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Research Paper

Response of Chickpea to Tillage Practices in Continuous Rotation with Wheat Under Spate Irrigation in Arid Environment

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In Pakistan wheat and chickpea constitute are the most important cropping system. The main objectives of this study were to evaluate the effect of different tillage practices on soil physical properties and water use efficiency. The experiments were conducted in spate irrigation service area in clay soil condition with the using of different tillage implements. In this study, the plot size used was 8 m x 40 m and replicated four times under Randomized Complete Block Design (RCBD). Wheat and chickpea were sown during October and November and harvested in April-May and moisture content, bulk density, soil strength and germination were evaluated. The chickpea grain yields during the study period ranged from 2143 to 2348 kg ha^{-1}. Mean maximum grain (2348 kg ha^{-1}), biomass yields (3866 kg ha^{-1}) and water use efficiency (9.05 kg ha^{-1} mm^{-1}) were obtained with the using of tillage treatment Disc plow once and tine type cultivator three times (DPTC3). While the minimum grain and biomass yield were recorded for Moldboard plow once and Tine Type Cultivator three times (MBTC3) of 2143 kg ha^{-1} and 3057 kg ha^{-1}, respectively. It can be concluded that disk plow may be more effective for better chickpea production in clay type of soil as compared to moldboard plow or tine type of cultivator in spate irrigated area arid environment.

Keywords: Tillage practices, irrigation, chickpea and wheat rotation, arid environment.

INTRODUCTION

Chickpea (*Cicer arietinum L.*) is one of the most important pulse as well as vegetable crops in the world. Its world production was about 7.5 million metric tons in 2003 (Alguacil et al., 2008). India and Pakistan are the major producers of chickpea and it also providing importance source of protein in the subcontinent (Barzegar et al., 2003). There are two kinds' desi and Kabuli their adoptability depends on rainfall and climatic condition. In Pakistan, the chickpea was sown on an area of 1.029 million ha and its production was 0.4795 million tons with average yield of 466 kg ha^{-1} (statistics., 2007). Wheat and chickpea constitute the most important cropping system under rain-fed conditions in the Southern region of North West Frontier Province (NWFP) of Pakistan. Average chickpea yields are very low as compared to other chickpea producing countries. There are many reasons but one of the most important is the improper use of tillage practices. The major factors responsible for low crop productivity of wheat and chickpea in NWFP are: low organic matter poor soil structure, deficiency of macro and micro nutrients, imbalance fertilizer use, soil erosion and improper use of tillage practices (Boriea et al., 2006).

There is need for adoption of strategy on sound footings in respect of transfer of technology as the cultivation in the country on subsistence farms is still carried out with the help of antiquated implements and tools. There is a need for selection of an appropriate technology through which there come reduction in social costs and increase in yield per hectare enormously. The term technology in fact has become a symbol of development. Thus modernization of agriculture cannot take place without transferring of appropriate technology. Modern tillage practices should be aimed at maintaining the productivity of a given piece of land at an optimum level. In the past several studies have investigated the effect of different tillage practices on crop production (Gustavo et al., 2010).

Hobbs et al. (1986) evaluated deep tillage with mold board plough gave 52% (1.3 t/ha) and 36% (0.7 t ha^{-1}) more wheat yield than shallow cultivator in 1983-84 and 1984-85, respectively. Biomass yield was increase on average 20% due to moldboard plowing during 1984-85. Better rooting associated with breaking of compact layer below the plough layer was the major contribution to this increase of yield. Insa et al., (2017) reported that the average grain yield of chisel plough significantly higher as compared to moldboard plough and cultivator. The increase in grain yield by chisel plough occurred due to deep root system, increased root spreading due to breaking sub-soil layer increased infiltration rate, decreased run-off and soil erosion, increase water efficiency and increase soil water storage.

Tillage practices facilitate water penetration into the soil and enhance the quantity of water retained for the longer use of crop (Iris et al., 2006). Subsoil tillage improves water infiltration, decrease bulk density, penetration resistance and increase water-holding capacity as compared to no-tillage treatments on sandy loam and loam soil and water use efficiency 20 - 25% more with plowing of chisel plow as compared to cultivator in loam soil (Ishaq et al., 2001). Another studies (Jin and Ballel, 2006) found that reduction in soil cone index from approximately 100 - 150 N cm^{-2} by deep tillage as compared to shallow tillage at 40 – 45 cm depth in a silty clay loam soil. A soil with a fine crumb structure is said to be in “good tilt” (Marinez et al., 2008). A soil in good tilt breaks up easily into crumbs or granules. They allow space in the soil for air and water.

In order to evaluate the impacts of different tillage practices on topsoil properties, Marinez et al.(2003) reported that sub soiling tillage produces a significant increase in the volume of larger pores (>50 m). They found that sub soil improved and a significant decreased in the volume of the smaller pores (<10 m), resulted in an improvement of water transmission at high water content and in a decrease of water retention capacity at low water content.

Min et al. (2013) evaluated draft requirement of selected tillage implements in silty clay loam soil. Tillage implements that is, cultivator, chisel plow, sub-soiler, disk plow and disk harrow were used at the field speed of 2.5 km/ha at 13.2% moisture content in the field. They reported that the draft consume by tillage implement increases with increases in the depth of penetration. Min et al. (2013) found subsoil compaction effects on physical properties of sandy clay loam soil and yield of wheat and sorghum. Subsoil compaction reduce both water and nutrient use efficiencies of wheat 24%; sorghum 18% and also reduce fodder yield. Root growth may be limited by high bulk density resulting in reduced aeration and increased penetration resistance.

The higher soil resistance may inhibit root development in a silt loam soil (Nielsen et al., 2005). The better root development associate with breaking of compact layer below the plow layer is the major contribution to increase crop yield (Roberto et al., 2017). Marinez et al. (2008) also reported better root development increase grain yield in silty loam and silty clay soil.

Sakine and Anıl, (2006) reported that chickpea yield and with chisel plow was greater as compared to moldboard plow. They found chisels plow the most appropriate tillage implement that improved the physical properties of soil.

In Pakistan, in rain-fed area, in general tin type cultivator is more commonly used for tillage. Due to continuous use of tin type cultivator the yield of chickpea is relatively low because its limited soil penetration ability (Sjoerd and Duiker, 2006).Scantly information is available about the effects of different tillage practices on chickpea yield in spate irrigated arid environment.

Therefore, this field study was conducted to investigate the effects of different tillage practices on soil physical properties, water use efficiency and crop root length of chickpea in southern region of North West Frontier Province (NWFP) of Pakistan.

MATERIALS AND METHODS

Description of study site

Tillage experiments were conducted at Tehsil Kulachi, District Dera Ismail Khan (Figure 1) of Pakistan and it is located at latitude of 31°, 50’ N, longitude 70°, 54’ W and altitude of 173 m from main sea level (Sjoerd and Duiker, 2006). The potential evaporation is about 1,500 mm per year. June and July are the hottest months with mean temperatures of 42°C January is the coolest month with an average temperature of 15°C (Xu and Mermoud, 2001). The climate in the project area is arid to semi-arid sub-tropical continental with average annual precipitation of 270 mm based on the metrological record from 1970 to 2013 (Boriea et al., 2006).

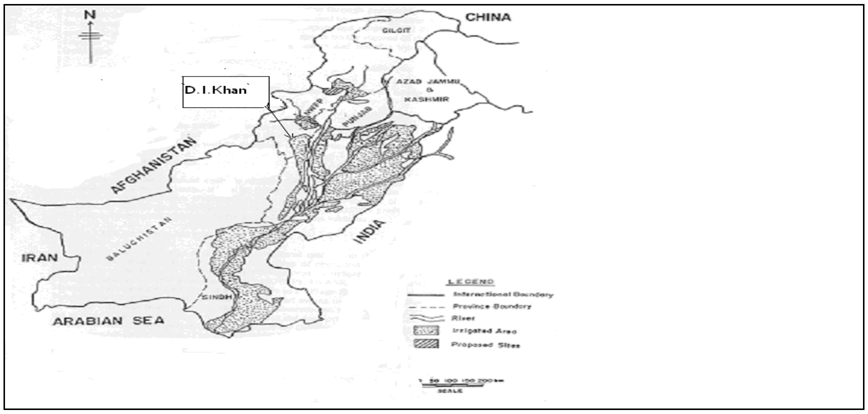

Figure 1. Experimental view of study area where samples were collected.

Table 1: Rainfall during (2010-2013) the crops growing and fallow season at the site.

Month	Average Monthly Normal Rainfall (mm)	2010	2011	2012
		Fallow Season rainfall (mm)		
May	17	0	0	0
Jun	14	13	0	0
Jul	61	0	25	32
Aug	58	7	240	132
Sep	18	7	41	0
Total	168	37	306	164
Month	**Average Monthly Normal Rainfall (mm)**	**2010-2011**	**2011- 2012**	**2012-2013**
		Crop Growing Season rainfall (mm)		
Oct	5	0	0	0
Nov	2	0	0	0
Dec	10	11	0	0
Jan	10	0	103	60
Feb	18	26	0	211
Mar	35	20	0	6
Apr	22	24	0	0
Total	102	80	103	277

Rainfall

A standard manual rain gauge was installed at the site and rainfall was recorded on daily basis. The rainfall data for the study period (2010-2013) is given in (Table 1). As it can be seen from the table, a very scanty rainfall was received during the year 2010-2011 as compared to years 2011-2012 and 2012-2013. However, the rainfall during the fallow season for year 2013 was higher.

Experimental design

The experimental set up consisted of the following treatments.

DPTC3: Disc plow once and Tine Type Cultivator three times
CPTC3: Chisel plow once and Tine Type Cultivator three times
MBTC3: Moldboard plow once and Tine Type Cultivator three times
DHTC3: Disc Harrow once and Tine Type Cultivator three times
TC4: Tine Type Cultivator four times (Farmer's practices)

The treatments were replicated four times. A total of 40 plots of wheat and chickpea were used for the experiments and each plot size was 40 m x 8 m at both

Table 2. Effect of various tillage operations on the bulk densities at 0-100 cm soil depth.

Treatments	Soil Depth(cm)	Before Tillage	After Tillage Mean Bulk Density (gm/cm^3)			
			2010-2011	2011-2012	2012-2013	Mean
DPTC3	0-30	1.40	1.30	1.30	1.10	1.23 bc
	31-60	1.40	1.40	1.10	1.17	1.22 b
	61-100	1.40	1.40	1.30	1.35	1.35
CPTC3	0-30	1.40	1.40	1.30	1.15	1.28 a
	31-60	1.40	1.40	1.10	1.17	1.22 b
	61-100	1.40	1.40	1.30	1.27	1.32
MBTC3	0-30	1.40	1.40	1.30	1.14	1.28 a
	31-60	1.40	1.40	1.30	1.20	1.30 a
	61-100	1.40	1.40	1.30	1.30	1.33
DHTC3	0-30	1.40	1.30	1.10	1.18	1.19 c
	31-60	1.40	1.40	1.20	1.16	1.25 b
	61-100	1.40	1.40	1.20	1.35	1.32
TC4	0-30	1.40	1.30	1.30	1.14	1.25 ab
	31-60	1.40	1.30	1.20	1.25	1.25 b
	61-100	1.40	1.40	1.30	1.35	1.35

Note: Means bearing the same letters are not statistically different from one another with $P<0.05$.

sites. Recommended doses of fertilizers and other inputs were applied uniformly to all treatments (Gustavo et al., 2010).

Physical properties of soil

On the basis of soil texture analysis the dominant textural class found at the experimental sits was clay and it consisted of sand 19.79%, silt 28.61% and clay 51.60% and. During the study period moisture content, infiltration rate, bulk densities and soil penetration resistance were determined (Insa et al., 2017).

Yield components and yield

Six samples were randomly collected from each plot for assessment of yield components (plant height, number of pods per plant, 1000-grain weight), grain and biomass yield (Jin and Ballel, 2006). Grain yield recorded after threshing six samples from 1 m^2 area of each plot and then converted into kg ha^{-1} (Min et al., 2013). Germination of seeds data was determined after germination of seeds by counting the number of plants m^{-2} in each plot at random at three locations (Sakine and C., 2006).

Water use efficiency (WUE)

WUE was determined from the yield of crop in kg $ha^{-1}$and divided by the available water for crop during its growing season (water in the root zone up to one meter at the time of sowing and the amount of rainfall received during crop growing season) (Iris et al., 2006).

Statistical analysis

The data recorded for the above-mentioned parameters were individually subjected to the ANOVA technique by using MINITAB computer software (Version 17, Pennsylvania State University, (Meryem and Funda, 2015) and using Fisher's Protected LSD test for comparison of means. Regression models were developed to relate grain yield with bulk density, moisture contents, and root length and soil penetration resistance.

RESULTS AND DISCUSSION

EFFECT OF TILLAGE ON PHYSICAL PROPERTIES OF SOIL

Bulk density

Bulk densities before tillage operations at depths of 0-30, 31-60 and 61-100 cm during 2010 were1.40 g cm^{-3} in the root zone. Bulk densities after tillage operations at depth of 0 - 100 cm; overall were ranged from 1.10 to 1.40 g cm^{-3} during chickpea growing season 2010-2013. The mean maximum soil bulk density was possessed by CPTC3 and MBTC3 of 1.28 g cm^{-3} and the mean minimum was recorded in tillage treatment DHTC3 of 1.19 g cm^{-3} as presented in (Table 2). A significant difference in bulk densities was found among various tillage treatments. Bulk densities at depth of 31-60 cm; ranged from 1.10 to 1.40 g cm^{-3} during chickpea growing season 2010-2013. The mean maximum soil bulk density was possessed by MBTC3 of 1.30 g cm^{-3} and the mean minimum was recorded in tillage treatment DPTC3 and CPTC3 of 1.22 g cm^{-3}. At depth of 61 - 100 cm overall, bulk densities ranged from 1.20 to 1.40 g cm^{-3} during

Table 3. Effect of various tillage operations on soil moisture on mass basis at 0-100 cm soil depth.

Treatments	Soil Depth(cm)	Before Tillage	Crop Growing season Soil Moisture on mass basis (%)			
			2010-2011	2011-2012	2012-2013	Mean
DPTC3	0-30	17.90	17.56	14.11	15.10	15.59 a
	31-60	21.70	21.60	13.53	15.20	16.78
	61-100	23.70	23.21	15.54	18.60	19.12
CPTC3	0-30	17.90	15.26	11.37	16.70	14.44 ab
	31-60	21.70	21.90	11.19	13.50	15.53
	61-100	23.70	23.45	13.58	15.40	17.48
MBTC3	0-30	17.90	15.10	12.41	15.70	14.40 b
	31-60	21.70	22.30	13.69	11.80	15.93
	61-100	23.70	21.15	16.90	17.60	18.55
DHTC3	0-30	17.90	17.13	13.46	15.50	15.36 a
	31-60	21.70	21.80	14.24	13.20	16.41
	61-100	23.70	23.14	16.91	16.40	18.82
TC4	0-30	17.90	16.54	13.61	15.10	15.08 a
	31-60	21.70	20.80	13.21	13.30	15.77
	61-100	23.70	21.26	16.91	16.10	18.09

Note: Means bearing the same letters are not statistically different from one another with P<0.05.

chickpea growing season 2010-2013. The mean maximum soil bulk density was possessed by DPTC3 and TC4 of 1.35 g cm^{-3} and the mean minimum was recorded in tillage treatment CPTC3 and DHTC3 of 1.32 g cm^{-3}. The tillage effect was not obvious beyond 60 cm soil depth and no significant difference in different tillage treatments was observed. In general, the deep tillage improved the bulk density as compared to the shallow tillage practices.

Soil moisture

Soil moisture before and after tillage operations at depth of 0-30, 31-60 and 61-100 cm during 2010-2013. At depth of 0-30 cm; an overall, soil moisture content varied from 11.3 to 17.56% during chickpea growing season 2010-2013. The mean maximum soil moisture was possessed by DPTC3 of 15.59 % and the mean minimum was recorded in tillage treatment MBTC3 of 14.40 % as given in (Table 3). Soil moisture contents varied from 11.19 to 22.30% during chickpea growing season 2010-2013 at depth of 31-60 cm. The mean maximum soil moisture content was possessed by DPTC3 of 16.78% and the mean minimum was recorded in tillage treatment CPTC3 of 15.53 % as given in (Table 3). No significant difference in moisture content was found among various tillage treatments. At depth of 61-100 cm; overall, soil moisture contents varied from 13.58 to 23.45% during chickpea growing season 2010-2013. The mean maximum soil moisture content was possessed by DPTC3 of 19.12% and the mean minimum was recorded in tillage treatment CPTC3 of 17.48%. No significant difference in moisture contents at depth of 61-100 cm among the various tillage treatments was found.

Soil penetration resistance

The soil penetration resistance before and after tillage operations at depth of 0-30, 31-60 and 61-100 cm during 2010-2013 is presented in (Table 4). Average soil penetration resistance ranged from 551 to 935 Ncm^{-2}.
An overall average soil penetration resistance ranged from 252 to 470 Ncm-2 during chickpea growing season 2010-2013. At a depth of 0-30 cm, the mean maximum soil penetration resistance was possessed by MBTC3 of 383 N cm-2 and the minimum was recorded in treatment DPTC3 of 346 N cm^{-2}. The overall average soil penetration resistance ranged from 382 to 565 Ncm^{-2} during chickpea growing season 2002-2005. The mean maximum soil penetration resistance was possessed by MBTC3 of 493 N cm^{-2} and the minimum was recorded in treatment DHTC3 of 446 Ncm^{-2}. The soil penetration resistance was also determined after tillage operations at depth of 61-100 cm during the chickpea growing season; the overall average soil penetration resistance varied from 518 to 821 N cm^{-2} during chickpea growing season 2010-2013. The mean maximum soil penetration resistance was possessed by MBTC3 of 652 N cm^{-2} and the minimum was recorded in treatment CPTC3 of 613 Ncm^{-2}. No significant effect of tillage treatments was found beyond 30 cm soil depth during the chickpea growing season. Soil penetration resistance was relatively low in deep tillage treatment as compared to shallow one.

Soil aggregates

The overall soil aggregates less than 0.5 cm ranged from 27.53 to 43.28% in all the tillage treatments. CPTC3

Table 4. Effect of various tillage practices on soil penetration resistance at 0-100 cm soil depth.

Treatments	Soil Depth(cm)	Before Tillage	After Tillage Mean Soil Penetration Resistance (N cm^{-2})			
			2010-11	**2011-12**	**2012-13**	**Mean**
DPTC3	0-30	551	375	412	252	346 b
	31-60	796	531	488	382	467
	61-100	935	741	520	658	640
CPTC3	0-30	551	410	438	264	371 a
	31-60	796	493	482	402	459
	61-100	935	781	532	527	613
MBTC3	0-30	551	408	455	285	383 a
	31-60	796	553	510	416	493
	61-100	935	821	573	563	652
DHTC3	0-30	551	373	417	288	359 b
	31-60	796	475	480	382	446
	61-100	935	762	518	568	616
TC4	0-30	551	373	470	295	379 a
	31-60	796	565	507	403	492
	61-100	935	781	530	573	628

Note: Means bearing the same letters are not statistically different from one another with $P<0.05$.

produced relatively large aggregates (> 7 cm) of 27.10%, followed by MBTC3 of 22.27%, while DHTC3 produced the large percentage of the smallest aggregates (43.28%) as shown in (Table 5).

Cumulative infiltration

Based on the overall mean of three years (2010-2013), the highest four hours cumulative infiltration rate was observed in MBTC3 (77 mm) followed by CPTC3 and DPTC3 of (72 mm) as compared to other treatments; while the lowest infiltration rate was noticed in DHTC3 and TC4 (64 mm) is depicted in (Figure 2). The four hours cumulative infiltration of MBTC3 under the wheat growing season 2010-2013 was 13% and 8% higher in deep tillage treatments than DHTC3 and TC4. In general, the deep tillage practices loosened the soil and enhanced the infiltration rate.

PERFORMANCE OF TILLAGE OPERATION

Speed of operation and field capacity

The speed of operation ranged from 3.14 to 5.16 km h^{-1} and field capacity varied from 0.27 to 0.98 ha h^{-1} during the crop growing season 2010-2013. TC4 has mean maximum speed of operation of 4.27 km h^{-1} and field capacity of 0.83 ha h^{-1}. Mean minimum field capacity was observed at CPTC3, followed by MBTC3 (Table 6).

YIELD COMPONENTS AND YIELD OF CHICKPEA

Germination of seeds

During the chickpea growing seasons of 2010-13, the mean maximum germination was recorded for CPTC3 of 52 seeds m^{-2} and the minimum was recorded for TC4 of 43 seeds m^{-2}. The overall germination data range from 40 to 54 seeds m^{-2}. There was significantly difference in germination of seeds among the various tillage treatments as presented in (Table 7). No significant difference in the plant height was found among the tillage treatments. The overall plant height of chickpea ranged from 39 to 79 cm. the maximum chickpea plant height was recorded for DPTC3 of 63 cm, while the minimum plant height was recorded for MBTC3 of 58 cm.

No. of pods/plant and 1000-grain weight

During the chickpea growing season 2010-13, the number of pods per plant data ranged from 50 to 153. Maximum number of pods per plant was recorded for CPTC2 of 106, while the mean minimum number of pods per plant was found in plots plowed with MBTC3 of 99. There was significant difference among the tillage treatments as shown in the (Table 8). The 1000 – grain weight during 2010-2013 ranged from 162 to 198 g. On the average basis for three years data of chickpea the minimum 1000-grains weight was recorded for MBTC3 of 183 g), while the maximum weight was recorded for DHTC3, DPTC3 and CPTC3 of 185 g. There was no

Table 5. Mean percent of soil aggregates obtained from chickpea plots after tillage for the period 2010-2013.

Treatments	>7	7 – 5	5 -4	4 – 3	3 – 2	2 -1	1-0.5	0.5-.2	<0.5
	Sieve size (cm) and Soil Aggregate (%)								
DPTC3	22.19	4.79	11.27	8.16	7.91	5.65	4.52	3.32	32.23
CPTC3	27.10	14.43	9.28	5.82	4.98	3.24	4.35	3.35	27.53
MBTC3	22.27	10.05	2.93	10.84	5.96	6.53	7.45	4.21	29.81
DHTC3	20.97	6.99	2.78	8.77	5.21	4.69	4.61	2.84	43.28
TC4	14.08	5.26	3.62	11.43	11.99	4.37	8.37	5.68	35.21

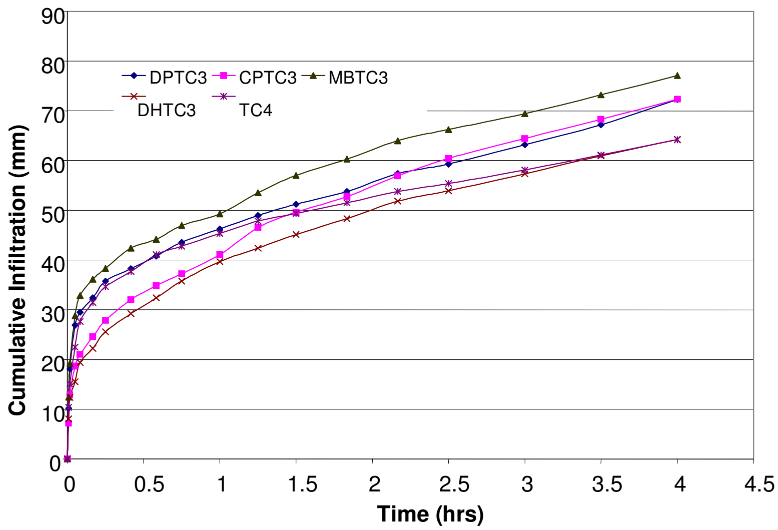

Figure 2. Cumulative infiltration with time under different tillage treatments in Chickpea growing plots during 2010 – 2013.

Table 6. Speed of Operation (SO) and Field Capacity (FC) of different tillage implements used in the study.

Treatments	Speed of Operation (SO) in km h^{-1} and Field Capacity (FC) in ha h^{-1}							
	2010-2011		2011-2012		2012-2013		Mean	
	SO	FC	SO	FC	SO	FC	SO	FC
DPTC3	4.17	0.40	3.14	0.30	4.40	0.42	3.90	0.37
CPTC3	3.73	0.30	3.34	0.27	3.81	0.35	3.63	0.31
MBTC3	3.57	0.32	3.34	0.26	3.80	0.39	3.57	0.32
DHTC3	3.72	0.54	3.42	0.55	3.86	0.54	3.67	0.54
TC4	4.11	0.81	3.55	0.70	5.16	0.98	4.27	0.83

Note: Means bearing the same letters are not statistically different from one another with P<0.05.

significant difference in 1000 – grain weight among the various tillage treatments.

Length of primary roots of chickpea

During the growing season 2010-2013, the length of primary root of chickpea ranged from 48 to 71 cm. The mean maximum length of primary roots for chickpea was found in DHTC3 of 70 cm, while the mean minimum length of primary roots was recorded for DPTC3 of 70 cm. There was significant difference among the tillage treatments for the primary root length of chickpea as shown in (Table 9).

Grain and biomass yield

The chickpea grain yield ranged from 1563 to 2746 kg ha^{-1} during the crop season 2010-2013. On the basis of

Table 7. Effect of different tillage treatments on germination and plant height.

Treatments	2010-2011		2011-2012		2012-2013		Mean	
	Germination (G) of seeds m^{-2} and plant height (PH) in cm							
	G	PH	G	PH	G	PH	G	PH
DPTC3	46	79	51	39	47	71	48 ab	63 a
CPTC3	52	70	52	42	52	69	52 a	60 ab
MBTC3	48	73	46	39	48	61	47 b	58 b
DHTC3	54	74	47	41	48	67	50 ab	61 ab
TC4	40	73	45	43	43	71	43 c	62 ab

Note: Means bearing the same letters are not statistically different from one another with P<0.05.

Table 8. Effect of different tillage treatments on Number of pods $plant^{-1}$ and 1000 Grain weight of Chickpea during growing season 2010-2013.

Treatments	2010-2011		2011-2012		2012-2013		Mean	
	No of Pods per Plant (NPP) and 1000-Grain Weight (GW) in g							
	NPP	1000-GW	NPP	1000-GW	NPP	1000-GW	NPP	1000-GW
DPTC3	148	188	93	197	62	170	101 b	185
CPTC3	145	195	108	198	50	162	101 b	185
MBTC3	139	186	86	196	72	167	99 b	183
DHTC3	147	189	99	197	78	169	108 a	185
TC4	153	188	90	191	75	173	106 a	184
$LSD_{0.05}$								

Note: Means bearing the same letters are not statistically different from one another with P<0.05.

Table 9. Effect of different tillage treatments on the primary root length of chickpea during growing seasons 2010-2013 at D.I. Khan.

Treatments	2010-2011	2011-2012	2012-2013	Mean
	Primary root length (cm)			
DPTC3	64	67	65	65 b
CPTC3	61	69	67	66 ab
MBTC3	48	68	50	55 c
DHTC3	71	71	68	70 a
TC4	61	71	70	67 ab

Note: Means bearing the same letters are not statistically different from one another with P<0.05.

Table 10: Effect of different tillage treatments on the grain and biomass yield of chickpea.

Treatments	2010-2011		2011-2012		2012-2013		Mean	
	Grain Yield (GY) and Bio-mass (BM) in kg ha^{-1}							
	GY	BM	GY	BM	GY	BM	GY	BM
DPTC3	2685	5225	2739	3341	1621	3032	2348 a	3866 a
CPTC3	2212	4011	2578	3327	1706	2848	2165 b	3395 c
MBTC3	2138	3138	2638	3155	1653	2877	2143 b	3057 d
DHTC3	2648	4935	2703	3115	1563	3199	2305 a	3750 b
TC4	2482	4371	2746	3293	1633	3556	2287 a	3740 b

Note: Means bearing the same letters are not statistically different from one another with P<0.05.

three years data, mean highest grain yield was recorded in DPTC3 of 2348 kg ha^{-1} and the lowest grain yield was found in MBTC3 of 2143 kg ha^{-1}), followed by CPTC3. Tillage treatment DPTC3 produced relatively better

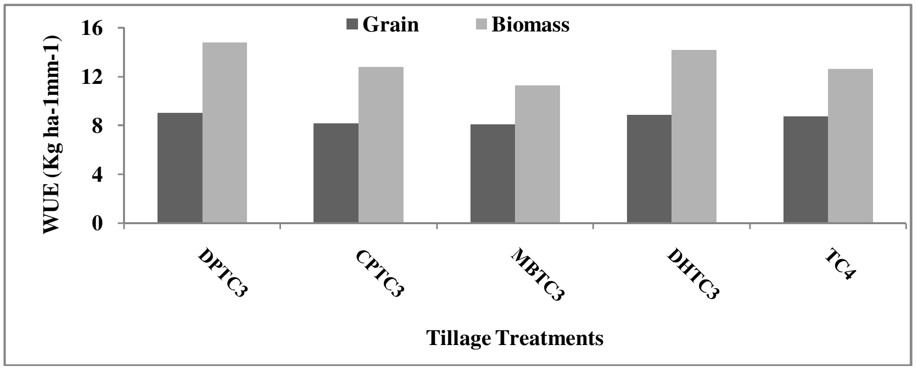

Figure 3. Water use efficiency of chickpea under different tillage treatment during the study period 2010-2013.

chickpea yield than TC3. MBTC3 and CPTC3 produced 5.32 and 6.30% less yield as compared to TC4. In general, the tillage effects on yields were significant (Table 10). Based on three years data the mean minimum biomass weight was recorded for MBTC3 of 3057 kg ha^{-1} and the maximum was recorded for DPTC3 of 38664 kg ha^{-1} (Table 10).

It can be concluded that the vigorous vegetative growth of chickpea with better water availability my not necessary resulted higher grain yield. The water use efficiency (WUE) of chickpea grain and biomass yield ranged from 8.11 to 9.05 kg ha^{-1} mm^{-1} and 11.29 to 14.80 kg ha^{-1} mm^{-1} (Figure 3). For biomass yield maximum WUE was recorded in plots plowed with DPTC3 and lowest in MBTC3.

Conclusion

Relatively better chickpea grain and biomass yield was obtained from plots plowed by disk plow, followed by disk harrow and lowest from the plots plowed with moldboard plow. Higher rainfall during chick pea growing season resulted decrease in grain yield. Increase in biomass did not improve the chickpea grain yield. Higher bulk density and soil penetration resistance resulted decrease in grain yield. A negative correlation was obtained between chickpea grain yield and soil penetration resistance and bulk density. Under clayey soil condition for better chickpea production disc plow or disc harrow should be used. The use of moldboard and chisel plow should not be used for chickpea production in spate irrigation service area under clayey soil conditions.

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