Land and water conservation with residue management & optimizing irrigation schedule in wheat

Abstract: The present study was conducted in wheat at the Punjab Agricultural University, Ludhiana, to study effect of four tillage and three irrigation practices viz mould board ploughing to a depth of 25 cm followed by rotavator (PT25+R), mould board ploughing to a depth of 14 cm followed by rotavator (PT14+R), zero tillage with happy seeder (ZT) and conventional practices (CT) and irrigation scheduling based on IW/PAN-E ratio I1 (0.6) I2 (0.8) and I3 (1.0) on soil water balance and crop growth for two consecutive years (2016-17 and 2017-18). During both the year straw and grain yield was significantly higher in I3 over I1 and I2 by 46.05 & 38.5% and 8.72% & 11.30 % respectively. Significantly higher water productivity was observed in I2 over I1 and I3 by 27.38 & 2.26% in 2016-17 and 27.70 & 1.91% in 2017-18. During both year higher water stored by ZT & I3 over PT25+R, PT14+R, CT, I1 and I2. During both year highest water depleted under PT14+R & I1 over PT25+R, ZT, CT, I2 and I3. Overall mean of number of tillers, leaf area index, root length and mass density were significantly higher under PT25+R over PT14+R, ZT and CT.

Keywords: soil organic carbon**,** water productivity, wheat, irrigation and mouldboard plough tillage

1. Introduction

Rice-wheat cropping system is the most prevalent production system in the world, with 24 million hectares (Mha) in Asia [1]. Rice is cultivated on 43.8 Mha in India, producing 118.43 Mt grain and an estimated 165.8 Mt straw. Punjab, Haryana, and Uttar Pradesh accounts for 6.67%, 3.31%, and 13.11% of the total area and 9.95%, 4.07%, and13.11% of the total production in 2019-2020, respectively [2]. Wheat is the most widely grown cereal crop in terms of area as well as productivity [3]. Punjab serves as the food bowl of the India, it contributes about 40%–45% of wheat and 25%–30% to the central pool of India. The state has about 28.94 lakh hectares (ha) under rice cultivation [4]. Residue generation from rice is a major issue in the north western Indo-Gangetic plains (Punjab, Haryana and U.P).

Because of wheat planting and paddy harvesting, the window period is quite brief. Therefore, handling the paddy straw calls for a huge number of inexpensive machines. Traditional rice stubble inclusion requires a minimum of 4-5 discing procedures, which are time- and energy-intensive and expensive for small farmers. Although deep ploughing uses more energy to incorporate rice leftovers into the soil, it improves seed germination and root development for greater absorption of water and nutrients [5]. Other methods include Happy Seeder and zero-tillage direct drilling of wheat in standing rice stubbles. Among them, Happy Seeder is a more affordable technique, but it has several drawbacks, including unsatisfactory performance in fields with a lot of straw [6]. The main issue with the rice-wheat cropping technique is the yellowing of the wheat caused by water stagnation after the initial irrigation [7] due to the puddling's subsurface compaction.

In addition to burning crop debris, Punjab also faces a groundwater shortage issue. According to the recommendations of the Ground Water Resources Estimation Committee (GEC), the current ground water development in the state is 145% based on the most recent information provided by the Central Ground Water Board (Government of India 2011). The fact that the water in a significant portion of the region is saline and unusable for irrigation despite having a good groundwater balance is another cause for concern. It's crucial to be aware that just 21% of the area in central Punjab that is irrigated by canals out of the 72% that is planted with paddy [8]. Therefore, the current study was undertaken to investigate the impact of irrigation timing and residue management tillage on wheat growth and water production.

2. Materials and Methods

Site & weather

Field experiment was carried out with wheat after paddy during the 2016–17 and 2017–18 at the University Seed Farm in Ladhowal, Ludhiana (30°58'29"N latitude and 75°47'15"E longitude at a height of 247 metres above mean sea level). The region experiences hot, dry summers from April to June, hot, humid weather from July to September, and chilly winters from November to January. The climate is subtropical and semi-arid. Mean maximum and lowest temperatures vary significantly throughout the year in different seasons. However, with dry summer spells, July temperatures hover around 38°C and reach 45°C [9]. Frequent icy spells occur during the winter, especially in December and January, when the minimum temperature can drop as low as 0.5°C. The region experiences 600–700 mm of rainfall on average per year, with July to September accounting for around 80% of the total [10]. Figures 1 and 2 show the meteorological data during the November to April wheat growing season.

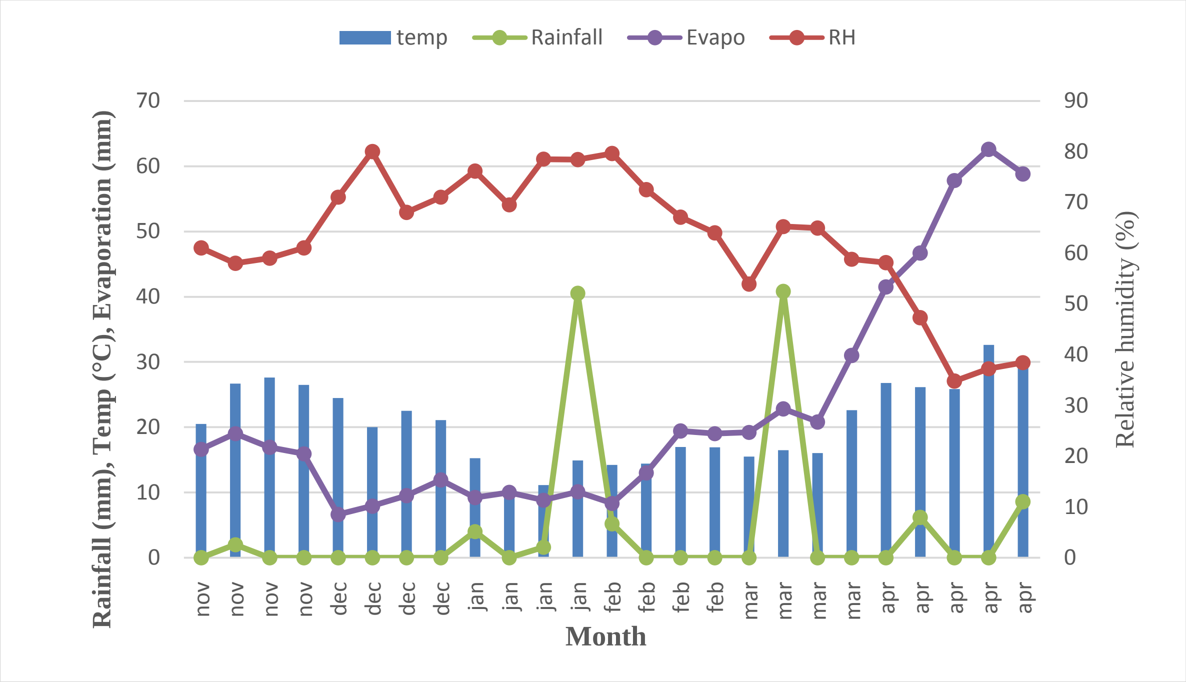

Fig. 1: Weekly average mean air temperature, relative humidity, pan evaporation and weekly rainfall and during the crop growing season 2016-17

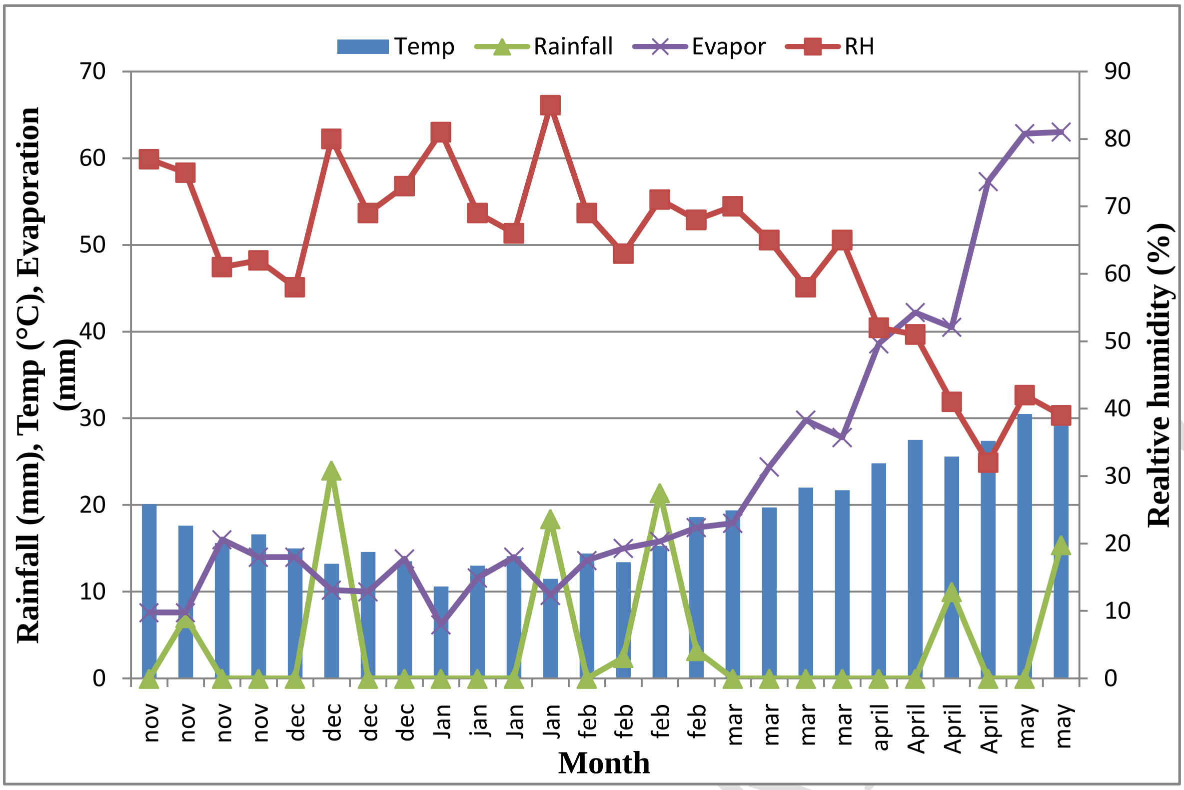

Fig. 2: Weekly average mean air temperature, relative humidity, pan evaporation and weekly rainfall and during the crop growing season 2017-18

Soil characteristics

The composite soil samples were taken at random between 0 and 15 cm below the surface. The samples were sieved through a 2.0 mm sieve for soil texture, pH, EC, soil organic carbon, and accessible N, P, and K analyses after initially being air dried in the shade (Supplementary Table 1).

Experimental details

The experiment was started during the 2016 rabi season with four tillage treatments and three irrigation treatments, including (PT25+R Primary tillage to 252 cm depth with mould board plough followed by rotavator, PT14+R Primary tillage to 142 cm depth with mould board plough followed by rotavator, ZT Zero Tillage, Wheat sowing with Happy Seeder in paddy straw, CT Conventional Tillage, two discing + two cultivator followed by Before the experiment began, the land had been continuously planted with rice and wheat for more than ten years.

With the aid of a seed cum fertiliser drill and a row spacing of 20 cm, wheat was planted on the 15th of November 2016 and the 18th of November 2017 at a seed rate of 100 kg ha^{-1}. The various agronomic procedures were carried out in accordance with the needs of the experiment. The crop was planted at the ideal soil moisture level. For crop growth, we adhered to the entire package of recommendations made by PAU, Ludhiana. In both seasons, the wheat was harvested on April 20 (2017 & 2018).

Fertilizers were sprayed at the rates of 125 kg N ha^{-1} in the form of urea and 62.5 kg P_2O_5 ha^{-1} in the form of single superphosphate to achieve the necessary dose. Half of the N and all of the P_2O_5 were applied as the basal dose at sowing. the remaining N applied two days before to the first irrigation. By using the recommended herbicides and hand weeding at the right time, weeds were maintained under control.

Observations recorded

Every day from seeding until a constant number, the number of wheat seedlings emerging from three locations along a one-meter row length in each plot was counted. In each plot, three randomly chosen locations with a one-meter row length were used to count the effective tillers. With the aid of a metre scale, the height of ten randomly chosen plants per plot was measured at 45, 60, 75, and harvesting DAS from the ground to the plant's top. Using a leaf area metre canopy analyser, the leaf area index was measured at 50, 75, 105, and 120 DAS.

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}}$$

After harvesting, the root distribution was measured. The soil layers from which the root samples were taken ranged from 0 to 15, 15, 30, 30, 45, and 60 cm. With the aid of a core sampler with a 5 cm diameter, soil samples were taken to sample the roots. The spaces between the plant rows were sampled. In plastic nets, the root-soil cores were then gathered and cleaned. The nets were thoroughly washed under water to gently remove the roots from the soil. To get rid of any remaining weed seeds, roots, or other organic matter, the washed roots underwent additional cleaning. From the total length of roots measured by scanning to the volume of the core, the root length density (cm cm^{-3}) was determined. After being dried at 60 °C in an oven, these roots were weighed on a precision scale to determine the root mass density (g cm^{-3}). From a $25m^2$ area, the crop straw was hand gathered and threshed. Each plot's 25 m^2 of grain and straw yield was recorded in kg, and the results were then reported in t ha^{-1}.

Each plot provided a representative sample of thousand grains, which was physically counted, weighed on a precision balance, and stated in grams. The irrigation amount (liter/minute) was measured using digital flow meter installed on delivery pipe of the tube well and was divided by area to calculate irrigation water in cm. The rainfall amount (mm) was recorded on the rainy day by using rain gauge installed at the experimental site. Drainage was calculated from measuring the amount of irrigation applied and field capacity of each profile layer. The amount of water exceeding the maximum storage was calculated as drainage (cm). Potential evapotranspiration (ETm) was measured from pan evaporation (EPAN) and a relationship of time (t) following seeding through a quadratic polynomial proposed by Arora et al. [11]. Substituting daily EPAN, in this relation gave an estimate of ET m:

$$ETm/EPAN = 0.56 + 0.021t - 0.000125t^2 \quad (1)$$

ETm was partitioned to plant transpiration (Tm) and evaporation from soil surface (Em) through the crop transpiration factor Kt (equations (2) and (3) that was obtained from information on progressive leaf area index (LAI). Earlier, Rasmussen and hanks [12] and Retta and Hanks [13] used Kt from LAI for potential water supplies conditions, and the effect of reduced water on transpiration was incorporated through reduced soil water status. But apart from affecting temporal variation in soil water status, timing and amount of water additions also effect the pattern of leaf area development and hence the transpiration load T of the plant. Thus, Kt should be assessed from leaf area development for specific wetting histories for partitioning ETm into T (that equals T m under plentiful water supplies):

$$T \text{ (or Tm)} = ETmKt, \qquad (2)$$

$$Em = (1 - Kt)ETm \qquad (3)$$

This factor Kt was assumed to have a maximum value of 0.90 for LAI equal to or greater than 4.00. However, for LAI less than 4.0, Kt was made to decrease gradually through a square root relation (equation (4)) rather than linearly with decreasing LAI. This modification was considered necessary, since at low LAI, transpiration per unit LAI is more than that at high LAI.

$$Kt = 0.90(LAI/4.00)^{0.5} \quad (4)$$

Daily actual soil evaporation (Ea) was calculated by relation

$$Ea = Em\ t^{-0.30} \quad (5)$$

and actual transpiration (Ta) by

$$Ta = T \times AWF/0.5 \quad (6)$$

where AWF is plant available water in each soil layer

The profile moisture was measured up to a depth 120 cm from (0-15, 15-30, 30-60, 60-90 and 90-120 cm) thermo-gravimetrically before sowing and at the time of harvesting each crop. For profile moisture storage, the gravimetric moisture content of each layer was multiplied with bulk density and depth of layer and was expressed as mm of water and then to obtain total profile moisture storage each layer storage was added. The WP (kg ha^{-1}cm^{-1}) was measured by dividing the grain yield over total evapotranspiration (Ea+Ta) of each treatment.

$$\textbf{Water productivity} = \frac{\textbf{Grain yield}}{\textbf{ET}}$$

3. Results

Germination

The data pertaining to germination, as affected by residue management tillage practices and irrigation levels is presented in the Table 1. The number of plants m^{-1} row length as affected by tillage for residue management practices and irrigation levels were statically at par with each other. Among the tillage for residue management practices number of plants m^{-1}row length were highest in PT$_{25}$+R (36) followed by PT$_{14}$+R (35) and the minimum under CT (34) and ZT (34), respectively. Leghari et al. [14] also reported that the seedling emergence was not affected by the tillage treatments during the wheat growing seasons where CT had higher emergence than reduced tillage.

Table 1: The effect of irrigation and tillage on number of plants germination and number of tillers

Treatments	**Plant germination (m^{-1} row)**				**Number of tillers (m^{-1} row)**			
	I$_{1(0.6)}$	I$_{2(0.8)}$	I$_{3(1.0)}$	**MEAN**	I$_{1(0.6)}$	I$_{2(0.8)}$	I$_{3(1.0)}$	**MEAN**
PT$_{25}$+R	37	35	35	**36**	122	114	132	**123**
PT$_{14}$+R	35	31	39	**35**	113	114	124	**117**
ZT	37	27	37	**34**	100	105	104	**103**
CT	36	31	34	**34**	103	112	114	**110**
MEAN	**36**	**31**	**36**		**110**	**111**	**119**	
CD (p=0.05)	Tillage = NS* Irrigation = NS Tillage × Irrigation = NS				Tillage = 8.05 Irrigation = NS Tillage × Irrigation = NS			

* NS non-significant

Irrigation levels were also statistically at par with each other. Maximum germination counted in I$_1$ (36) and I$_3$ (36) and least found in I$_2$ (31) respectively. Similarly, no significant difference among tillage treatment on germinations was reported by Amin and Khan [15].

Number of tillers

The data pertaining to number of tillers as affected by tillage for residue management practices and irrigation levels is presented in the Table 1. The number of tillers were significantly affected by tillage treatments. Among the residue management tillage practices overall mean number of tillers were significantly higher under PT_{25}+R over ZT and CT by 19.42 and 11.18% respectively. However, PT_{25}+R was at par with PT_{14}+R, while CT was at par with ZT. Leghari et al. [14] also reported that mould board plough had a greater number of tillers per plant as compared to no tillage. The effect of irrigation levels on number of tillers was non-significant

Plant height

The plant height was recorded at 45, 60, 75 and 105 days after sowing during 2017-18 and is presented in Table 2. At 45 days after sowing, tillage had significant effect. The plant height under the tillage residue management treatment was significantly higher by 9.7% in PT_{25}+R as compared to ZT, however, PT_{14}+R and CT were statistically at par with each other at 45 day after sowing. The maximum plant height was recorded under PT_{25}+R (40.7 cm) which was statistically at par with PT_{14}+ R but significantly higher than the ZT and CT. Similar trend was also observed at 60 and 75 days after sowing. At 105 days after sowing, both the tillage and irrigation had significant effect on plant height. The maximum plant height was recorded under PT_{25}+R (110.1 cm) which was statistically at par with PT_{14}+R (108.5 cm) but significantly higher than ZT (102 cm) and CT (102.4 cm). The higher plant height in PT_{25}+R may be because of enhanced nutrients and moisture availability compared to CT [16]. Similarly, taller plants in deeply tilled (disc ploughed) plots than CT were recorded by Aikins and Afuakwa [17]. more moisture is likely conserved by tillage, which results in more plant height [18].

Overall higher mean plant height was observed in I_3 than I_2 and I_1 by 2.8% and 2.13% respectively. Among the different irrigation levels, the maximum plant height was recorded under I_3 (107.4 cm) which was significantly higher than I_1 (104.2 cm) and I_2 (105.7 cm). Higher plant height in I_3 may be due to more availability of water for plant growth as reported by Yousaf et al. [19]. Five irrigations increase plant height by 28.58% over one irrigation, due to no moisture stress [20]. At harvest, two irrigations at the CRI + flowering stage produced the tallest plant, whereas one irrigation produced the shortest plants [21].

Leaf area index

The leaf area index (LAI) was recorded at 50, 75, 105 and 120 days after sowing (DAS) during 2017-18 and shown in the Table 3. Among the residue management tillage practices overall mean LAI was significantly higher in PT_{25}+R over PT_{14}+R, ZT and CT by 13.45, 26.17 and 27.36 % respectively. Higher LAI was observed in PT_{25}+R over PT_{14}+R, ZT and CT in 50, 75, 105 and 120 DAS. Sun et al. [22] showed that subsoil tillage could lead to maintenance of a relatively high LAI and more prolonged LAI at different crop growth stages, which provided the possibility for plants to capture more light for photosynthesis. Shahzad et al. [23] represent that Bed sowing had better LAI while zero tilled wheat had the minimum LAI under all cropping systems at 60, 75, 90 and 105 DAS during both years. The plots where ridge sowing was used under deep tillage had the highest leaf area per plant, while the plots where flat sowing under minimum tillage was used had the least [24]. Zero tillage and reduced tillage both consistently produced much lower leaf area index than conventional tillage, which was likely due to the latter's finer seed bed preparation [25]. According to Gajri et al. [26], tilled treatments had higher leaf-area development than NT, Khan et al. [27] observed that deep tillage procedures improved leaf area index by up to 9.89%.

Table 2: The effect of irrigation and tillage on plant height (cm)

45 days after sowing				
	$I_{1(0.6)}$	$I_{2(0.8)}$	$I_{3(1.0)}$	**MEAN**
PT$_{25}$+R	41.0	39.0	42.0	**40.7**
PT$_{14}$+R	39.3	36.7	40.0	**38.7**
ZT	35.3	36.0	40.0	**37.1**
CT	35.0	37.0	40.0	**37.3**
MEAN	**37.7**	**37.2**	**40.5**	
CD (p=0.05)	Tillage = 2.31	Irrigation = NS		Tillage × Irrigation = NS
60 days after sowing				
PT$_{25}$+R	56.7	57.0	57.3	**57.0**
PT$_{14}$+R	53.7	54.0	54.3	**54.0**
ZT	51.3	51.7	52.0	**51.7**
CT	48.7	49.0	49.3	**49.0**
MEAN	**52.6**	**52.9**	**53.3**	
CD (p=0.05)	Tillage = 3.67	Irrigation = NS		Tillage × Irrigation = NS
75 days after sowing				
PT$_{25}$+R	80.2	80.7	81.0	**80.6**
PT$_{14}$+R	77.2	77.7	78.0	**77.6**
ZT	74.9	75.4	75.7	**75.3**
CT	72.2	72.7	73.0	**72.6**
MEAN	**76.1**	**76.6**	**77.0**	
CD (p=0.05)	Tillage = 3.66	Irrigation = NS		Tillage × Irrigation = NS
105 days after sowing				
PT$_{25}$+R	109.0	110.5	110.8	**110.1**
PT$_{14}$+R	106.5	108.0	110.9	**108.5**
ZT	101.4	102.9	101.6	**102.0**
CT	99.7	101.2	106.3	**102.4**
MEAN	**104.2**	**105.7**	**107.4**	
CD (p=0.05)	Tillage = 3.80	Irrigation = .88		Tillage × Irrigation = NS
Mean of irrigation mean	**67.65**	**68.1**	**69.55**	

The LAI was significantly higher both under I_3 and I_2 over I_1, at 75, 105 and 120 DAS. Overall higher mean LAI was observed in I_3 over I_1 than I_2 by 16.8 and 7.7%. Higher leaf area index with tillage and irrigation may be due to more proliferation of roots because of less bulk density [7]. Similar results have also been reported by [28-29]. Kalaydjieva et al. [30]. Reducing irrigation rates has a detrimental effect on LAI values. Subsequent irrigations, according to Benbi (1994), prolonged leaf area by slowing the process of leaf senescence. LAI generally decreased more quickly when irrigation was applied later.

Table 3: The effect of irrigation and tillage on leaf area index

50 days after sowing				
	$I_{1(0.6)}$	$I_{2(0.8)}$	$I_{3(1.0)}$	**MEAN**
PT$_{25}$+R	1.3	1.6	1.7	**1.6**
PT$_{14}$+R	1.0	1.2	1.4	**1.2**
ZT	0.8	0.9	1.3	**1.0**
CT	0.7	0.8	0.9	**0.8**
MEAN	**1.0**	**1.1**	**1.3**	
CD (p=0.05)	Tillage = 0.086	Irrigation = 0.07	Tillage × Irrigation = NS	
75 days after sowing				
PT$_{25}$+R	3.0	3.2	3.4	**3.2**
PT$_{14}$+R	2.5	2.6	2.9	**2.7**
ZT	2.1	2.4	2.7	**2.4**
CT	2.0	2.3	2.5	**2.3**
MEAN	**2.4**	**2.6**	**2.9**	
CD (p=0.05)	Tillage = 0.060	Irrigation = 0.8	Tillage × Irrigation = NS	
105 days after sowing				
PT$_{25}$+R	4.7	4.9	4.9	**4.8**
PT$_{14}$+R	4.2	4.3	4.8	**4.4**
ZT	3.4	4.1	4.4	**4.0**
CT	4.0	4.1	4.5	**4.2**
MEAN	**4.1**	**4.4**	**4.6**	
CD (p=0.05)	Tillage = 0.20	Irrigation = 0.1	Tillage × Irrigation = NS	
120 days after sowing				
PT$_{25}$+R	3.7	3.8	4.0	**3.9**
PT$_{14}$+R	3.3	3.6	3.8	**3.6**
ZT	2.9	3.4	3.7	**3.3**
CT	3.1	3.3	3.5	**3.3**
MEAN	**3.2**	**3.5**	**3.7**	
CD (p=0.05)	Tillage = 0.11	Irrigation = 0.15	Tillage × Irrigation = NS	
Mean of irrigation mean	**2.7**	**2.9**	**3.1**	

Root length density

The root length density was recorded at harvesting from 0-15, 15-30, 30-45 and 45-60 cm soil depths and given in Table 4. Overall higher mean RLD was observed in PT$_{25}$+R than PT$_{14}$+R, ZT and CT by 19.30, 61.81 and 46.17% respectively. At surface layer (0-15 cm), RLD was maximum under PT$_{25}$+R (1.108 cm cm^{-3}), which is significantly higher than PT$_{14}$+R (1.002 cm cm^{-3}) followed by CT (0.850 cm cm^{-3}) and ZT (0.749 cm cm^{-3}). Among the irrigation levels, there was no significant difference in I_3 (0.944 cm cm^{-3}), I_1 (0.933 cm cm^{-3}) and I_2 (0.905 cm cm^{-3}). Similar trend was followed under15-30 and 45-60 cm depths in tillage and irrigation treatments. Ji et al. [31] also reported significantly higher (41.4%) RLD with mouldboard over CT. However, at 30-45 cm depth, significantly higher RLD was observed under I_1 (0.363 cm cm^{-3}) compared to I_2 (0.311 cm cm^{-3}) but at par with I_3 (0.332 cm cm^{-3}). Overall higher mean RLD was observed in I_3 over I_1 and I_2 by 5.83 and 8.74% respectively.

Table 4: The effect of irrigation and tillage on root length density (cm cm^{-3})

0-15 cm				
	$I_{1(0.6)}$	$I_{2(0.8)}$	$I_{3(1.0)}$	**MEAN**
PT$_{25}$+R	1.104	1.100	1.119	**1.108**
PT$_{14}$+R	1.010	0.990	1.007	**1.002**
ZT	0.727	0.750	0.770	**0.749**
CT	0.890	0.780	0.880	**0.850**
MEAN	**0.933**	**0.905**	**0.944**	
CD (p=0.05)	Tillage = 0.065	Irrigation = NS		Tillage × Irrigation = NS
15-30 cm				
PT$_{25}$+R	0.547	0.543	0.553	**0.548**
PT$_{14}$+R	0.403	0.373	0.420	**0.399**
ZT	0.237	0.290	0.300	**0.276**
CT	0.350	0.360	0.390	**0.367**
MEAN	**0.384**	**0.392**	**0.416**	
CD (p=0.05)	Tillage =0.036	Irrigation = NS		Tillage × Irrigation = NS
30-45 cm				
PT$_{25}$+R	0.507	0.383	0.410	**0.433**
PT$_{14}$+R	0.417	0.310	0.350	**0.359**
ZT	0.283	0.303	0.313	**0.300**
CT	0.243	0.247	0.253	**0.248**
MEAN	**0.363**	**0.311**	**0.332**	
CD (p=0.05)	Tillage = 0.028	Irrigation = 0.036		Tillage × Irrigation = 0.04
45-60 cm				
PT$_{25}$+R	0.377	0.377	0.417	**0.390**
PT$_{14}$+R	0.293	0.340	0.320	**0.318**
ZT	0.197	0.197	0.227	**0.207**
CT	0.223	0.230	0.240	**0.231**
MEAN	**0.273**	**0.286**	**0.301**	
CD (p=0.05)	Tillage = 0.015	Irrigation = NS		Tillage × Irrigation = NS
Mean of irrigation mean	**0.48825**	**0.4735**	**0.49825**	

Root mass density

The root mass density was determined from 0-15, 15-30, 30-45 and 45-60 cm soil depths at harvesting and is presented in Table 5. At 0-15 cm depth, overall higher mean RMD was observed in PT$_{25}$+R than PT$_{14}$+R, ZT and CT by 35.9, 317.7 and 48.2% respectively. PT25+R (0.528 µg cm^{-3}) was significantly higher RMD over PT$_{14}$+R (0.403 µg cm^{-3}), CT (0.367 µg cm^{-3}) and ZT (0.367 µg cm^{-3}). Similarly, I_3 (0.375 µg cm^{-3}) had significantly higher RMD than I_2 (0.355 µg cm^{-3}) and I_1 (0.354 µg cm^{-3}). Similar results were found in 30-45 cm depth for tillage treatments, and irrigation levels. At

15-30 cm depth, tillage showed significant difference in RMD, but irrigation levels were at par with each other. PT_{25}+R (0.157 $\mu g\ cm^{-3}$) had significantly higher than PT_{14}+R (0.098 $\mu g/cm^3$), CT (0.092 $\mu g\ cm^{-3}$) and ZT (0.032 $\mu g\ cm^{-3}$). Ren et al. [32] found that Mouldboard plough tillage has higher root mass density than NT. Mu et al. [33] also found that deep mouldboard plough tillage has higher RMD than shallow mouldboard plough tillage. Zhao et al. [34] reported that deep tillage increased root proliferation and root penetration depth where it was employed [35], but also increased the biomass of deeper root [36].

Table 5: The effect of irrigation and tillage on root mass density ($\mu g\ cm^{-3}$)

0-15 cm				
	$I_{1(0.6)}$	$I_{2(0.8)}$	$I_{3(1.0)}$	**MEAN**
PT_{25}+R	0.503	0.530	0.550	**0.528**
PT_{14}+R	0.413	0.390	0.407	**0.403**
ZT	0.140	0.140	0.163	**0.148**
CT	0.360	0.360	0.380	**0.367**
MEAN	**0.354**	**0.355**	**0.375**	
CD (p=0.05)	Tillage = 0.012	Irrigation = 0.013		Tillage × Irrigation = 0.021
15-30 cm				
PT_{25}+R	0.190	0.157	0.220	**0.189**
PT_{14}+R	0.150	0.147	0.120	**0.139**
ZT	0.027	0.030	0.045	**0.034**
CT	0.101	0.109	0.112	**0.107**
MEAN	**0.117**	**0.111**	**0.124**	
CD (p=0.05)	Tillage = 0.037	Irrigation = NS		Tillage × Irrigation = NS
30-45 cm				
PT_{25}+R	0.150	0.150	0.170	**0.157**
PT_{14}+R	0.093	0.093	0.107	**0.098**
ZT	0.031	0.032	0.034	**0.032**
CT	0.091	0.091	0.095	**0.092**
MEAN	**0.091**	**0.092**	**0.101**	
CD (p=0.05)	Tillage =0.009	Irrigation = 0.008		Tillage × Irrigation = NS
45-60 cm				
PT_{25}+R	0.094	0.090	0.102	**0.095**
PT_{14}+R	0.094	0.045	0.080	**0.073**
ZT	0.018	0.017	0.019	**0.018**
CT	0.084	0.087	0.092	**0.088**
MEAN	**0.073**	**0.060**	**0.073**	
CD (p=0.05)	Tillage = 0.037	Irrigation = NS		Tillage × Irrigation = NS
Mean of irrigation mean	**0.15875**	**0.1545**	**0.16825**	

Straw yield

The data pertaining to straw yield recorded at harvesting during 2016-17 and 2017-18 is presented in Table 6. Among the tillage treatments, maximum straw yield was recorded under PT_{25}+Rduring both the years and had a significant effect. Overall, significantly higher straw yield was observed in PT$_{25}$+R than PT$_{14}$+R, CT and ZT by 12.31, 32.71 & 21.67 in 2016-17 and 10.45, 32.14 & 19.35 in 2017-18 respectively. The straw yield during 2016-17 was 7.3, 6.5, 6.0 and 5.5 t ha^{-1} under PT$_{25}$+R, PT$_{14}$+R, CT and ZT respectively.

Irrigation levels also showed statistically significant effect during both the years. Overall higher mean straw yield was observed in I$_3$ than I$_1$ and I$_2$ by 46 and 8.95% in 2016-17 and 47 and 8.70 in 2017-18 respectively. I$_3$ had maximum straw yield in I$_3$ (7.3 t ha^{-1}) which was significantly higher than I$_1$ (5.0 t ha^{-1}) but at par with I$_2$ (6.7 t ha^{-1}) in 2016-17. Similar results were recorded in year 2017-18. these results are in accordance with earlier study by Ali et al. [37].

The pooled analysis of two years data of straw yield showed that significantly higher straw yield was recorded under PT$_{25}$+R (7.4 t ha^{-1}) than ZT (5.6 t ha^{-1}) and CT (6.1 t ha^{-1}) and PT$_{14}$+R (6.6 t ha^{-1}). Significantly higher pooled straw yield was recorded in I$_3$ (7.40 t ha^{-1}) than I$_1$ (5.05 t ha^{-1}) and I$_2$ (6.80 t ha^{-1}).

Table 6: The effect of irrigation and tillage on straw yield and grain yield

Treatments	**Straw yield (t ha^{-1})**								**Grain yield (t ha^{-1})**							
	2016-2017				**2017-18**				**2016-2017**				**2017-18**			
	I$_{1(0.6)}$	I$_{2(0.8)}$	I$_{3(1.0)}$	**MEAN**	I$_{1(0.6)}$	I$_{2(0.8)}$	I$_{3(1.0)}$	**MEAN**	I$_{1(0.6)}$	I$_{2(0.8)}$	I$_{3(1.0)}$	**MEAN**	I$_{1(0.6)}$	I$_{2(0.8)}$	I$_{3(1.0)}$	**MEAN**
PT$_{25}$+R	6.1	7.8	8.0	**7.3**	6.3	7.9	8.1	**7.4**	4.2	5.2	5.6	**5.0**	4.4	5.3	5.8	**5.2**
PT$_{14}$+R	5.0	6.9	7.5	**6.5**	5.2	7.1	7.7	**6.7**	3.9	4.9	5.5	**4.8**	4.0	5.1	5.6	**4.9**
ZT	4.2	5.8	6.5	**5.5**	4.3	5.9	6.7	**5.6**	3.5	4.4	4.9	**4.3**	3.6	4.6	5.1	**4.4**
CT	4.4	6.4	7.3	**6.0**	4.6	6.5	7.4	**6.2**	3.7	4.6	5.2	**4.5**	3.9	4.7	5.4	**4.7**
MEAN	**5.0**	**6.7**	**7.3**		**5.1**	**6.9**	**7.5**		**3.8**	**4.8**	**5.3**		**4.0**	**4.9**	**5.5**	
CD (p=0.05)	Tillage = 0.56 Irrigation= 0.60 Tillage × Irrigation = NS				Tillage = 0.56 Irrigation = 0.93 Tillage × Irrigation = NS				Tillage =0.18 Irrigation= 0.62 Tillage × Irrigation = NS				Tillage = 0.25 Irrigation = 0.63 Tillage × Irrigation = NS			

Grain yield

The data pertaining to grain yield was recorded at harvesting during both the years and is illustrated in Table 6. Overall, significantly higher mean grain yield was observed in PT$_{25}$+R than PT$_{25}$+R, ZT and CT by 4.17, 16.28 and 11.11% in 2016-17 and 6.12, 18.18 and 10.64% in 2017-18 respectively. Among the tillage treatments maximum grain yield was recorded under PT$_{25}$+R during2016-17 and 2017-18. PT$_{25}$+R had (5.0 and 5.2 t ha^{-1}) significantly higher grain yield than PT$_{14}$+R (4.8 and 4.9 t ha^{-1}), CT (4.5 and 4.7 t ha^{-1}) and ZT (4.3 and 4.4 t ha^{-1}) for 2016-17 and 2017-18 respectively. Ding et al. [38] found that deep tillage systems increased the performance of soil amendments, which in turn improved wheat yield. Schneidera et al. [39] represent that deep tillage has the highest potential to increase yield. Higher grain yield has been observed under deep tillage compared to shallow tillage [40]. Ozpinar [41] observed that the mouldboard plough recorded higher grain production than NT because these tillage systems were more effective at controlling weeds. Lund et al [42] found that grain yield was reduced under NT by 10-15% than mouldboard plough.

Irrigation levels also have statistically significant effect on grain yield during both years. Overall, significantly higher mean grain yield was observed in I_3 than I_1 and I_2 by 39.47 and 10.41% in 2016-17 and 37.5 and 12.24 % in 2017-18 respectively. In year 2016-17 maximum grain yield was recorded in I_3 (5.3 t ha^{-1}) which is significantly higher than I_1 (3.8 t ha^{-1}) but statistically at par with I_2 (4.8 t ha^{-1}). In year 2017-18, I_3 (5.5 t ha^{-1}) had highest mean grain yield which is significantly higher than I_1 (4.0 t ha^{-1}) but statistically at par with I_2 (4.9 t ha^{-1}). Shirazi et al [35] also discovered that the 200 mm irrigation treatment produced the highest grain yield, whereas the control produced the lowest. Sarwar et al [20] and Maqsood [43] who also reported that the wheat yield increased with increase in irrigation scheduling. overall results are in accordance with Ali et al [37] and Martinez et al [44].

Water balance components and Water productivity

The data pertaining to water balance as affected by tillage and irrigation practices is represented in Table 7. Maximum ET recorded in PT_{25}+R followed by PT_{14}+R, CT and ZT during both years. ET was maximum in I_3 followed by I_2 and I_1. Maximum soil water depletion was under I_1 where less irrigation was applied in both years. More drainage was reported in I_3 where more irrigation was applied in both years. In I_2 maximum drainage observed under ZT during both years. In irrigation level I_3 maximum drainage was observed in CT and minimum drainage under PT_{14}+R during both years.

Table 7: The effect of irrigation and tillage on water balance during 2016-17 and 2017-18

Treatments		2016-17								2017-18							
		E (cm)	T (cm)	R (cm)	D (cm)	I (cm)	S (cm)	H (cm)	ΔS(cm)	E (cm)	T (cm)	R (cm)	D (cm)	I (cm)	S (cm)	H (cm)	ΔS(cm)
I_1	PT_{25}+R	7.22	27.77	9.8	0	15	22.6	12.41	8.79	27.27	7.9	0	15	21.43	8.27	13.16	10.19
	PT_{14}+R	9.38	26.1	9.8	0	15	22.6	11.92	8.50	27.05	7.9	0	15	21.43	8.78	12.65	10.68
	ZT	8.65	25.5	9.8	0	15	22.6	13.25	8.42	25.8	7.9	0	15	21.43	10.11	11.32	9.35
	CT	9.91	25.4	9.8	0	15	22.6	12.09	8.48	26.9	7.9	0	15	21.43	8.95	12.48	10.51
I_2	PT_{25}+R	6.24	28.18	9.8	0	15	22.6	12.98	4.56	29.9	7.9	0	15	21.43	9.87	11.56	9.62
	PT_{14}+R	8.6	26.78	9.8	0	15	22.6	12.02	6.92	28.5	7.9	0	15	21.43	8.91	12.52	10.58
	ZT	6.18	26.48	9.8	1.51	15	22.6	13.23	4.5	28.2	7.9	1.40	15	21.43	10.23	11.20	9.37
	CT	6.93	26.98	9.8	1.19	15	22.6	12.3	5.25	28.7	7.9	1.11	15	21.43	9.27	12.16	10.3
I_3	PT_{25}+R	9.48	29.19	9.8	3.12	22.5	22.6	13.11	8.21	30.5	7.9	3.00	22.5	21.43	10.12	11.31	9.49
	PT_{14}+R	10.87	28.99	9.8	2.64	22.5	22.6	12.4	9.6	30.3	7.9	2.53	22.5	21.43	9.40	12.03	10.2
	ZT	9.97	28.19	9.8	3.37	22.5	22.6	13.37	8.7	29.5	7.9	3.22	22.5	21.43	10.41	11.02	9.23
	CT	10.37	27.59	9.8	4.26	22.5	22.6	12.68	9.1	28.9	7.9	4.18	22.5	21.43	9.65	11.78	9.92

Where E stands for Evaporation, T for transpiration, R for rainfall, D for drainage I for irrigation, S for profile water storage at sowing, H for profile water storage at harvesting and ΔS for profile water depletion

The data pertaining to the effect of irrigation and tillage on water productivity is recorded illustrated in Table 8. Overall mean higher water productivity was observed in I_2 than I_1 and I_3 by 27.39 and 2.26 % in 2016-17 and 27.70 and 1.91 % in 2017-18 respectively. Maximum WP observed under I_2 was 140.0 and 143.8 kg ha^{-1} cm^{-1} for years 2016-17 and 2017-18 which was significantly higher than I_1 having WP 109.9 and 112.6 kg ha^{-1} cm^{-1} respectively. Zain et al [45] found that rise in WUE when the irrigation changed from I20 to I35, WUE declined dramatically when irrigation level changed from I35 to I50. Ali et al [37] found that the alternating deficit treatment, whereby imposed deficits at the growth period's peak tillering (jointing to shooting) and flowering to soft dough stages, followed by a single irrigation at the crown root initiation stage, produced the highest water production. It was observed that WUE increased with an increase in irrigation up to a certain limit and then tended to decrease. Tillage treatment had not any significant difference in WP during both years. However, maximum WP was found under PT_{25}+R (138.3, 141.9 kg ha^{-1} cm^{-1}) followed by PT14+R (128.9, 132.3 kg ha^{-1} cm^{-1}), ZT (128.6, 132.3 kg ha^{-1} cm^{-1}) and least under CT (119.9, 123.5 kg ha^{-1} cm^{-1}) for 2016-17 and 2017-18 respectively. Similarly, higher WP in deep tillage has been reported by Memon et al [16].

Table 8: The effect of irrigation and tillage on water productivity

Water productivity (kg ha^{-1} cm^{-1})								
	2016-17				**2017-18**			
	$I_{1(0.6)}$	$I_{2(0.8)}$	$I_{3(1.0)}$	**MEAN**	$I_{1(0.6)}$	$I_{2(0.8)}$	$I_{3(1.0)}$	**MEAN**
PT_{25}+R	121.0	150.1	144.0	**138.3**	121.1	153.8	150.7	**141.9**
PT_{14}+R	110.1	139.4	137.1	**128.9**	113.6	143.0	140.4	**132.3**
ZT	109.3	139.8	136.7	**128.6**	113.0	143.7	140.1	**132.3**
CT	99.1	130.7	130.0	**119.9**	102.7	134.5	133.3	**123.5**
MEAN	**109.9**	**140.0**	**136.9**		**112.6**	**143.8**	**141.1**	
CD (p=0.05)	Tillage = NS Irrigation= 17.7 Tillage × Irrigation = NS				Tillage = NS Irrigation = 17.3 Tillage × Irrigation = NS			

Soil organic carbon

SOC affected with tillage practices is shown in Table 9. SOC was significantly more in ZT by 12.9% and 12.8% than CT during 2016–17 and 2017–18 respectively. However, in both years SOC was at par in PT_{25} + R, PT_{14} + R and CT. High SOC in ZT may be carbon addition from rice residues on the surface and more crop residues decomposition with different tillage treatments. Bhattacharyya et al [46] had found that significantly higher SOC than by 14%. Hazarika et al. [47] also reported 14% and 17% higher SOC in surface soil under ZT than rotary tillage and CT practices respectively.

Table 9. The effect of tillage on soil organic carbon of different years.

Soil organic carbon (g kg^{-1})	Tillage treatments				
Year of experiment	PT_{25} + R	PT_{14} + R	ZT	CT	**CD (p=0.05)**
2016-17	6.66	6.48	7.36	6.41	**0.46**
2017–18	6.92	6.68	7.45	6.50	**0.47**

5. Conclusions

This is concluded that primary tillage up to 45 cm depth followed by rotavator pulverize the soil which helps in more penetration of roots into the deeper layer which enhances uptake of nutrients and moisture, ultimately increasing crop ET, growth and yield. Minimum water depletion and lower ET loss was observed in ZT due to less root growth. $I_{3(1.0)}$ found higher crop yield due to availability of moisture throughout the cropping season, crop experiences no moisture stress Water productivity found to be significantly higher in $I_{2(0.8)}$ which effectively use irrigation water without stress and minimum loss of water. Overall, significantly higher ET was observed in $I_{3(1.0)}$.

References

1. Nawaz, A.; Farooq, M.; Nadeem, F.; Siddique, K.H.M.; Lal, R. Rice wheat cropping systems in South Asia: issues, options and opportunities. *Crop Pasture Sci* **2019**, 70(5), 395–427.
2. Kaur, M.; Malik, D.P.; Malhi, G.S.; Sardana, V.; Bolan, N.S.; Lal, R.; Siddique, K.H. Rice residue management in the Indo-Gangetic Plains for climate and food security. A review. *Agron Sust Devlp* **2022,** 42(5), 92.
3. Dhaliwal, S.S.; Sharma, V.; Shukla, A.K.; Gupta, R.K.; Verma, V.; Kaur, M.; Singh, P. Residual Effect of Organic and Inorganic Fertilizers on Growth, Yield and Nutrient Uptake in Wheat under a Basmati Rice–Wheat Cropping System in North-Western India. *Agric* **2023,** 13(3), 556.
4. Kumar, S.; Kaur, B. Impact of climate change on the productivity of rice and wheat crops in Punjab. *Econ Pol Weekly* **2019,** 54(46), 38-44.
5. Amin, M.; Khan, M.J. Response of wheat growth characteristics to various tillage practices and sowing methods under semi-arid environment. *Sarhad J Agric* **2013,** 29(4), 529-535.
6. Sidhu, H.S.; Humphreys, E.; Dhillon, S.S.; Blackwell, J.; Bector, V. The Happy Seeder enables direct drilling of wheat into rice stubble. *Australian J Exper Agric* **2007,** 47(7), 844-854.
7. Singh, M.; Singh, K.B. Effect of Tillage for Rice Residue Management on Physical Properties of Soil. *Comm Soil Sci Plant Anal* **2021,** 52(18), 2098-2109.
8. Kumar, P.; Kumar, S.; Joshi, L. Socioeconomic and environmental implications of agricultural residue burning: A case study of Punjab, India (p. 144). *Springer Nature,* **2015**. DOI 10.1007/978-81-322-2014-5
9. Kingra, P.K.; Kaur, P. Effect of dates of sowing on thermal utilization and heat use efficiency of groundnut cultivars in central Punjab. *J Agric Phy* **2012,** 12(1), 54-62.
10. Krishan, G.; Chandniha, S.K.; Lohani, A.K. Rainfall trend analysis of Punjab, India using statistical non-parametric test. *Curr Wrld Envir* **2015**, 10(3), 792-800.
11. Arora, V.K.; Prihar, S.S.; Gajri, P.R. Synthesis of a simplified water use simulation model for predicting wheat yields. *Water Reso Res* **1987,** 23(5), 903-910.
12. Rasmussen, V.P.; Hanks, R.J. Spring Wheat Yield Model for Limited Moisture Conditions 1. *Agron J* **1978,** 70(6), 940-944.
13. Retta, A.; Hanks, R.J. Manual for using model plantgro. Utah State University, **1980.**
14. Leghari, N.; Mirjat, M.S.; Mughal, A.Q.; Rajpar, I.; Magsi, H. Effect of different tillage methods on the growth, development, yield and yield components of bread wheat. *Agro Agric Res* **2015,** 6, 36-46.
15. Amin, M.; Khan, M. J. Response of wheat growth characteristics to various tillage practices and sowing methods under semi-arid environment. *Emergence* **2013,** *1000*(2).
16. Memon, S.Q.; Mirjat, M.S.; Mughal, A.Q.; Amjad, N. Effect of conventional and non-conventional tillage practices on maize production. *Pak J Agri Agril Engg Vet Sci* **2013,** 29(2), 155-163.

17. Aikins, S.H.M.; Afuakwa, J.J. Effect of four different tillage practices on cowpea performance. *World J Agric Sci* **2010,** 6(6), 644-651.

18. Licht, M.A.; Al-Kaisi, M. Strip-tillage effect on seedbed soil temperature and other soil physical properties. *Soil Till res* **2005,** 80(1-2), 233-249.

19. Yousaf, M.; Fahad, S.; Shah, A.N.; Shaaban, M.; Khan, M.J.; Sabiel, S.A.I.; Osman, K.A. The effect of nitrogen application rates and timings of first irrigation on wheat growth and yield. Int. J. *Agric Innovat Res* **2014,** 2(4), 645-65.

20. Sarwar, N.; Maqsood, M.; Mubeen, K.; Shehzad, M.; Bhullar, M.S.; Qamar, R.; Akbar, N. Effect of different levels of irrigation on yield and yield components of wheat cultivars. *Pak J Agri Sci* **2010,** 47(3), 371-374.

21. Rummana, S.; Amin, A.K.M.R.; Islam, M.S.; Faruk, G.M. Effect of irrigation and mulch materials on growth and yield of wheat. *Bangladesh Agron J* **2018,** 21(1), 71-76.

22. Sun, J.; Gao, J.; Wang, Z.; Hu, S.; Zhang, F.; Bao, H.; Fan, Y. Maize canopy photosynthetic efficiency, plant growth, and yield responses to tillage depth. *Agron* **2019,** 9(1), 3.

23. Shahzad, M.; Farooq, M.; Jabran, K.; Yasir, T.A.; Hussain, M. Influence of Various Tillage Practices on Soil Physical Properties and Wheat Performance in Different Wheat-based Cropping Systems. *Intrn J Agric Bio* **2016,** 18(4), 821-829.

24. Anjum, S.A.; Ashraf, E.U.; Tanveer, M.; Qamar, R.; Khan, I. Morphological and phenological attributes of maize affected by different tillage practices and varied sowing methods. *American J Plant Sci* **2014,** 5(11), 180-188.

25. Gangwar, K.S.; Singh, K.K.; Sharma, S.K. Effect of tillage on growth, yield and nutrient uptake in wheat after rice in the Indo-Gangetic Plains of India. *J Agric Sci* **2004,** 142(4), 453-459.

26. Gajri, P.R.; Arora, V.K.; Prihar, S.S. Tillage management for efficient water and nitrogen use in wheat following rice. *Soil Till Res* **1992,** 24(2), 167-182.

27. Khan, S.; Shah, A.; Nawaz, M.; Khan, M. Impact of different tillage practices on soil physical properties, nitrate leaching and yield attributes of maize (Zea mays L.). *J soil sci plant nut* **2017,** 17(1), 240-252.

28. Qamar, R.; Rehman, A.; Ali, A.; Ghaffar, A.; Mahmood, A.; Javeed, H.M.R.; Aziz, M. Growth and economic assessment of wheat under tillage and nitrogen levels in rice-wheat system. *American J Plant Sci* **2013,** 4(11), 20830-2091.

29. Xu, X.; Zhang, M.; Li, J.; Liu, Z.; Zhao, Z.; Zhang, Y.; Wang, Z. Improving water use efficiency and grain yield of winter wheat by optimizing irrigations in the North China Plain. *Field Crops Res* **2018,** 22, 219-227.

30. Kalaydjieva, R.; Matev, A.; Zlatev, Z. Influence of irrigation regime on the leaf area and leaf area index of French bean (Phaseolus vulgaris L.). *Emir J Food Agric* **2015,** 171-177.

31. Ji, B.; Zhao, Y.; Mu, X.; Liu, K.; Li, C. Effects of tillage on soil physical properties and root growth of maize in loam and clay in central China. *Plant Soil Env* **2013,** *59*(7), 295-302.

32. Ren, B.; Li, X.; Dong, S.; Liu, P.; Zhao, B.; Zhang, J. Soil physical properties and maize root growth under different tillage systems in the North China Plain. *Crop J* **2018,** *6*(6), 669-676.

33. Mu, X.; Zhao, Y.; Liu, K.; Ji, B.; Guo, H.; Xue, Z.; Li, C. Responses of soil properties, root growth and crop yield to tillage and crop residue management in a wheat–maize cropping system on the North China Plain. *European J Agron* **2016,** *78*, 32-43.

34. Zhao, Y.; Pang, H.; Wang, J.; Huo, L.; Li, Y. Effects of straw mulch and buried straw on soil moisture and salinity in relation to sunflower growth and yield on the Loess Plateau of China. *Soil Till Res* **2014**, 161, 16-25.

35. Shirani, H.; Hajabbasi, M.A.; Afyuni, M.; Hemmat, A. Effects of farmyard manure and tillage systems on soil physical properties and corn yield in Central Iran. *Soil Till Res* **2002,** 68**,** 101–08.

36. Varsa, E.C.; Chong, S.K.; Abolaji, J.O.; Farquhar, D.A.; Olsen, F.J. Effect of deep tillage on soil physical characteristics and corn (*Zea mays* L.) root growth and production. *Soil Till Res* **1997,** *43***,** 219–28.

37. Ali, M.H.; Hoque, M.R.; Hassan, A.A.; Khair, A. Effects of deficit irrigation on yield, water productivity, and economic returns of wheat. *Agric Water Mang* **2007,** 92(3), 151-161.

38. Ding, Z.; Kheir, A.M.; Ali, O.A.; Hafez, E.M.; ElShamey, E.A.; Zhou, Z.; Seleiman, M.F. A vermicompost and deep tillage system to improve saline-sodic soil quality and wheat productivity. *J Envl Mang* **2021,** 277, 111388.

39. Schneider, F.; Don, A.; Hennings, I.; Schmittmann, O.; Seidel, S.J. The effect of deep tillage on crop yield–What do we really know? *Soil till res* **2017,** 174, 193-204.

40. Alamouti, M.Y.; Navabzadeh, M. Investigating of plowing depth effect on some soil physical properties. *Pakistan J Bio Sci* **2007,** 10(24), 4510-4514.

41. Ozpinar, S. Effects of tillage systems on weed population and economics for winter wheat production under the Mediterranean dryland conditions. *Soil Till Res* **2006,** 87(1), 1-8.

42. Lund, M.G.; Carter, P.R.; Oplinger, E.S. Tillage and crop rotation affect corn, soybean, and winter wheat yields. *J Prod Agric* **1993,** *6*(2), 207-213.

43. Maqsood, M.; Ali, A.S.I.F.; Aslam, Z.; Saeed, M.; Ahmad, S. Effect of irrigation and nitrogen levels on grain yield and quality of wheat (Triticum aestivum L). *Int J Agri Biol* **2002,** 4(1), 164-165.

44. Martínez, E.; Fuentes, J.P.; Silva, P.; Valle, S.; Acevedo, E. Soil physical properties and wheat root growth as affected by no-tillage and conventional tillage systems in a Mediterranean environment of Chile. *Soil Till Res* **2008,** 99(2), 232-244.

45. Zain, M.; Si, Z.; Li, S.; Gao, Y.; Mehmood, F.; Rahman, S.U.; Duan, A. The coupled effects of irrigation scheduling and nitrogen fertilization mode on growth, yield and water use efficiency in drip-irrigated winter wheat. *Sustainability* **2021**, 13(5), 2742.

46. Bhattacharyya, R.; Pandey, S.C.; Bisht, J.K.; Bhatt, J.C.; Gupta, H.S.; Tuti, M.D.; Kundu, S. Tillage and irrigation effects on soil aggregation and carbon pools in the Indian sub-Himalayas. *Agronomy J* **2013,** 105(1), 101–12.

47. Hazarika, S.; Parkinson, R.; Bol, R.; Dixon, L.; Russell, P.; Donovan, S.; Allen, D. Effect of tillage system and straw management on organic matter dynamics. *Agron Sustainable Develop* **2009,** 29 (4), 525–33.