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National Academy of Agricultural Science (NAAS) Rating : 3. 03

Effect of Tillage Practices and Irrigation Regimes on Soil Profile Moisture Distribution and Maize (*Zea mays* L.) Growth

Kunal Khurana[1] *and Meharban Singh Kahlon*[1*]

Abstract: *Irrigation regimes in relation to tillage practices significantly affect soil profile moisture distribution and crop growth parameters such as plant height, relative leaf water content, chlorophyll content and stover yield. Hence, a study was conducted with three irrigation regimes i.e. IW/PAN-E 0.6, 0.9 and 1.2 ($I_{0.6,}$ $I_{0.9}$ and $I_{1.2}$) and four tillage practices i.e. no-tillage with residue (NT), strip tillage (ST), conventional tillage (CT), deep tillage (DT). At 80 DAS, maximum soil profile moisture storage (cm) was recorded in NT (23.1) followed by ST (20.1), CT (19.4) and DT (18.9). The least $\grave{e}_v$ was observed in $I_{0.6}$ as compared to other irrigation regimes ($I_{0.9}$ and $I_{1.2}$). At harvest, $\grave{e}_v$ decreased considerably and it ranged from 3.8-11.3% throughout the soil profile among different irrigation regimes. The frequently irrigated regime ($I_{1.2}$) stored more moisture than other two regimes due to more number of irrigation applied. At harvest, maximum soil moisture storage was observed at $I_{1.2}$ (11.6) followed $I_{0.9}$ (10.7) and least under $I_{0.6}$ (9.9). The plant height in NT treatment (276.0) was significantly greater than other tillage treatments. The highest chlorophyll content was observed in ST (54.2) followed by DT (52.9), NT (52.8) and CT (51.0). No significant differences in RLWC were reported among different tillage practices and irrigation regimes. The DT (11.6 Mg ha^{-1}) showed significantly higher stover yield followed by ST (11.3 Mg ha^{-1}), NT (10.2 Mg ha^{-1}) and CT (9.5 Mg ha^{-1}). Likewise tillage practices, irrigation regimes also experienced a significant effect on maize stover yield. The mean highest maize stover yield was found under $I_{1.2}$ (11.8 Mg ha^{-1})*

Keywords: *Moisture distribution, tillage, irrigation, stover yield, maize.*

INTRODUCTION

Tillage is practice of modifying state of soil in order to provide suitable conditions for the growth of crops. Tillage has been part of most agricultural systems throughout history, because it achieves many agronomic objectives (*e.g.*, seed bed preparation, soil conditioning, weed suppression, land and residue management). But, the excessive tillage without residue management practices adversely affect soil health, crop productivity and environment quality by affecting soil structure and soil carbon loss (Alam *et al* 2014). There are also chances of hard pan formation at sub surface soil layer due to conventional tillage practices. This hard pan restricts the root proliferation and also affects the water transmission characteristics of soil. As a solution to solve this problem, deep tillage (DT) is the most preferred practice. On the other hand, conservation tillage results in retention of more than 30% of crop residue that helps in improving the overall soil quality, carbon sequestration and crop productivity (Tessier *et al* 1990). Many researchers reported that NT conserved more water which significantly improved the corn grain yield and water use efficiency (Su *et al* 2007, Wang *et al* 2009, Sharma *et al* 2011 and Wang *et al* 2011). Studies in Punjab (Kukal and Aggarwal 2003 and Singh *et al* 2009) have shown the presence of high bulk density layer at 15-25 cm soil depth, which may affect the growth of maize due to reduced root proliferation (Gajri *et al* 1994). Thus, chiselling of such soils could help to improve the root system of the crop for better

[1] Department of Soil Science, Punjab Agricultural University, Ludhiana. 141004. Pb, India
* *Corresponding author. Email: dr.mskahlon@rediffmail.com*

exploitation of deeper layers for moisture and nutrients. Water stress (both due to excessive and deficient soil moisture conditions) at any growth stage of maize crop reduces its land as well as water productivity (WP) (Paudyal *et al* 2001). However, optimum irrigation is a solution to this problem. The knowledge of maize crop performance at various stages of water deficit in a semi-arid environment is important to improve WP. Water scarcity is considered to be the primary limiting factor affecting maize production in the semiarid areas; shortages and uneven distribution of water resources throughout the year restricts crop growth (Kang *et al* 2002 and Wang *et al* 2009). The cultural practices can help in conserving water by influencing the hydrothermal properties of the soil. For example, mulching and tillage can affect the temperature and moisture content of the soil (Li *et al* 1999 and Acharya *et al* 2005) and directly influence the micro-climate of the field (Ramalan and Nwokeocha 2000 and Li *et al* 2001). Straw mulching systems conserve soil water and reduce temperature because they reduce soil disturbance and increase residue accumulation at the soil surface (Zhang *et al* 2009a). However, effect of different irrigation regimes on maize yield were reported only under CT practices by different workers (Kang *et al* 2000, Ko and Piccinni 2009 and El-Halim and El-Razek 2014). Research is needed to develop site-specific packages of technologies that are user friendly, meet the local bio-climate and can be implemented for enhancing soil health and crop productivity. Therefore, a study is planned to test the hypothesis that soil moisture storage and maize growth parameters may differ under conservation tillage (NT and ST) and other tillage (CT and DT) practices.

MATERIAL AND METHODS

The field experiment was conducted during *kharif* 2014 in sandy loam soil at research farm of Department of Soil Science, Punjab Agricultural University, Ludhiana (30° 56 N, 75° 52′ E, 247 m above the mean sea level), Punjab, India. The area is characterized by sub-tropical and semi-arid type of climate with hot and dry summer from April to June followed by hot and humid period during July to September and cold winters from November to January. The average rainfall of the area is 600-700 mm, of which about 80 percent is received during July to September. The mean maximum and minimum air temperatures show considerable fluctuations during different parts of the year. Summer temperature is generally around 38°C and rises up to 45°C with dry summer spells. Winter experiences frequent frosty spells especially in December and January and minimum temperature dips up to 0.5°C. The meteorological data on maximum and minimum temperature, evaporation and rainfall was collected from the meteorological observatory of the Punjab Agricultural University, Ludhiana located at a distance of 2.5 km from the experimental field during the crop growing season (June to October). Composite soil samples were taken randomly from 0-15 cm depth. The samples collected from field were first air dried in shade and then sieved through 2.0 mm sieve and analysed for various physico-chemical properties (Table 1).

Table 1
Basic soil physico-chemical properties of experimental field

Soil parameters	*Range values*	*Soil parameters*	*Range values*
Sand (%)	66.8-68.3	pH	7.37-7.58
Silt (%)	19.1-21.4	EC (dS m^{-1})	0.20-0.23
Clay (%)	11.8-12.6	Organic carbon (g kg^{-1} soil)	2.72-3.42
Soil type	Sandy loam	Available N (kg ha^{-1})	122.0-126.8
Bulk density (Mg m^{-3})	1.38 -1.44	Olsen's extractable P (kg ha^{-1})	40.7-43.1
Final infiltration rate (cm hr^{-1})	2.62-3.88	Available K (kg ha^{-1})	101.2-105.6
Aggregation (MWD) (mm)	0.35-0.47	Field capacity (%, *v/v*)	17.8-18.9
WSA (%, > 0.25 mm)	35.7-40.3	Permanent wilting point (%, *v/v*)	7.9-8.6

The soil is non calcareous, non-saline and neutral in nature. The soil is medium in organic carbon content. The bulk density of surface soil ranged from 1.38 to 1.44 Mg m^{-3}. Water content at 0.3 bar (field capacity) and 15 bar (permanent wilting point) varied from 17.8-18.9% and 7.9-8.6% on volume basis, respectively.

Experimental Details

Treatments :

Irrigation regimes (Three)

(i) $I_{0.6}$ = IW/PAN-E ratio 0.6

(ii) $I_{0.9}$ = IW/PAN-E ratio 0.9

(iii) $I_{1.2}$ = IW/PAN-E ratio 1.2

Tillage (Four)

(i) No tillage with residue (NT): Surface wheat residue retention and sowing of maize by special attachment to happy seeder machine.

(ii) Strip tillage (ST): Seedbed is tilled in strips leaving the residue in between undisturbed

(iii) Conventional tillage (CT): Two disks followed by cultivator and planking operation

(iv) Deep tillage (DT): Deep ploughing of soil up to 45 cm followed by CT.

PREPARATION OF THE FIELD

Different tillage operations were performed on experimental field and then pre-sowing irrigation was applied. The maize crop was sown at proper moisture content. The recommended dose of fertilizers as per PAU package of practices were applied at the rate of 125 kg N ha^{-1} in the form of urea, 60 kg P_2O_5 ha^{-1} in the form of single superphosphate and 30 kg K_2O ha^{-1} in the form of muriate of potash were applied to the crop. At sowing, one third of N, all P_2O_5 and K_2O were applied as basal dose. The remaining N applied in two splits, one at knee high stage and other at pre-tasseling stage. The crop was sown in second week of June, 2014 with the recommended seed rate of 20 kg ha^{-1}. Weeds were kept under check with use of recommended herbicides and hand weeding. Crop was harvested in first week of October.

The plant height of ten randomly selected plants in each plot was measured with the help of meter scale from ground surface to apex of the plant at 80 DAS. The RLWC was determined at 80 DAS according to the method described by Barrs and Weatherley (1962) and later modified by Esparza-Rivera *et al* (2006). Three plants were randomly sampled from each plot to determine RLWC. The RLWC determination was accomplished by excising discs from the uppermost, medium and lower leaves with two discs from each leaf, thus making a total of six discs per plant and eighteen discs per plot. These disks were collected in plastic vials and weighed immediately, providing a measure of fresh weight (FW). After weighing, the disks were soaked in de-ionized water for 4 hours and then weighed again to obtain a fully turgid weight (TW). Finally, the leaf discs were dried at 60 °C till the constant weight achieved to obtain the dry weight (DW).

$$RLWC(\%) = \frac{FW - DW}{TW - DW} \times 100$$

The maize stover yields were recorded in kg from 24 m^2 area in each plot and finally expressed in Mg ha^{-1}. The data collected on various aspects of the investigations were statistically analysed as prescribed by Cochran and Cox (1967) and adapted by Cheema and Singh (1991) in statistical package CPCS-I. The treatment comparisons were made at 5% level of significance.

RESULTS AND DISCUSSION

Soil Moisture Content on Volumetric basis (θ_v, % v/v)

The data pertaining to θ_v at different soil depths as affected by tillage practices is presented in Figure 1. At sowing, the data indicate that θ_v ranged from 17.0-24.5%. Though at time of sowing the differential irrigations were not applied, even then the differences in θ_v were observed only due to different tillage and residue management practices already prevailing in the field. Mukherjee *et al* (2010) observed that evapotranspiration rate declined 31% with residue mulch. Least values of θ_v were obtained in DT in comparison to other tillage and residue management practices. In general soil moisture content increased with increasing soil depth. The plots where residue was incorporated retained higher soil moisture at 20, 35, 48 and 80 DAS. Due to interception of incoming solar energy by mulch, less water evaporated from the mulched plots. Even

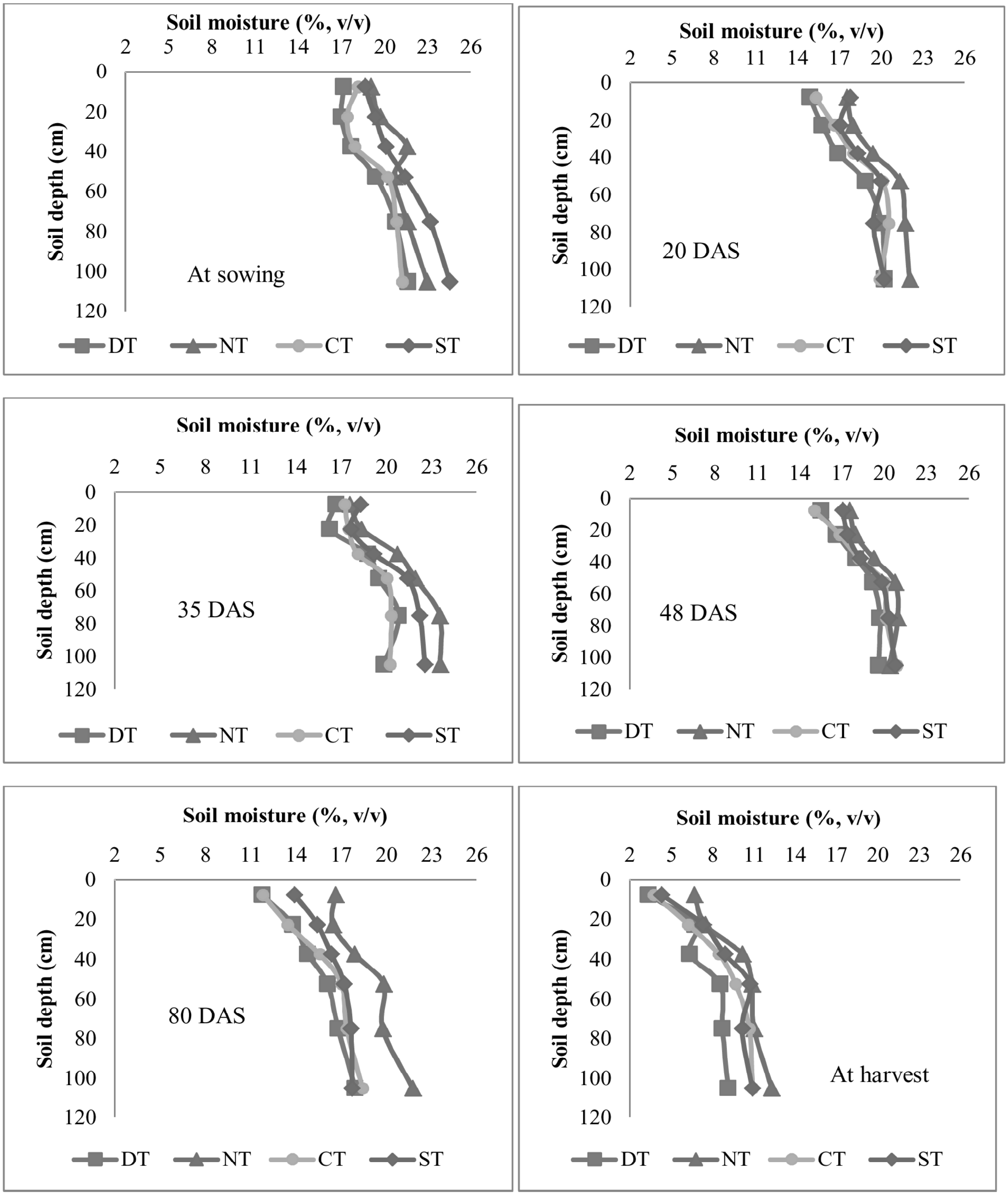

Figure 1: Effect of tillage practices on volumetric soil water content at different DAS

at harvest, NT retained higher values of soil moisture in comparison to other treatments. The data pertaining to θ_v at different soil depths as affected by irrigation regimes is presented in (Figure 2). At 20 DAS, data indicate that θ_v ranged from 15.4-21.0%. Least θ_v was observed in $I_{0.6}$ as compared to other irrigation regimes ($I_{0.9}$ and $I_{1.2}$). At harvest, θ_v decreased considerably and it ranged from 3.8-11.3% throughout the soil profile among different irrigation regimes.

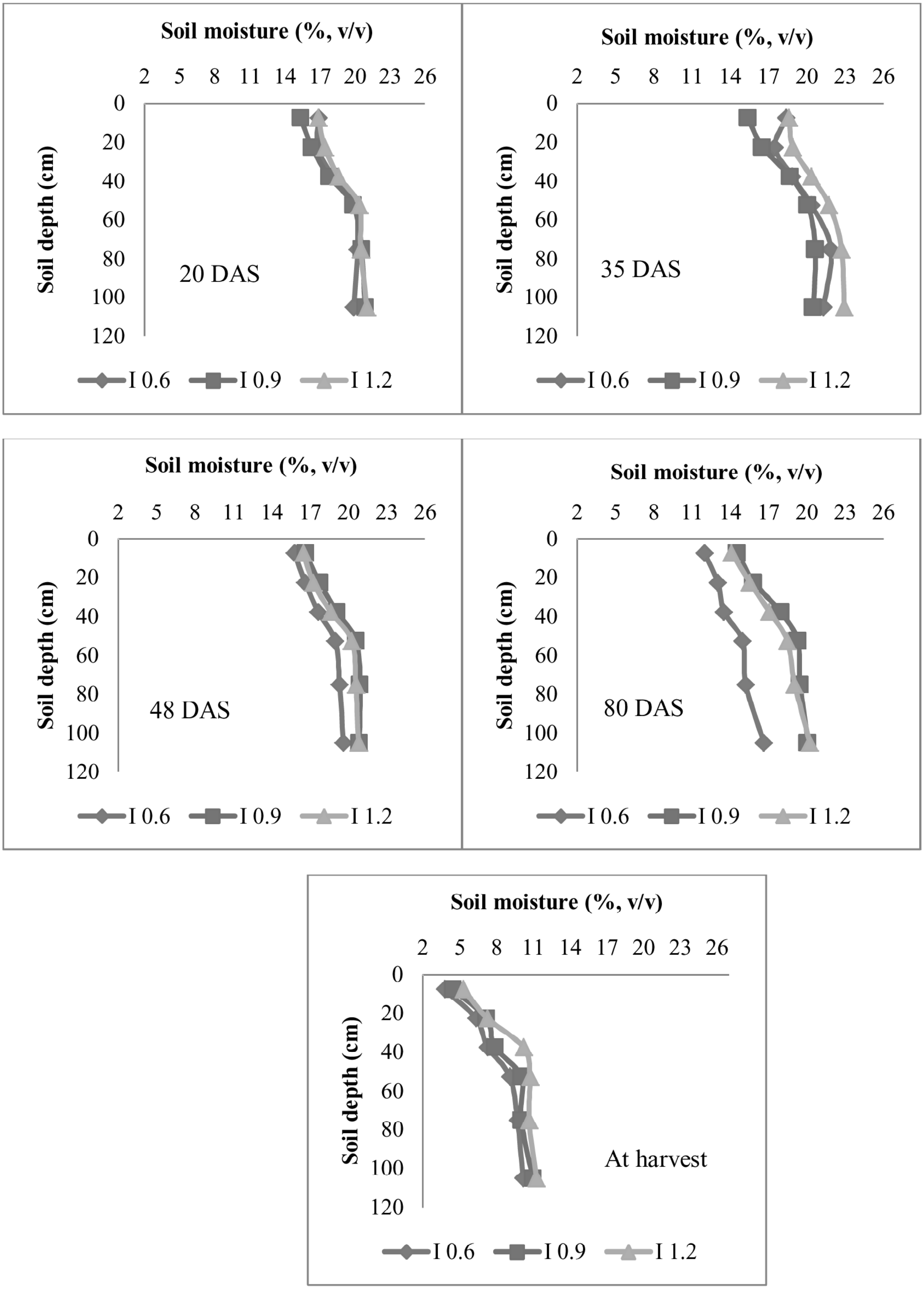

Figure 2: Effect of irrigation regimes on volumetric soil water content at different DAS

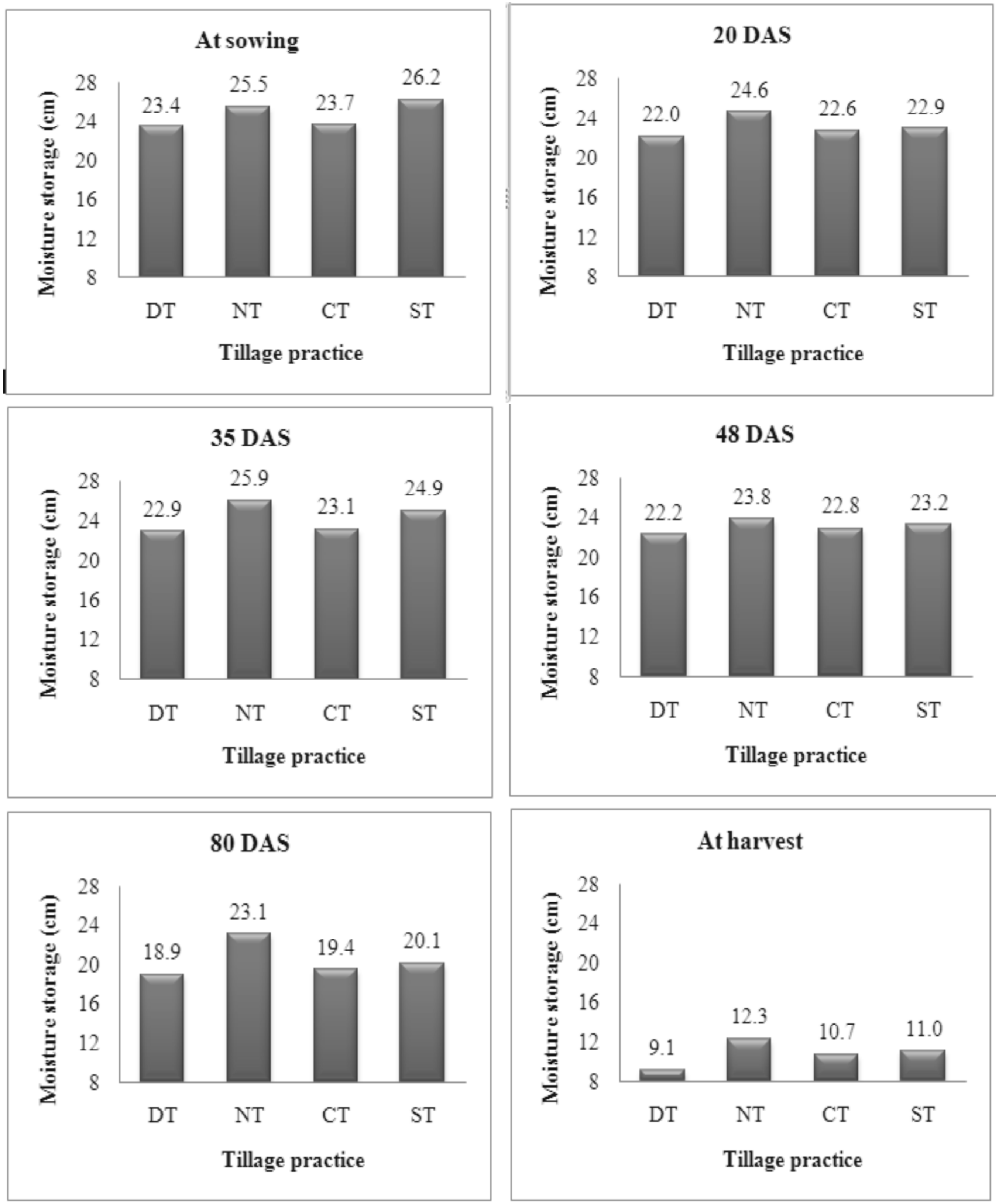

Figure 3: Effect of tillage practices on soil profile water storage at different DAS

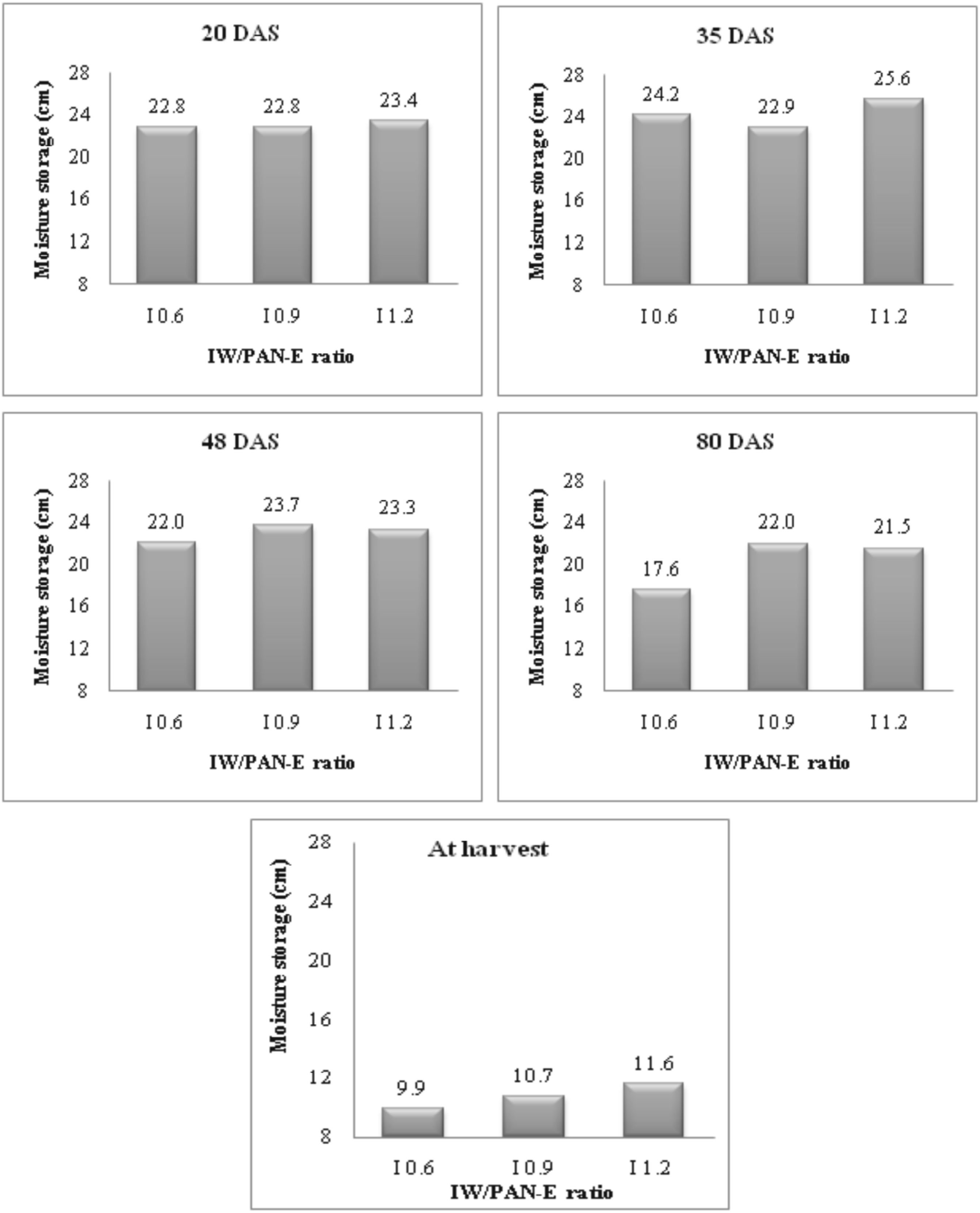

Figure 4: Effect of irrigation regimes on soil profile moisture storage

Table 2
Effect of tillage practices and irrigation regimes on plant height (cm)

	Irrigation regime			
Tillage practice	$I_{0.6}$	$I_{0.9}$	$I_{1.2}$	*Mean*
DT	246.9	253.7	258.2	252.9
NT	277.7	276.9	273.5	276.0
CT	228.4	231.2	228.7	229.4
ST	266.0	264.9	260.9	263.9

LSD (< 0.05) Tillage = 10.02 Irrigation = NS

Table 3
Effect of tillage practices and irrigation regimes on chlorophyll content

	Irrigation regime			
Tillage practice	$I_{0.6}$	$I_{0.9}$	$I_{1.2}$	*Mean*
DT	56.0	53.8	48.8	52.9
NT	55.2	55.8	47.3	52.8
CT	54.7	54.3	44.1	51.0
ST	57.2	55.1	50.2	54.2

LSD (<0.05) Tillage = 1.16 Irrigation = NS

Soil Profile Moisture Storage

The data pertaining to soil profile moisture storage (cm) as affected by tillage practices is presented in (Figure 3). The conservation tillage practices (NT and ST) stored more water in profile as less water was lost due to residue retention. The residue retention also adds to more soil water storage through reduced evaporation losses. At 80 DAS, maximum soil profile moisture storage (cm) was recorded in NT (23.1) followed by ST (20.1), CT (19.4) and DT (18.9). The data pertaining to soil profile moisture storage (cm) as affected by irrigation regimes at different DAS is presented in (Figure 4). The frequently irrigated regime ($I_{1.2}$) stored more moisture than other two regimes due to more number of irrigation applied. At harvest, maximum soil moisture storage was observed at $I_{1.2}$ (11.6) followed $I_{0.9}$ (10.7) and least under $I_{0.6}$ (9.9).

Plant Height

The data pertaining to the effect of tillage practices and irrigation regimes on plant height (cm) is presented (Table 2). It is seen that plant height in NT treatment (276.0) was significantly greater than other tillage treatments. Medium sized plants were observed in DT (252.9). However, CT showed the least value of plant height (229.4). Irrigation regimes did not show any significant change in plant height.

Chlorophyll Content and Relative Leaf Water content (RLWC)

The data presented in Table 3 demonstrates the effect of tillage practices and irrigation regimes on chlorophyll content. Healthy plants capable of maximum growth, generally can be expected to have larger amount of chlorophyll than unhealthy plants. Highest chlorophyll content was observed in ST (54.2) followed by DT (52.9), NT (52.8) and CT (51.0). However, there was decrease in chlorophyll content with increase in irrigation regimes, which adds to dilution affect with more water application. No significant differences in RLWC were reported among different tillage practices and irrigation regimes (Table 4).

Table 4
Effect of tillage practices and irrigation regimes on relative leaf water content

	Irrigation regime			
Tillage practice	$I_{0.6}$	$I_{0.9}$	$I_{1.2}$	*Mean*
DT	86.7	93.1	89.5	89.8
NT	87.3	83.8	86.4	85.8
CT	88.7	94.9	87.4	90.3
ST	92.2	89.7	94.0	92.0
Mean	88.8	90.4	89.3	

Table 5
Effect of tillage practices and irrigation regimes on maize stover yield (Mg ha^{-1})

	Irrigation regime			
Tillage practice	$I_{0.6}$	$I_{0.9}$	$I_{1.2}$	*Mean*
DT	10.3	11.6	12.9	11.6
NT	9.2	10.2	11.2	10.2
CT	8.7	9.5	10.4	9.5
ST	10.0	11.3	12.6	11.3

LSD (< 0.05) Tillage = 0.57 ; Irrigation = 0.31; Interaction = NS

Stover Yield

Tillage practices showed a significant effect on maize stover yield (Table 5). Numerically, DT (11.6 Mg ha^{-1}) showed significantly higher maize stover yield followed by ST (11.3 Mg ha^{-1}), NT (10.2 Mg ha^{-1})

and CT (9.5 Mg ha^{-1}). Similar results were obtained by (Khurshid*et al* 2006 and Khan *et al* 2007). Irrespective of tillage practices, irrigation regimes also experienced a significant effect on maize stover yield. The mean highest maize stover yield was found under $I_{1.2}$ (11.8 Mg ha^{-1}) followed by $I_{1.2}$ (10.7 Mg ha^{-1}) and $I_{0.6}$ (9.6 Mg ha^{-1}).

CONCLUSION

The volumetric water content was observed to be higher under NT in comparison to other tillage practices. Higher moisture storage under NT may be due to more macroporosity under undisturbed soil condition and continuity of pore channels, moreover the mulching effect under NT reduces evaporation losses and allows more water to infiltrate. Highest plant height (cm) was experienced under NT (276 cm) and least under CT (229.4). The RLWC was found to be non- significantly affected by tillage practices and irrigation regimes. Maize stover yield was also found to be significantly affected by tillage practices and irrigation regimes. DT recorded highest stover yield (11.6 Mg ha^{-1}) while CT recorded the least (9.5 Mg ha^{-1}). Amongst irrigation regimes, lowest stover yield were found under $I_{0.6}$ (9.6 Mg ha^{-1}) while highest were recorded under $I_{1.2}$ (11.8 Mg ha^{-1}).

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