrigation where the treatments comprised 4 irrigation levels (no irrigation, 1 irrigation at tillering, 2 irrigations at tillering and flowering and 3 irrigations at tillering, flowering and dough stages). Two irrigations scheduled at CRI and milk stages gave the maximum plant height (1.026 cm) in wheat (Yadav *et al.* 1995). Patel *et al.* (1992) explained that 12 cm irrigation significantly increased the plant compared with 6 cm irrigation depth and significantly higher values of plant height was recorded with irrigation internal of 6 days than that of 12 days.

Jamal *et al.* (2004) stated that highest number of effective tillers hill^{-1} was found with 6 irrigations, it was far with 4 and 5 irrigations.

Sharrma et al., (1990) obtained higher yield with three irrigations given at crown root initiation, tillering and milking stages of wheat than other treatments with three irrigations. They also found maximum water use efficiency with three irrigations given at crown root initiation, tillering and milking stages.

Ahmed and Haque (1987) conducted an experiment in drums (with and without bottom) at the field condition to determine ground water contribution and irrigation requirement of wheat. Comparatively higher yield was obtained with unbottomed drums, due to ground water contribution.

Ahmed and Hoque (1987) conducted an experiment in drums (with and without bottom) at the field condition to determine the ground water contribution and irrigation requirement of wheat. Comparatively higher yield was obtained with unbottomed drums, due to ground water contribution.

Singh et al., (1987) reported that crop required five irrigations at crown root initiation, late tillering, late jointing, flowering and milking stage. Irrigation at CRI was essential for higher yields.

Singh *et al.* (1984) found that tillers hill^{-1} and growth of wheat were low and poor, respectively under rain fed condition. Irrigation from tillering to heading of wheat had a beneficial effect on tillers hill^{-1} (Massunaka *et al.* 1992).

Singh *et al.* (1984) reported that wheat plant growth was poor and panicle length was low and crop was rain fed.

Hefni *et al.* (1983) stated that irrigation plays a positive role in increasing the number of tillers, ear per plant and grain of wheat. Ear length and number of grains reduced significantly if irrigation is stopped at tillering and booting stages of wheat.

With respect of relative sensitivity, Bhardwaj (1978) and Cheema *et al.* (1973)

concluded that CRI, flowering and milk stages ranked first, second and third, respectively in terms of growth and yield response of wheat.

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CHAPTER 3

MATERIALS AND METHODS

This chapter presents a brief description of the experimental site, soil, climate and methodology used in conducting the experiment. The experiment was carried out during from 26 November, 2019 to 23 March, 2020 to study the influence of tillage intensity and irrigation on soil properties, water conservation and yield of wheat.

Location

The experiment was conducted at the Gopalgonj District during the winter (Rabi) season in the year of 2019-2020. The experimental field was located at 24^{0}54''N latitude and 90^{0}50''Elongitude at a height of 18 m above the mean sea level.

Climate

It appeared that low temperature in the month of November and December and medium temperature in the month of January to March. The maximum , minimum and mean temperature (^{0}C) , rainfall (mm), relative humidity (%), sunshine (hours day^{-1}), evaporation (mm) during the experimental period were recorded by the Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University presented in the Appendix 3.

Agro- ecological region

The experimental farm belongs to the agro-ecological region (Old Brahmaputra Alluvial Soil Tract) under Old Brahmaputra Flood Plain. "AEZ 9" (FAO and UNDP, 1988).

Soil

The soil in the experimental site belongs to the Old Brahmaputra Flood Plain. Soil samples of 0-15 cm depth were collected from the experimental site after harvesting the test crop (wheat). Morphological characteristics, physical properties and chemical composition of the soil which were collected from different sites of experiment at 0-10 cm depth have been presented as follows:

Taxonomic and morphological characteristics of the experimental site

Table 3.1 Taxonomic soil characteristics

The taxonomic characteristics of the experimental field are shown in the table 3.1:

Order	:	Inceptisol
Sub-Order	:	Aquept
Sub-Group	:	Aeric Haplaquet
Series	:	Sonatola

Table: 3.2 Morphological characteristics of the experimental field

The morphological characteristics of the experimental field are shown in the table 3.2:

Location	:	Gopalgonj District
Agro-ecological zone	:	Old Brahmaputra Floodplain (AEZ-9)
Land type	:	Medium high land
General soil type	:	Non-Calcareous Dark Grey Floodplain Soil
Topography	:	Fairly level
Field Level	:	Above flood level
Drainage	:	Fairly good
Firmness (Consistency)	:	Friable when dry
Cropping pattern	:	Fallow-wheat

Table: 3.3 Physical and chemical characteristics of the initial soil

Constituent	Units	Value
Particle size distribution	-	
Sand	%	15.64
Silt	%	72.00
Clay	%	12.36
Textural class	-	Silt loam
Bulk density	g cm^{-3}	1.39
Particle density	g cm^{-3}	2.63
Porosity	%	47.17
pH (1: 2.5)	-	6.30
Organic carbon	%	1.02
Organic matter	%	1.76
Total nitrogen	%	0.0075
C:N ratio	-	15.34

Test crop

The recommended high yielding wheat variety, "Prodip" was used as a test crop. The variety was released by the Bangladesh Agricultural Research Institution, Joydevpur, Gazipur recommended cultivating in robi season. The variety was semi dwarf characteristics. Life cycle of this variety ranges from 110 to 120 days. The variety is very popular among the country. It is resistant to disease and insect attack. The seed was collected from the BADC registered seed dealer in Gopalgonj.

Inputs

The wheat seeds were collected from the Bangladesh Agricultural Research Institution, Joydevpur, Gazipur. Urea, TSP, Mop, gypsum, ZnO and boric acid collected from the Soil, Water and Environment Discipline, Khulna University, Khulna.

Treatments of the experiment

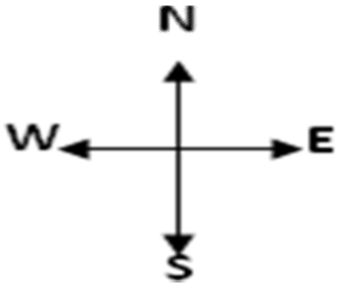
The experiment consisted of the three main plot and four sub-plot treatments. The treatments were as follows:

Main plot treatment:

Tillage treatment code	**Tillage treatment applied to the experiment**
T_1	Land prepared by 1 passing of a power tiller
T_2	Land prepared by 2 passing of a power tiller
T_3	Land prepared by 3 passing of a power tiller

Sub-plot treatment:

Irrigation treatment code	**Irrigation treatment applied at different stages of crop growth**
I_0	No irrigation
I_1	One irrigation at crown root initiation (CRI) stage i.e., at 17 days after sowing (DAS)
I_2	Two irrigations, at crown root initiation (CRI) stage and another at jointing stage i.e., at 54 days after sowing (DAS)
I_3	Three irrigations, at crown root initiation (CRI) stage, another at jointing stage and the final irrigation at booting stage i.e., at 65 days after sowing (DAS)



Block I			Block II			Block III		
T_1	T_2	T_3	T_3	T_1	T_2	T_2	T_3	T_1
I_3	I_3	I_3	I_0	I_0	I_0	I_2	I_2	I_2
I_2	I_2	I_2	I_1	I_1	I_1	I_0	I_0	I_0
I_1	I_1	I_1	I_2	I_2	I_2	I_3	I_3	I_3
I_0	I_0	I_0	I_3	I_3	I_3	I_1	I_1	I_1

Figure 3.1 Layout of the experiment

Land preparation

The land was first plowed on the 21 November, 2017 with the help of a power tiller and it was further plowed followed by laddering on 24 and 25 November, 2010 as per tillage treatment to prepare finally for sowing seed of wheat.

Design of the experiment

The experiment was laid out in a split-plot design. There are two sets of experimental treatments viz. (i) three tillage practices arranged as main plot and (ii) the four irrigation practices are allocated into the sub-plots. The treatments were replicated at three times. Thus, the total number of plots was 36. The unit plot size was 4m×2.5m having spacing of the plot to plot 0.5 m and block to block 1.0 m. the layout of the experiment is shown in Fig. 3.1.

Rates and sources of fertilizers and manures

Table 3.3 Name, rates and sources of the different fertilizers and rice straw (well decomposed)

Fertilizers and rice straw	Rate	Sources
N	100 Kg/ha	Urea (46%N)
P	18 Kg/ha	TSP (20%P)
K	50 Kg/ha	MoP (50%)
S	20 Kg/ha	Gypsum (18%S)
Zn	3 Kg/ha	ZnO (78%Zn)
B	1 Kg/ha	Boric acid (17% B)

Rice straw (well decomposed) and fertilizers application

The total amount of rice straw (well decomposed), TSP. MoP, Gypsum, Zinc Oxide and Boric acid were applied during the final land preparation but urea was applied in the two equal splits. The first split was applied, during final land preparation, the second split at Crown Root Initiation (CRI) stage. Rice straw was applied in the soil two weeks before sowing of wheat seeds. Well decomposed rice straw was applied due to low nutrient status of the soil.

Sowing of seeds

Seeds of wheat were sown manually on 26 November, 2018 @ 120 kg ha^{-1} in lines at the depth of 4-5 cm. The line to line distance was 20 cm. After sowing, the seeds were covered with the soil. A strip of wheat crop was established around the experimental field for protection. Cares were taken to avoid the damage of seed and emerging seedlings by birds.

Intercultural operations

To ensure and maintain the normal growth of wheat, intercultural operations were done in time. The intercultural operations were as follows:

Irrigation

As irrigation is the treatment of the experiment, control plots were not irrigated. Some plots received one, some plots two and some plots received three irrigations. First irrigation was applied 17 days after sowing at crown root initiation (CRI) stage, second being at 54 days after sowing at jointing stage and third being at 65 days after sowing at booting stage. Care was taken to protect the control plots from water during irrigation.

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Weeding

Different species of weeds infested the experimental plots. Two hand weeding was done one at 25 days after sowing and another was done at 46 days after sowing by the help of nirani.

Plant protection

During the experimental periods the wheat was affected by Cut Worm and Mole Cricket. The pests were controlled by the application of Tricosale 20 EC. The pesticide was mixed with rice bran and Chita Ghur and broadcasted in the field. The crop was also affected by the rat and it was controlled by the application of zinc phosphide at the hole. Mechanical procedure was undertaken to protect the mature grains from birds in the field.

Harvesting

The crop was harvested at the full maturity. Harvesting was done on 23 March, 2019. Ten hills were selected randomly from each plot for sampling and they were uprooted before harvesting for recording data. The harvested crop of each plot was bundled separately, tagged properly and bought to the clean threshing floor. Threshing, cleaning and drying of grain were done separately plot by plot. The weights of grain and straw were recorded plot by plot.

Collection and preparation of soil sample for analysis

Soil sample

The initial soil sample was collected just before at the harvesting time from the plough depth layer (0-15 cm). The samples were taken from each experimental plot. The samples were kept separately as plot by plot and the unwanted materials such as weeds, stubbles etc. were removed from the samples. Each soil sample was air dried at ground and sieved through 10-mesh sieve. The soil samples were stored in the clean plastic containers for subsequent physical and chemical analysis. The containers were leveled separately.

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The soil samples were analyzed for the following characteristics:

Physical properties:

- Moisture Content (%)
- Particle density (g cm^{-3})
- Bulk density (g cm^{-3})
- Porosity (%)

Chemical properties:

- Organic carbon (%) and Organic matter (%)
- Total N (%)

Plant sample

Ten plants were selected randomly from each plot at maturity to keep records on yield contributing characters like plant height, number of tillers $hill^{-1}$, spike length and weight of 1000 grains. The grain and straw yield were recorded and expressed as t ha^{-1} and 1000 grains in gram on 14% moisture basis.

Data collection

- Plant height (cm)
- Number of tillers $hill^{-1}$
- Spike length (cm)
- 1000 grains weight (g)
- Grain yield (t ha^{-1})
- Straw yield (t ha^{-1})

A brief out line of data collection given below:

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Plant height

Plant height was measured with the help of a meter scale from the base of the plant to the tip of the upper most spikelet of the panicle. From each plot plants of 10 hills were measured and averaged.

Number of tillers hill^{-1}

Ten hills were selected from each plot randomly. The number of effective and non –effective tillers plant^{-1} were counted and averaged.

Spike length

Length of spikes in ten selected plants per plot was recorded in cm and their average values were calculated.

1000-grains weight

1000-grains were randomly selected from each plots and the weight of grains recorded in gram after sun drying in an electrical balance.

Grain and Straw yield

Grain and straw obtained from each unit plot were dried, weighted carefully and the results were recorded and expressed as t ha^{-1} on 14% moisture basis.

Methods of soil analysis

Soil samples were analyzed for both physical and chemical properties in the laboratory, Department of Soil, Water and Environment Discipline, Khulna University, Khulna. The result has been presented in tables 3.2. 4.1, 4.2, 4.3 and 4.6. Thesoil was analyzed following standard methods as follows:

Physical analysis of soil sample

Particle size distribution

Particle size distribution was done by hydrometer method. Fifty grams of air dry soil was taken in a dispersion cup and 10 ml of 5% Calgon solution was added to the samples and allowed to soak for 15 minutes. Ninety mililiters of distilled water was added to the cup. The suspension was then stirred with an electrical stirrer for 10 minutes. The content of the dispersion cup was then transferred to 1 liter sedimentation cylinder and distilled was added to make the volume up to the mark. A cork was placed on the mouth of the cylinder and the cylinder was inserted several times until the whole soil mass appeared in the suspension. The cylinder was set upright and hydrometer reading was taken at 40 seconds and 2 hours of sedimentation. The temperature of the suspension was also recorded with a thermometer at 40 seconds and 2 hours of sedimentation. The correction of hydrometer reading was made as the hydrometer was calibrated at 68^0 F.

The percentage of sand, silt and clay were calculated as follow

$$\%(\text{Silt+Clay}) = \frac{\text{C.H.R. after 40 seconds sedimentation}}{W} \times 100$$

$$\%\text{Clay} = \frac{\text{C.H.R. after 2 hours sedimentation}}{W} \times 100$$

C.H.R. = Corrected Hydrometer Readind

W = Weight of soil (g)

%Sand = 100 - %(Silt+Clay)

%silt = %(Silt+Clay) -%Clay

The textural class was determined by plotting the values of percentages of sand, silt and clay content on the Marshall's triangular coordinate following USDA, system (1974).

Particle density

Particle density was determined by the volumetric flask method. The particle density was determined by using the following formula:

$$\text{Particle density} = \frac{\text{Weight of soil solid (g)}}{\text{Volume of soil solids (cm}^3\text{)}} \text{ g cm}^{-3}$$

Bulk density

The bulk density was determined with the help of core sampler made of metal cylinder of known volume (Blake and Hartge, 1986). The diameter and the length of core sampler were 4.2 and 4.4 cm respectively.

Bulk density was calculated by the following formula:

$$\text{Bulk density} = \frac{\text{Weight of oven dry soil}}{\text{Volume of solid + Volume of pore space}} \text{ g cm}^{-3}$$

Air filled porosity

The air filled porosity was calculated by the following formula given by Vomocil (1965).

$$\text{Air filled porosity (\%)} = \frac{\text{Volume of the air (cm}^3\text{)}}{\text{Total volume of the soil (cm}^3\text{)}} \times 100$$

Volume of the air (cm^3) = Total volume of the soil (cm^3) - Volume of water (cm^3)

- Volume of soil solids (cm^3)

$$\text{Volume of water (cm}^3) = \frac{\text{Mass of water (g)}}{\text{Density of water (g cm}^{-3})}$$

$$\text{Volume of soil solids (cm)} = \frac{\text{Mass of soil solids (g)}}{\text{Density of soil solids (g cm}^{-3})}$$

Soil moisture

The soil moisture was determined by the gravimetric method and was calculated by using following formula:

$$\text{Soil moisture (\%)} = \frac{W - W_1}{W} \times 100 \text{ (mass basis)}$$

Where, W =Weight of moist soil (g)

W_1 =Weight of oven dry soil (g)

Soil moisture (%) (Volume basis)= % Moisture (mass basis) × bulk density (gcm^{-3})

Chemical analysis of the soil sample

Organic carbon and organic matter

Organic carbon of the soil sample was determined by wet oxidation method of Walkley and Black (1934). The underlying principle of this method is to oxidize the organic matter with an excess of $K_2Cr_2O_7$ in presence of concentrated H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 0.5 N $FeSO_4$. The organic matter content of the soil was calculated multiplying the percent of organic carbon with Van Bemmelen factor. The result was expressed in percentage.

$$\text{Organic Carbon (\%)} = \frac{V_1 - (V_2 \times N)}{W} \times 0.003 \times 1.3 \times 100$$

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Where,

V_1 =Volume of N $K_2Cr_2O_7$ solution

V_2 = Volume of N $FeSO_4$ solution

W = Weight of soil

N = Normality of $FeSO_4$ solution

1.3 = Conventional recovery factor

Organic matter (%) = Organic carbon (%) × 1.73

1.73 = Van Bemmelen factor

Total Nitrogen

Total nitrogen of soil was estimated by Micro–kjeldahl method were soil was digested with 30% H_2O_2 Conc. H_2SO_4 and Catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se =100:10:1). Nitrogen in digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.1 N H_2SO_4.

C: N ratio

The C: N ratio of the soil was calculated from the value of organic carbon was divided by the value of nitrogen.

Correlation and Regression analysis

Correlation and Regression among soil properties, yield components and yield were studied.

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Statistical analysis

The data was analyzed statistically (Gomez and Gomez, 1984) by F– test to examine whether the treatment effects were significant. The mean comparisons of the treatments were evaluated by DMRT (Duncan's Multiple Range Test). The analysis of variance (ANOVA) for different parameters was done by a computer package program "MSTAT–C ".

CHAPTER 4

RESULTS

A field experiment was carried out to study the effect of tillage intensity and irrigation on soil properties, water conservation and yield of wheat. The results obtained from the experiment have been presented and discussed in this chapter under different headings. A summary of analysis of variance (ANOVA) on various characters under study has been shown in the Appendix section.

Effects of tillage and irrigation on some soil physical properties

Moisture content

The tillage treatments influenced the moisture content in the soil profile significantly (Table 4.1). The results under different treatments varied from one another. The soil moisture ranged from 33.32% to 35.52% at 0 to 10 cm depth under different tillage intensity (Table 4.1). The lowest moisture content 33.32% was found under T_1 (one passing of a power tiller) treatment and the highest moisture content of 35.52% was found under T_3 (three passing of a power tiller) treatment, respectively. All the treatments conserved significantly more soil moisture over one passing of a power tiller.

Application of irrigation water increased soil moisture content in the soil. The moisture content range was 28.44% to 38.40% (Table 4.1). The lowest moisture content 28.44% was found under I_0 (no irrigation) treatment and the highest soil moisture content 38.40% was found under I_3 (three irrigations) treatment.

The interaction effect of tillage and irrigation had influence on moisture content of soil profile. The moisture ranged from 27.30% to 39.23% at 0-10 cm depth of soil profile (Table 4.1). The lowest moisture content 27.30% was found under T_1I_0 treatment combination and the highest moisture content 39.23% was found under T_3I_3 treatment combination.

Bulk density

The bulk density of soil showed significant results under three tillage practices (Table 4.1). The lowest bulk density 1.32 g cm^{-3} was found in T_3 and the highest bulk density of 1.51 g cm^{-3} was found in T_1 which was significantly different from T_1 and T_2 treatments.

The lowest bulk density was 1.30 g cm^{-3} was found in I_3 (three irrigations) treatment and the highest bulk density of 1.50 g cm^{-3} was found in I_0 (no irrigation) (Table 4.1).

The interaction effects of tillage and irrigation treatments on bulk density were also significant. The lowest value of soil bulk density 1.19 g cm^{-3} was found at T_3I_3 treatment and the highest value of soil bulk density 1.74 g cm^{-3} was found at T_1I_0 (Table 4.1). The value of soil bulk density was positively correlated (r= - 0.534*) with the yield of wheat (Table 4.6).

Air filled porosity

Different tillage practices significantly changed the air filled porosity. The lowest porosity of soil 74.56% were found in T_3 (three passing of a power tiller) and the highest air filled porosity of 76.96% and T_1 (one passing of a power tiller) treatments respectively (Table 4.1). From the above result, it was clear that air filled porosity was significantly influenced by tillage.

The air filled porosity was also significantly influenced by irrigation (Table 4.1). The lowest value of soil porosity 74.68% was found in I_0 (no irrigation) treatments and the highest value of air filled porosity 76.86% was found in I_3 (three irrigations).

The interaction effect of tillage and irrigation on soil porosity was significant (Table 4.1). The lowest 73.98% was recorded in the T_1I_0 treatment combination and the highest value of soil porosity 77.76% was recorded in the treatment combination of T_3I_3 respectively.

Table 4.1 Effects of tillage and irrigation and their interaction on some physical properties of soil

Treatment	Moisture (%)	Bulk density(g cm^{-3})	Air filled porosity(%)
Tillage			
T1	33.32c	1.51a	74.56c
T2	34.15b	1.42b	75.86b
T3	35.52a	1.32c	76.96a
CV(%)	7.02	4.74	6.58
Level of sig.	*	**	**
$LSD_{(0.05)}$	1.208	0.108	1.692
Irrigation			
I0	28.44d	1.50a	74.68c
I1	34.09c	1.44ab	75.50b
I2	36.39b	1.42ab	76.13ab
I3	38.40a	1.30b	76.86a
CV(%)	7.02	4.74	6.58
Level of sig.	**	**	**
$LSD_{(0.05)}$	0.644	0.077	0.857
Tillage × Irrigation			
T1I0	27.31h	1.74a	73.98e
T1I1	32.56f	1.42bc	74.07de
T1I2	35.74d	1.51b	74.50de
T1I3	37.68b	1.36bc	75.68bcd
T2I0	27.80h	1.40bc	74.64de
T2I1	34.27e	1.49b	74.80de
T2I2	36.25cd	1.44bc	76.87abc
T2I3	38.29ab	1.36bc	77.12ab
T3I0	30.22g	1.36bc	75.42cde
T3I1	35.43d	1.43bc	77.63a
T3I2	37.18bc	1.32cd	77.01abc
T3I3	39.23a	1.19d	77.76a
CV(%)	7.02	4.74	6.58
Level of sig.	**	**	**
$LSD_{(0.05)}$	1.116	0.133	1.484

Figures in a column having common letter(s) do not differ significantly but figures bearing dissimilar letter(s) differ significantly

NS= Not significant

**=Significant at 1% level of probability CV= Coefficient of variation

*= Significant at 5% level of probability LSD= Least Significant Difference

Effects of tillage and irrigation and their interaction on some chemical properties

Soil organic matter

The organic matter content of the post harvest soil was found to be significantly increased in all treatment as compared to the initial soil. Soil organic matter content was influenced by different tillage (Table: 4.2). The lowest (1.09%) was found under T_3 treatment and the highest soil organic matter content (1.87%) was found under T_1 treatment.

Irrigation water supply was also significantly influenced the organic matter content of soil. The lowest amount (1.18%) was found in I_3 treatment and the highest amount of organic matter (1.84%) was found in I_0 treatment (Table 4.2).

The interaction effect of tillage and irrigation on organic matter content was also significant. The lowest value of organic matter content (0.97%) was found under T_3I_3 treatment combination and the highest organic matter content (2.41%) was found under T_1I_0 treatment.

Total N

Tillage influenced the total nitrogen content of soil was significantly (Table 4.2). The lowest total nitrogen (0.12%) was found under T_2 treatment and the highest total nitrogen (0.14%) was observed under T_3 treatment

The total nitrogen percent was decreased significantly due to irrigation (Table 4.2). The lowest amount total nitrogen (0.12%) was found in I_3 treatment and the highest amount of nitrogen (0.17%) was found in I_0 treatment.

The interaction effect of tillage and irrigation on total nitrogen content of soil also significant (Table 4.2). The T_1I_2 gave the lowest (0.10%) soil nitrogen content and treatment combination T_3I_0 gave the highest soil nitrogen content (o.25%).

Table 4.2 Effects of tillage and irrigation and their interaction on some chemical properties of soil

Treatment	Organic carbon(%)	Organic matter (%)	Total N(%)
Tillage			
T_1	1.08a	1.87a	0.13
T_2	0.90b	1.56b	0.12
T_3	0.63c	1.09c	0.14
CV(%)	6.12	5.58	6.25
Level of sig.	**	**	NS
$LSD_{(0.05)}$	0.072	0.124	0.016
Irrigation			
I_0	1.06a	1.84a	0.17a
I_1	0.96b	1.66b	0.12b
I_2	0.79c	1.36c	0.12b
I_3	0.68d	1.18d	0.12b
CV(%)	6.12	5.58	6.25
Level of sig.	**	**	**
$LSD_{(0.05)}$	0.089	0.153	0.010
Tillage × Irrigation			
T_1I_0	1.39a	2.41	0.14b
T_1I_1	1.22b	2.12	0.13bc
T_1I_2	0.95cd	1.64	0.14b
T_1I_3	0.77ef	1.33	0.11d-g
T_2I_0	1.06c	1.84	0.13b-e
T_2I_1	0.97cd	1.68	0.12c-g
T_2I_2	0.86de	1.49	0.12b-f
T_2I_3	0.72efg	1.24	0.13bcd
T_3I_0	0.73efg	1.26	0.25a
T_3I_1	0.68fgh	1.18	0.11efg
T_3I_2	0.55h	0.96	0.10g
T_3I_3	0.56gh	0.97	0.11fg
CV(%)	6.12	5.58	6.25
Level of sig.	**	NS	**
$LSD_{(0.05)}$	2.544	0.266	0.017

Figures in a column having common letter(s) do not differ significantly but figures bearing dissimilar letter(s) differ significantly

NS= Not significant

**=Significant at 1% level of probability CV= Coefficient of variation

*= Significant at 5% level of probability LSD= Least Significant Difference

Effects of tillage and irrigation and their interaction on the yield contributing

Plant height

The plant height of wheat was significantly changed by the impact of tillage practices (Table 4.3). The plant height ranged from 84.73 cm to 93.58 cm. The lowest plant height 84.73 cm was recorded in T_1 (one passing of a power tiller) treatment and the highest plant height 93.58 cm was recorded in T_3 (three passing of a power tiller).

The plant height also significantly influenced by irrigation (Table 4.3). The shortest plant (83.66 cm) was found under the treatment I_0 (no irrigation) treatment and the tallest plant (91.70 cm) was found in I_3 (three irrigations).

The interaction effect of tillage and irrigation showed significant effects on plant height. From the data in Table 4.3 it was clear that the shortest plant (78.50 cm) was found under T_1I_0 treatment combination and the tallest plant (96.55 cm) was found under T_3I_3 treatment combination, respectively. Plant height was positively correlated (r=0.682 **) with the yield of wheat (Figure 4.1).

Spike length

Tillage significantly influenced spike length of wheat (Table: 4.3). The shortest spike length (14.29 cm) was recorded in T_1 treatment. The treatment T_3 produced the tallest spike (16.31 cm).

Application of irrigation water had significant impact on spike length of wheat. From Table 4.3, it was observed that the shortest spike length (13.01 cm) was found under the I_0 treatment and the tallest spike (17.67 cm) was found under the treatment I_3.

The interaction effect of tillage and irrigation was significant (Table 4.3). The shortest spike (11.30 cm) was found under T_1I_0 treatment combination and the tallest spike of (18.60 cm) was found under T_3I_3 treatment combination. Spike length was positively correlated (r=0.841 **) with the grain yield of wheat (Figure 4.2).

Number of effective tillers hill^{-1}

Tillage influenced significantly the number of effective tillers hill^{-1} of wheat (Table 4.3). The lowest number of effective tillers hill^{-1} (3.36) was found under T_1 (one passing of a power tiller) treatment whereas the highest number of effective tillers hill^{-1} (4.64) was recorded in T_3 (three passing of a power tiller) treatment.

Minimum number of effective tillers hill^{-1} (3.17) was recorded in I_0 (no irrigation) treatments and maximum number of effective tillers hill^{-1} (5.04) was observed in I_3 (three irrigations).

The interaction effect of tillage and irrigation on the effective tillers hill^{-1} was statistically significant (Table 4.3). The T_1I_0 treatment combination gave the lowest number (2.30) of effective tillers hill^{-1} and treatment combination T_3I_3 gave the highest number (5.90) of effective tillers hill^{-1}. Effective tillers hill^{-1} were positively correlated (r= 0.785 **) with the grain yield of wheat (Figure 4.3).

1000-grain weight

The 1000-grain weight of wheat was significantly influenced due to tillage (Table 4.3). The lowest 1000-grain weight (35.99 g) was found under T_1 treatment and the highest 1000-grain weight was (40.93 g) was found in T_3.

Irrigation did not affect 1000-grain weight significantly (Table 4.3). The minimum weight of 1000-grain (32.30 g) was found under I_0 treatment and the maximum weight of 1000-grain (47.14 g) was found under I_3 treatment.

Interaction effects of tillage and irrigation was not significant to 1000-grain weight (Table 4.3). The lowest weight of 1000-grain (29.80 g) was found under T_1I_0 treatment combination and the highest weight of 1000-grain (50.57 g) was observed under T_3I_3. 1000-grain weight were positively correlated (r=0.856 **) with the grain yield of wheat (Figure 4.4).

Table 4.3 Effects of tillage and irrigation and their interaction on yield contributing characters of wheat

Treatment	Plant height (cm)	Spike length (cm)	Effective tiller hill^{-1}	1000-grain weight (g)
Tillage				
T_1	84.73c	14.29c	3.36c	35.99c
T_2	86.37b	15.24b	3.91b	37.73b
T_3	93.58a	16.31a	4.64a	40.93a
CV(%)	5.23	6.23	4.47	5.44
Level of sig.	**	**	**	**
$LSD_{(0.05)}$	1.897	0.718	0.253	0.720
Irrigation				
I_0	83.66d	13.01d	3.17d	32.30d
I_1	87.38c	14.53c	3.66c	34.59c
I_2	90.19b	15.92b	4.02b	38.86b
I_3	91.70a	17.67a	5.04a	47.14a
CV(%)	5.23	6.23	4.47	5.44
Level of sig.	*	**	**	**
$LSD_{(0.05)}$	2.461	0.840	0.191	0.716
Tillage × Irrigation				
T_1I_0	78.50e	11.30g	2.30g	29.81h
T_1I_1	85.64cd	13.37f	3.23ef	32.71g
T_1I_2	86.42bcd	15.10de	3.68d	37.62e
T_1I_3	88.37bc	17.41ab	4.24c	43.84c
T_2I_0	82.09de	13.22f	3.12f	32.05g
T_2I_1	85.72cd	14.70ef	3.51de	34.07f
T_2I_2	87.51bc	16.05b-e	4.04c	37.99e
T_2I_3	90.17bc	16.99bc	4.97b	46.84b
T_3I_0	90.39bc	14.51ef	4.07c	35.03f
T_3I_1	90.77b	15.51cde	4.23c	37.00e
T_3I_2	96.63a	16.61bcd	4.34c	40.96d
T_3I_3	96.55a	18.60a	5.90a	50.75a
CV(%)	5.23	6.23	4.47	5.44
Level of sig.	*	*	*	*
$LSD_{(0.05)}$	4.263	1.455	0.330	1.241

Figures in a column having common letter(s) do not differ significantly but figures bearing dissimilar letter(s) differ significantly

**=Significant at 1% level of probability CV= Coefficient of variation

*= Significant at 5% level of probability LSD= Least Significant Difference

Grain yield

Different tillage practices result a significant grain yield (Table 4.4). Minimum grain yield (3.32 t ha^{-1}) was obtained in T_1 (one passing of a power tiller) treatments and maximum grain yield of (3.74 t ha^{-1}) was found under treatment T_3 (three passing of a power tiller) respectively. Three passing of a power tiller increased grain yield by 12.65% more than one passing.

Irrigation also influenced the grain yield (Table 4.4). The lowest grain yield (2.68 t ha^{-1}) was found in I_0 (no irrigation) treatments and the highest grain yield (4.26 t ha^{-1}) was achieved in I_3 (three irrigations) respectively.

The interaction effects of tillage and irrigation showed significant result for producing grain yield of wheat (Table 4.4). The lowest grain yield (2.60 t ha^{-1}) was found under T_1I_0 treatment combination and the highest yield (4.67 t ha^{-1}) was found under T_3I_3 treatment combination.

Straw yield

Straw yield was significantly influenced by tillage. The lowest straw yield (6.29 t ha^{-1}) was obtained under T_1 treatment and the highest straw yield (6.98 t ha^{-1}) was obtained under T_3 treatment (Table 4.4). Three passing of a power tiller increased straw yield by 10.97% more than one passing.

Irrigation showed significant result on the straw yield of wheat (Table 4.4). The lowest straw yield (5.78 t $h^{-1}a$) was recorded in I_0 treatment and the highest straw yield of (7.29 t ha^{-1}) was recorded under I_3 treatment.

The interaction effects of tillage and irrigation showed significant result on the straw yield (Table 4.4). The lowest straw yield (5.64 t ha^{-1}) was found under T_1I_0 treatment combination and the highest straw yield (7.91 t ha^{-1}) was found under T_3I_3 treatment combination.

Table 4.4 Effects of tillage and irrigation and their interaction on the yield of wheat

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Tillage		
T_1	3.32b	6.29b
T_2	3.68ab	6.59ab
T_3	3.74a	6.98a
CV(%)	4.58	4.28
Level of sig.	**	**
$LSD_{(0.05)}$	0.095	0.051
Irrigation		
I_0	2.68c	5.78c
I_1	3.39b	6.44b
I_2	3.98ab	6.97ab
I_3	4.26a	7.29a
CV(%)	4.58	4.28
Level of sig.	**	**
$LSD_{(0.05)}$	0.089	0.070
Tillage × Irrigation		
T_1I_0	2.60g	5.64i
T_1I_1	3.17f	5.92g
T_1I_2	3.53d	6.73e
T_1I_3	3.96c	6.88d
T_2I_0	2.67g	5.79h
T_2I_1	3.66d	6.60f
T_2I_2	4.21b	6.90d
T_2I_3	4.17b	7.08c
T_3I_0	2.76g	5.93g
T_3I_1	3.33e	6.80de
T_3I_2	4.20b	7.29b
T_3I_3	4.67a	7.91a
CV(%)	4.58	4.28
Level of sig.	**	**
$LSD_{(0.05)}$	0.153	0.121

Figures in a column having common letter(s) do not differ significantly but figures bearing dissimilar letter(s) differ significantly

NS= Not significant

**=Significant at 1% level of probability CV= Coefficient of variation

*= Significant at 5% level of probability LSD= Least Significant Difference

Correlation and regression analysis among soil physical properties, yield contributing characters and grain yield of wheat

Correlation and regression equation show that grain yield has a significant positive correlation with the plant height (r= 0.682**), spike length (r=0.841**), effective tillers hill^{-1} (r=0.785**), and 1000-grain weight (r=0.856**) but negatively correlated with bulk density (r=-0.534*) of soil. The graphical representation between grain yield with plant height, spike length, effective tillers hill^{-1}, 1000 grain weight and bulk density have been shown in Figure 4.1- 4.5.

Table 4.5 Correlation and regression analysis among soil physical properties, yield

contributing characters and grain yield of wheat

Independent variable	Dependent variable	Regression equation	Correlation Coefficient (r)
Plant height (cm)	Grain yield (t ha^{-1})	GY = 0.083x - 3.805	0.682**
Spike length (cm)	Grain yield (t ha^{-1})	GY = 0.269x - 0.543	0.841**
Effective tiller $hill^{-1}$	Grain yield (t ha^{-1})	GY = 0.576x + 1.287	0.785**
1000-grain weight (g)	Grain yield (t ha^{-1})	GY = 0.092x + 0.035	0.856**
Bulk density (g cm^{-3})	Grain yield (t ha^{-1})	GY = -2.447x + 7.045	-0.534*

Means followed by common letters do not differ significantly

NS= Not significant

**=Significant at 1% level of probability

*= Significant at 5% level of probability

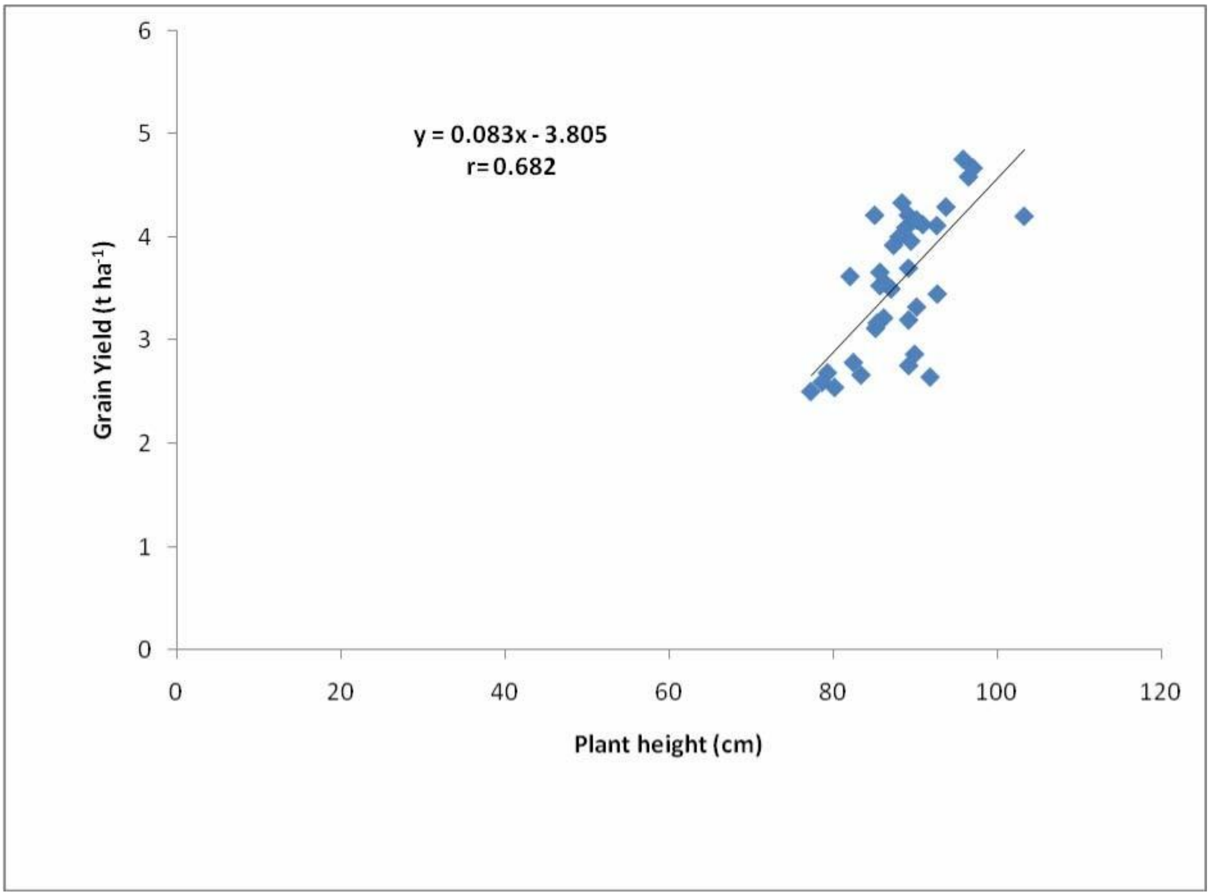

Figure 4.1 Relationship between plant height (cm) and grain yield (t ha^{-1})

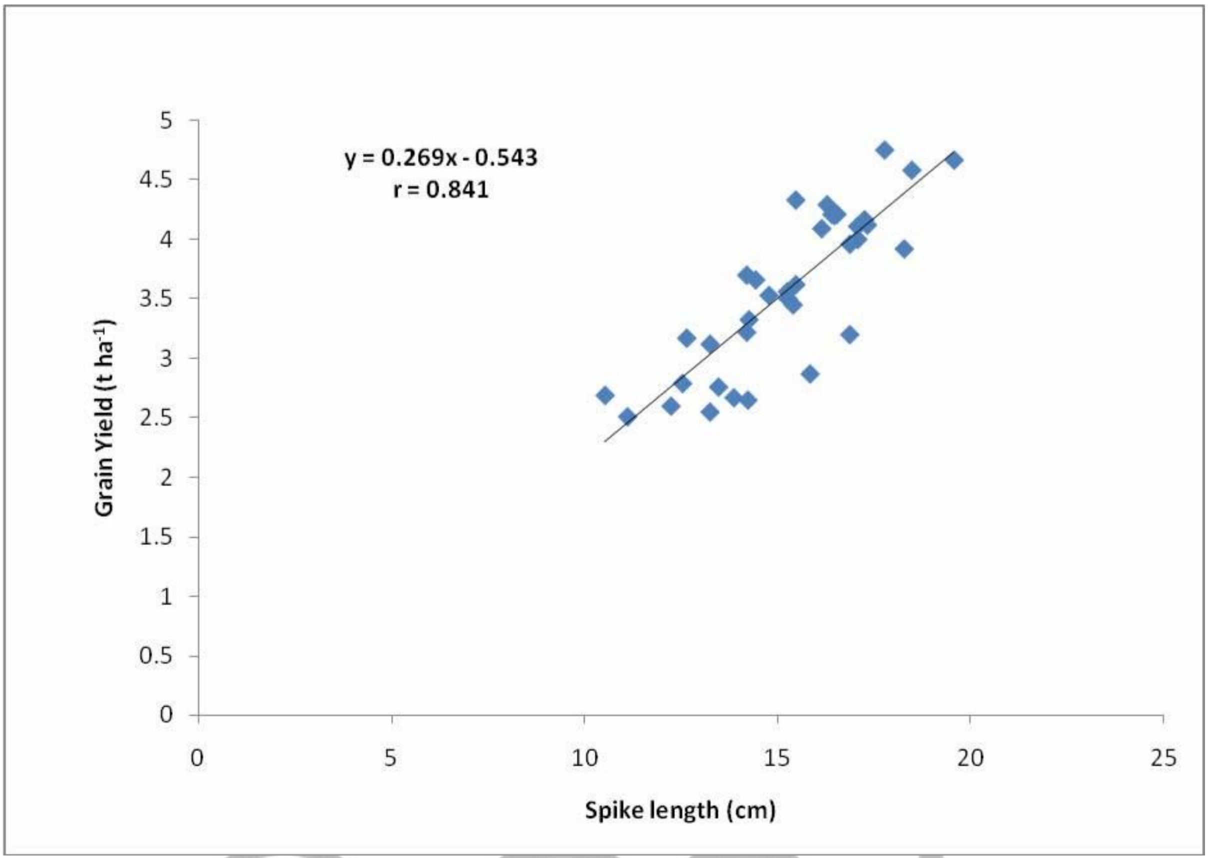

Figure 4.2 Relationship between spike length (cm) and grain yield (t ha^{-1})

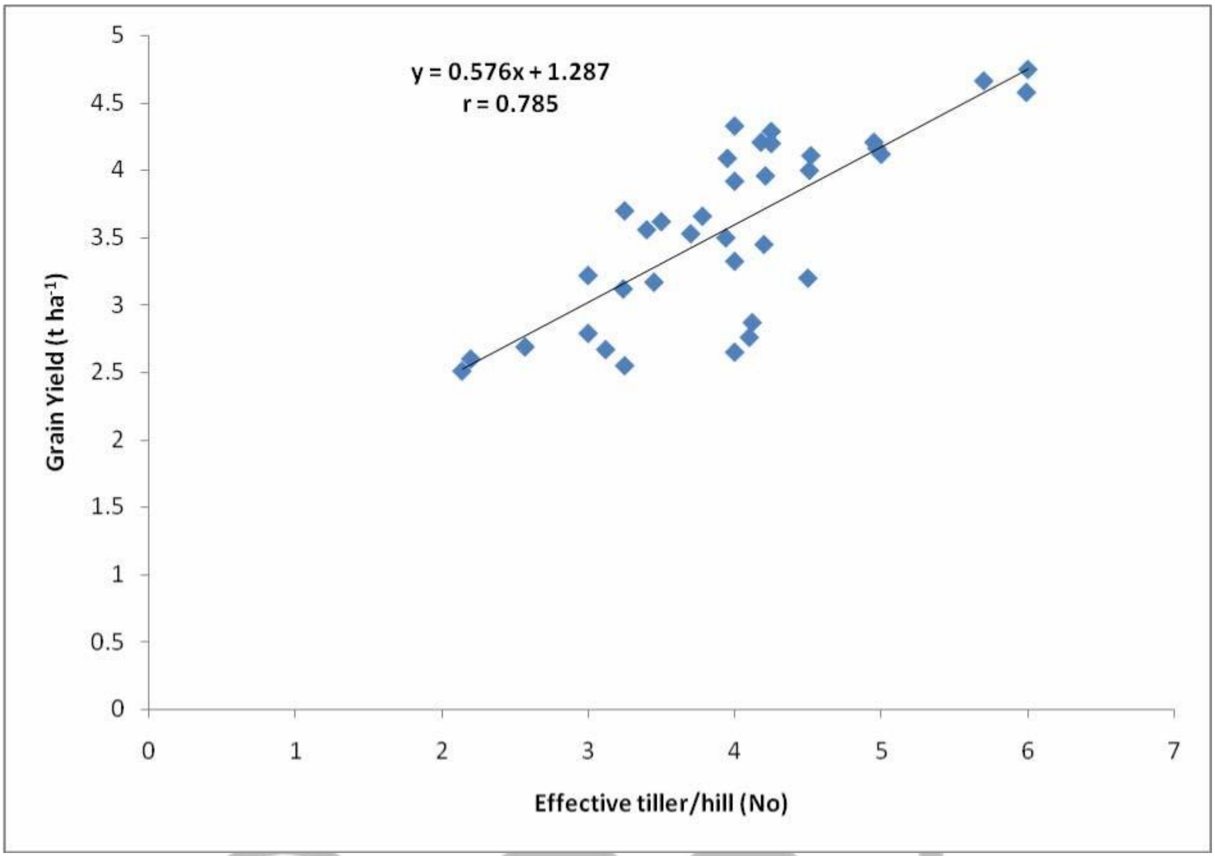

Figure 4.3 Relationship between effective tillers hill^{-1} and grain yield (t ha^{-1})

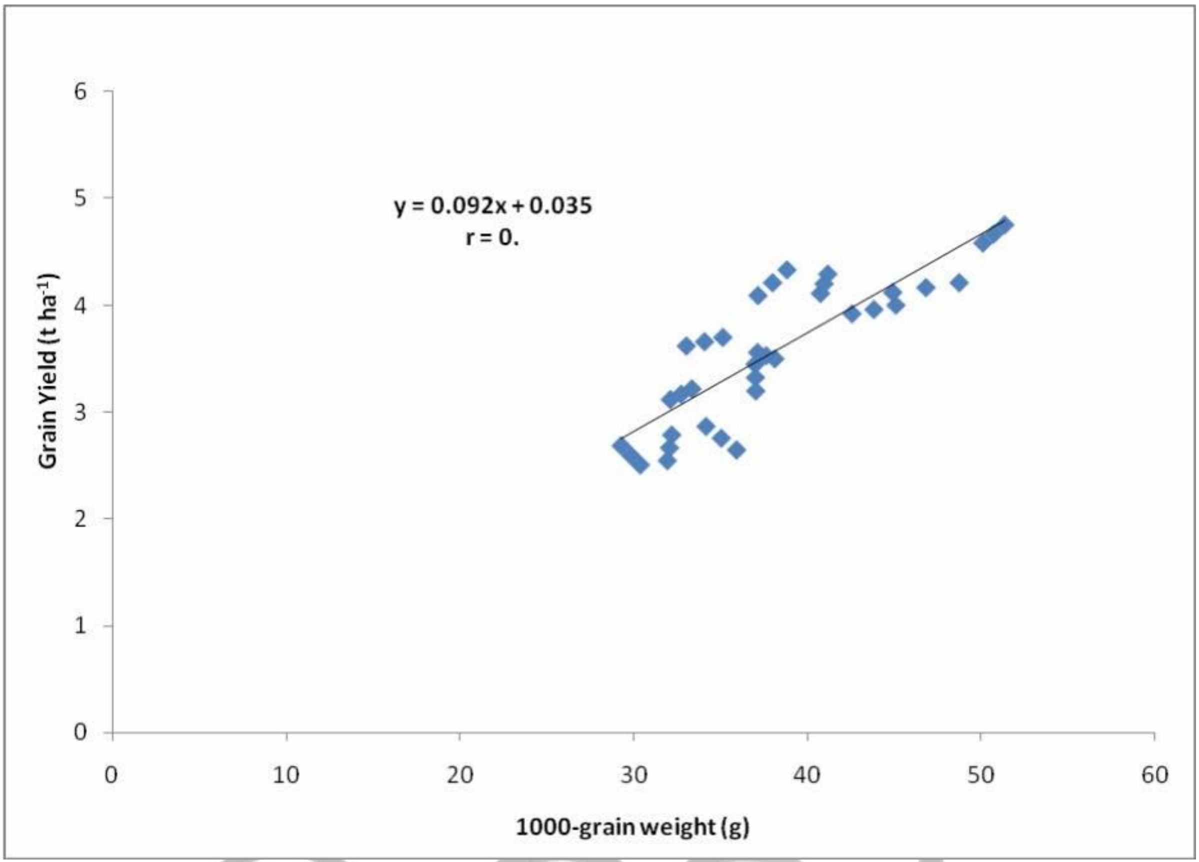

Figure 4.4 Relationship between 1000-grain weight (g) and grain yield (t ha^{-1})

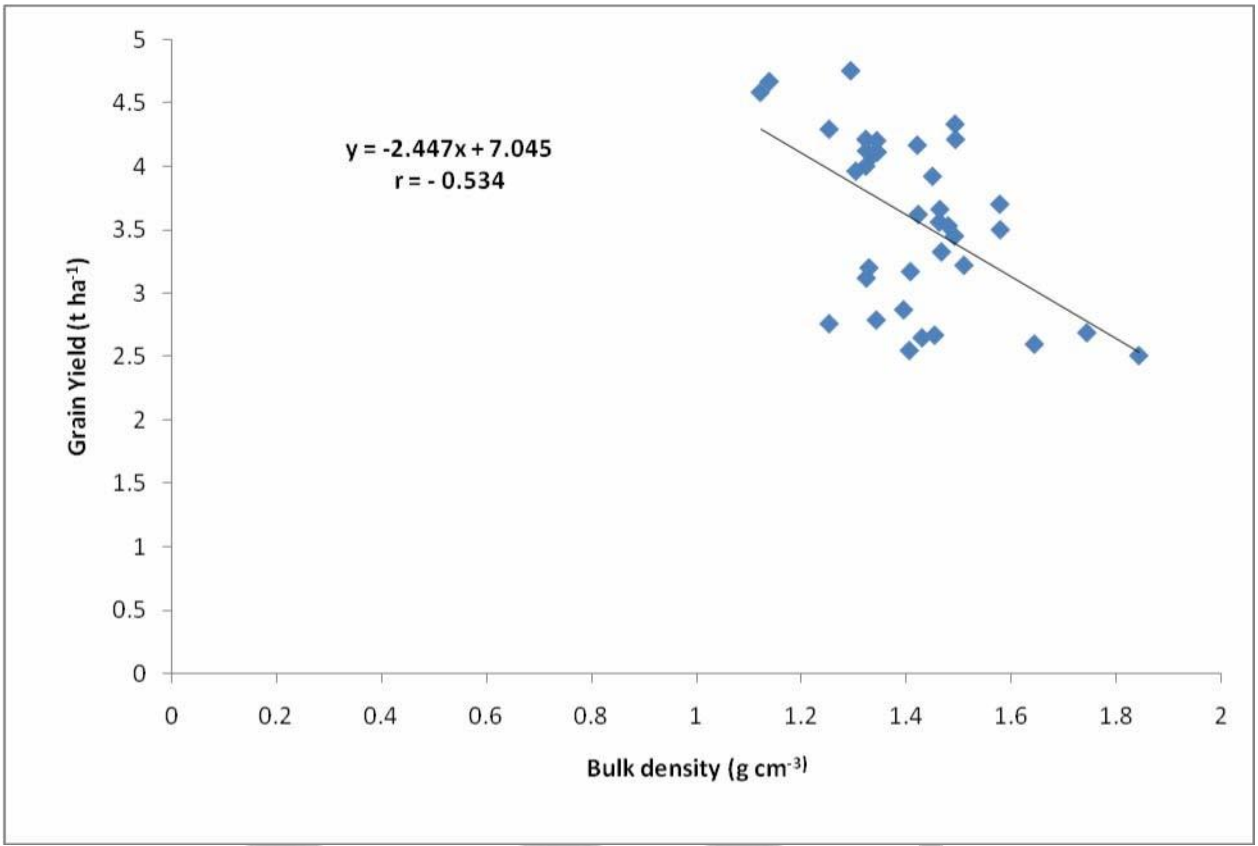

Figure 4.5 Relationship between bulk density (g cm^{-3}) and grain yield (t ha^{-1})

CHAPTER 5

DISCUSSION

The highest moisture content was found under T_3 (three passing of a power tiller) treatment and the lowest moisture content was found under T_1 (one passing of a power tiller) treatment (Table 4.1). The result was supported to by Vita *et al.* (2007) and Vulliod *et al.* (2006). This might be due to more tillage intensity that made the soil looser and also indicated that the more loose soil absorbed more soil moisture compared to compact soil.

Considering the irrigation, the highest soil moisture content was found under I_3 (three irrigations) and the lowest moisture content was found under I_0 (no irrigation) treatments (Table 4.1). Application of more water increased the content of water in the soil. It also increased the capacity of soil to conserve water. Application of irrigation water significantly increased the water holding capacity of soil.

The maximum and minimum bulk densities were obtained from T_1 and T_3 treatments, respectively (Table 4.1). The result of the experiment was supported by Ranjan *et al.* (2006) and Dam (2005). In surface layer, soils were manipulated with different tillage operations thereby reduced compactness of soil and increased the number of pore space which decreased soil bulk density. The deeper soil showed significantly higher bulk density which indicates the compactness of soil due to the formation of a hard pan. Higher bulk density refers to the poor physical condition of soil.

For irrigation, the highest bulk density was found in I_0 and lowest bulk density was found in I_3 treatment (Table 4.1). It may be due to application of irrigation, which improves the granulation of soil, increased aeration and porosity of soil. This result was also supported by Wannas *et al.* (2001).

Different tillage practices significantly changed the air filled porosity. The highest and lowest air filled porosity was found in T_3 and T_1 treatments, respectively

(Table 4.1). From the above result, it was clear that air filled porosity was significantly influenced by tillage. This result was supported by Benegas and Kokuban (1998). More loose soil was present under T_3 treatment that allowed more water into the soil and increased the air filled porosity. On the other hand, T_1 produced the harder layer of the soil and did not allow to occur the greater space and ultimately decreased the air filled porosity.

In case of irrigation, the highest value of air filled porosity was found in I_3 and the lowest value of soil porosity was found in I_0 treatments. This result accorded with Hullugalle *et al.* (2002).

The highest soil organic matter content was found under T_1 (one passing of a power tiller) treatment and lowest was found under T_3 (three passing of a power tiller) treatment. More tillage favor rapid decomposition of organic matter and less tillage enhanced organic matter content. Less soil disruption resulted in greater accumulation of surface residue, consequently the organic matter content remains.

The highest amount of organic matter was found in I_0 (no irrigation) treatment and the lowest amount was found in I_3 (three irrigations) treatment. This is due to higher microbial activities and higher decomposition of organic matter for the presence of more moisture. The result of the present research was similar to the statement of Janusiene and Sleinys (2003).

The highest total nitrogen was observed under T_3 and the lowest total nitrogen was found under T_0 treatments, respectively. Slower mineralization under minimum tillage may have been responsible for the lower nitrogen concentration in the soil and higher nitrogen concentration in the T_3 tillage may be due to decomposition of organic matter which was supported by Roldan *et al.* (2005).

In case of irrigation, the highest amount of nitrogen was found in I_0 and the lowest amount of total nitrogen was found in I_3 which was accorded with Ghanbari *et al.* (2007).

The highest plant height was recorded in T_3 (three passing of a power tiller) and the lowest plant height was recorded in T_1 (one passing of a power tiller) treatments, (Table 4.3). The similar result was accorded with Basunia (2000).

The result of height response of wheat to irrigation as obtained in the present experiment were in agreement with many researchers who had shown that irrigation plays significant role in increasing plant height. The tallest plant was found in I_3 (three irrigations) and the shortest plant was found under the treatment I_0 (no irrigation) the result was also supported by Abodorrahmani *et al.* (2005) and Singh *et al*. (1991). Plant height also positively correlated (r=0.465**) with the grain yield of the wheat.

The treatment T_3 produced the tallest spike and the shortest spike length was recorded in T_1 treatment. Ogbodo (2005) reported that crop growth and yield increased with the tilled soil over untilled soil.

The tallest spike was found under the treatment I_3 and the shortest spike length was found under the treatment I_0 which was correlated with the findings of Hefni (1983).

The highest number of effective tillers hill^{-1} was recorded in T_3 treatment whereas the lowest number of effective tillers hill^{-1} was found under T_1 treatment (Table 4.3). This result was in agreement with Panjab *et al.* (1998).

Maximum number of effective tillers hill^{-1} was observed in I_3 and minimum number of effective tillers hill^{-1} was recorded in I_0 treatments. The result was accorded with the findings of Jamal *et al.* (2004) and Sawar and Khanif (2005). Effective tillers hill^{-1} and grain yield was found to be positively correlated (r=0.82.94**) and statistically significant (Fig. 4.3). It is possible due to absorption of more water and nutrients from deeper soil.

The highest 1000-grain weight was found in T_3 (three passing of a power tiller) and the lowest 1000 grain weight was found under T_1 (one passing of a power tiller) treatment. This result was in agreement with Rahman (1997).

The maximum weight of 1000-grain was found under I_3 and the minimum weight of 1000 grain was found under I_0 treatment. This result was in agreement with Rajput and Pandey (2004) and Wang *et al.* (2001). Ismail (1984) also observed that three irrigations in wheat generated the highest number of effective tillers hill^{-1}.

The maximum grain yield was found under treatment T_3 (three passing of a power tiller) and minimum grain yield was obtained in T_1 (one passing of a power tiller) treatment (Table 4.4). More tillage intensity favored better root growth and nutrients uptake, as a result the yield became maximum. Matin and Uddin (1994) and Siritanu *et al.* (2002) observed similar findings. A bar graph for the yield under different treatment was presented in Fig. 4.1 to show the magnitude of increase yield with the increase of tillage intensity.

Considering the irrigation, the highest grain yield was achieved in I_3 (three irrigations) and the lowest grain yield was found in I_0 (no irrigation) which is correlated with Rajput and Pandey (2004). Irrigation increase the availability of nutrients thus plants uptake more nutrients and finally yield increased.

The highest straw yield was obtained under T_3 and the lowest straw yield was obtained under T_1 treatments respectively. Under T_3 treatment, soil was looser that permitted the penetration of the roots into the deeper soil layer for up taking water and mineral nutrients. Positive physiological and metabolic activities of wheat were probably influenced by tillage operation. Thus the grain and straw yields of were increased.

In case of irrigation, the highest straw yield was recorded under I_3 treatment and the lowest straw yield was recorded in I_0 treatment (Table 4.4). Rafiq *et al.* (2005) were observed similar findings.

CHAPTER 6

SUMMARY

The experiment was conducted from 25 November 2019 to 23 March 2020 to study the effects of tillage and irrigation on the soil properties, water conservation and yield of wheat. The experiment was laid out in a split-plot design with three tillage treatments in main plot and four levels of irrigation in sub plots. The unit plot size was 4m×2.5 m having spacing plot to plot 0.5 m and between blocks 1.0 m. Prodip was used as the variety. All the data were analyzed following F-Test and the mean comparisons were made by DMRT at 5% level. The results of the experiment were summarized below.

Moisture content in the soil profile was significantly influenced by tillage and irrigation. The highest (35.52%) and the lowest (33.32%) moisture content were recorded in T_3 and T_1 treatments, respectively. Considering the irrigation, the highest (38.40%) and the lowest (28.44%) moisture content were recorded under I_3 and I_0 treatments, respectively, during the growing season.

The highest soil bulk density (1.51 g cm^{-3}) was recorded in T_1 treatment and the lowest soil bulk density (1.32 g cm^{-3}) was obtained in T_3 treatment. In case of irrigation, the highest and lowest soil bulk density (1.50 g cm^{-3}) and (1.30 g cm^{-3}) were found under I_0 and I_3 treatment respectively.

Tillage and irrigation significantly influenced the air filled porosity. The maximum and minimum values of air filled porosity (76.96%) and (74.56%) were recorded in T_3 and T_1 treatments, respectively. In case of irrigation, the maximum and minimum values of air filled porosity (76.86%) and (74.68%) were recorded in I_3 and I_0 treatments, respectively.

Soil organic matter content was significantly changed due to tillage and irrigation. The highest (1.87%) and the lowest (1.09%) soil organic matter content were found in T_1 and T_3 treatments, respectively. In case of irrigation, the highest (1.84%) and the lowest (1.18%) soil organic matter content were found in I_0 and I_3 treatments, respectively.

Total nitrogen content of soil was not significantly influenced by tillage. The maximum (0.14%) and minimum (0.12%) total nitrogen were found in T_3 and T_2 treatments, respectively. In the irrigation treatments, the highest (0.17%) and the lowest (0.12%) total nitrogen were found in I_0 and I_3 treatments respectively.

All yield contributing characters of wheat were responded significantly by tillage. The highest value of plant height (93.58 cm), number of effective tillers /hill (4.64), spike length (16.31 cm) and 1000 grain weight (40.93 g) were observed under T_3 treatment. On the other hand, the lowest value of plant height (84.73 cm), number of effective tillers/hill (3.36), spike length (14.29 cm) and 1000 grain weight (35.99 cm) were observed under I_0 treatment. All the yield components of wheat were significantly influenced by irrigation. The highest value of plant height (91.70 cm), number of effective tillers/hill (5.04), spike length (17.67 cm) and 1000 grain weight (47.14 g) were found in T_3 treatment. The lowest value of plant height (83.66 cm), number of effective tillers/hill (3.17), spike length (13.01 cm) and 1000 grain weight (32.30 g) were found in I_0 treatment.

The highest grain yield (3.74 t/ha) and the straw yield (6.98 t/ha) were obtained in T_3 treatment. The lowest grain yield (3.32 t/ha) and straw yield (6.29 t/ha) were obtained in T_1 treatment. Considering the irrigation the highest grain yield (4.26 t/ha) and straw yield (7.29 t/ha) were achieved in I_3 treatment. The lowest grain yield (2.68 t/ha) and straw yield (5.78 t/ha) were achieved in I_0 treatment.

Grain yield was found to be positively correlated with plant height (r=0.682**), effective tillers/hill (r=0.785**), spike length (r=0.841**) and 1000 grain weight (r=0.856**) but negatively correlated with bulk density (r= - 0.534*) of soil.

CHAPTER 7

CONCLUSION

The overall results indicate that the physical properties of soil, water conservation and yields of wheat (*Triticum aestivum L.*) were significantly influenced by different levels of tillage and irrigation.

Based on the study the following conclusion may be drawn:-

1. Tillage and irrigation improved soil physical properties i.e., reduced the bulk density but increased air filled porosity and also increased water holding capacity of soil.
2. With the increase of tillage, organic matter content, available total nitrogen content decreased in the soil.
3. Higher grain and straw yields were recorded due to higher tillage and irrigation.
4. A strong relationship was found between the properties of soil, yield and yield components of wheat.

However, further investigation is necessary to establish the present findings in different AEZs of Bangladesh with different crops.

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APPENDICES

Appendix I. Record of meteorological monthly observation during the experiment (November 2019-March 2020)

Year	Month	*Air temperature (^{0}C)			*Humidity (%)	**Rainfall (mm)	**Sunshine (hrs.)	*Evaporation (mm)
		Max.	Min.	Aver.				
2019	November	24.3	12.6	18.5	83.2	00.0	106.0	64.6
	December	25.6	14.1	19.9	76.9	43.6	148.2	65.5
2020	January	30.6	18.3	24.5	72.5	47.7	229.2	122.4
	February	29.6	16.1	22.4	81.6	00.0	218.1	89.5
	March	25.1	13.6	19.4	84.5	00.6	97.5	72.3

* **=Monthly average**
** **=Monthly total**

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh.

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Appendix II. Analysis of Variance (ANOVA) for moisture content, bulk density and air filled porosity of post harvest soil as influenced by tillage and irrigation

Source of variation (SV)	Degrees of freedom (df)	Mean square values		
		Moisture (%)	Bulk density (g cm^{-3})	Air filled porosity (%)
Replication	2	1.299	0.005	0.063
Tillage (A)	2	14.725*	0.102**	17.271**
Error	4	1.135	0.009	2.228
Irrigation (B)	3	166.591**	0.065**	7.681**
A×B	6	0.758**	0.032**	1.415**
Error	18	0.423	0.006	0.748
CV(%)		7.02	4.74	6.58

Means followed by common letters do not differ significantly at 5 % level of DMRT

NS= Not significant

**=Significant at 1% level of probability

*= Significant at 5% level of probability

Appendix III. Analysis of Variance (ANOVA) for organic carbon content (%), organic matter (%) and Total N (%) of post harvest soil as influenced by tillage and irrigation

Source of variation (SV)	Degrees of freedom (df)	Mean square values (MS)		
		Organic carbon (%)	Organic matter (%)	Total N (%)
Replication	2	0.005	0.014	0.001
Tillage (A)	2	0.624**	1.867**	0.001^{NS}
Error	4	0.004	0.012	0.0002
Irrigation (B)	3	0.257**	0.769**	0.007**
A×B	6	0.032**	0.095^{NS}	0.005**
Error	18	0.008	0.024	0.0001
		6.12	5.58	6.25

Means followed by common letters do not differ significantly at 5% level of DMRT

NS= Not significant

**=Significant at 1% level of probability

*= Significant at 5% level of probability

Appendix IV. Analysis of Variance (ANOVA) for yield contributing characters and yield of wheat as influenced by tillage and irrigation

Source of variation (SV)	Degrees of freedom (df)	Mean square values					
		Plant height (cm)	Spike length (cm)	No. of effective tiller hill^{-1}	1000- grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Replication	2	1.944	0.353	0.036	3.73	0.007	0
Tillage (A)	2	266.075**	12.188**	4.888**	75.35**	0.626**	1.431**
Error	4	2.801	0.401	0.05	0.403	0.007	0.002
Irrigation(B)	3	112.4*	35.448**	5.65**	384.631**	4.443**	3.905**
A×B	6	7.036*	1.002*	0.222*	1.914*	0.144**	0.135**
Error	18	6.175	0.719	0.037	0.523	0.008	0.005

Means followed by common letters do not differ significantly at 5 % level of DMRT

NS= Not significant

**=Significant at 1% level of probability

*= Significant at 5% level of probability