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GROWTH, YIELD AND ROOT DEVELOPMENT OF MAIZE AS INFLUENCED BY TILLAGE AND TRACTOR TRAFFIC

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ABSTRACT

A field study was carried out to determine the effect of tillage treatments on growth and yield of maize (*Zea mays* L.). The experiment was conducted in the autumn 2012 and was repeated in the spring 2013. Four tillage treatments included in the study were: conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and controlled traffic farming (CTF). Randomized complete block design was used to arrange treatments with three replications. The crop parameters studied were: seedling emergence, crop growth, root development and yield. The seed emergence of maize crop was greater under CT, followed by MT, CTF and ZT during both seasons. The plant height was highest under CT (181.5 and 181.6 cm), followed by MT (173.3 and 173.6 cm), CTF (172.8 and 173.0 cm) and ZT (166.6 and 167.1 cm). Leaves plant $^{-1}$, grains cob^{-1}, 1000-grain weight were maximum under CT, followed by MT, CTF, while minimum under ZT for both the seasons. The grain yield was maximum under CT (5359.3 and 5378.0 kg ha^{-1}), followed by MT (4939 and 4963 kg ha^{-1}), CTF (4907.2 and 4961.2 kg ha^{-1}) and minimum under ZT (4321.4 and 4331.7 kg ha^{-1}). However, there was no significant difference among MT and CT treatments. The similar trends were observed during both seasons. Root length, fresh and dry root weights were maximum under CT, followed by MT, CTF and ZT during autumn 2012 and similar trends were observed during spring 2013. However, non-significant difference was found between MT and CTF during both seasons. Significant effects of root development on plant height and grain yield were recorded. It is concluded that CT is suitable for maize cultivation in a clay loam soil.

Keywords: tillage, maize crop, seed emergence, plant height, crop yield, root development

INTRODUCTION

Tillage is basically the manipulation of soil to provide conducive environment to germinating seeds and emerging seedlings. It breaks hard pans of soil, pulverizes, loosens, inverts and rearranges the soil aggregates, as well as controls weeds or unwanted plants. Tillage modifies the physical environment of soil such as soil aggregation, porosity, density, hydraulic conductivity, infiltration

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rate and water holding capacity (Ofori, 2007). In addition, it alters soil structure (Lio, 2006; Memon *et al.,* 2013; Laghari *et al.,* 2014) and increases growth and yield.

There are many types of tillage systems such as conventional tillage, conservation tillage, minimum tillage, reduced tillage and no tillage systems. Conventional tillage breaks and overturns the structure of soil (Kribaa *et al.,* 2001) and as a result, produces a finer and loose soil structure (Rashidi and Keshavarzpour, 2007). In a conservation tillage system, the plant residues cover soil surface portion upto 30% after planting. Ahn and Hintze (1990) reported that terms no tillage, reduced tillage, minimum tillage and mulch tillage are the same with conservation tillage. The controlled trafficing farming (CTF) is a system of farming in which the field traffic is limited to the permanent and different similar traffic lanes. The soil in intervening beds is managed in such a way that the ideal conditions for crop performance with less traffic and relevant compaction is provided (Tullberg, 2001). However, the use of proper tillage improves physical soil environment, while an improper tillage destroys soil aggregation that lowers down the fertility status (Lal, 1993).

Ketema and Yimer (2014) pointed out that in the sustainable cropping system, tillage plays a key role as it modifies properties of soil, affects roots growth and ultimately results in increased crop yield. In a study West *et al.* (1996) revealed that deep tillage resulted in significant increase of maize yield compared with no-tillage. Nizami and Khan (1990) reported increase in the grain yield under moldboard plow compared to chisel and cultivator in Guliana soils. Ahadiyat and Ranamukhaarachchi (2008) evaluated the effects of conventional tillage, deep tillage and zero tillage and four cropping patterns on maize and intercropped maize accompanied different grasses i.e. clump, lemon and elephant grass. Maize yield components and harvest index increased with conventional and deep tillage in comparison with zero tillage whereas, non-significant effects were observed in maize yield between cropping pattern. Holanda *et al.* (2011) compared conventional plowing, minimum tillage and zero tillage on soybean-corn and continuous corn and reported significant increase in corn yield when planted through conventional tillage system against zero and minimum tillage associated with continuous crop.

Maize (*Zea mays* L.) is a member of Gramineae family. It occupies the important position among cereal crops after wheat and rice in respect of area and production. In Pakistan maize is cultivated on an area of about 1030 thousand hectares with the total production of 3560 thousand tons. Maize grain is reported to contain 72% starch, 4.8% oil, 10% protein, 5.8% fiber, about 1.7% ash and 3.0% sugar (Chaudhry, 1983). Soil and climatic conditions of Pakistan are ideal for maize production; however farmers are unable to achieve their targeted yields. We therefore hypothesize that the maize yields could be improved with proper tillage systems. This paper reports the results of study designed to investigate the influence of different tillage methods on maize production.

MATERIALS AND METHODS

Site description

Experiments were carried out at the field of Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam, during the autumn season of 2012 and were repeated in the spring season of 2013. The treatments were: conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and controlled traffic farming (CTF). In CT one pass of moldboard plow and two passes of cultivator were applied, in MT three passes of disk harrow were used, while in ZT direct drilling was done using seeder. In CTF two passes of cultivator were used in which the tractor wheel base was kept 1.94 m and the implement width 2.88 m. The traffic lanes were designed with normal wheelbase of tractor without modifications. The experiments were laid down in a randomized complete block design (RCBD) with three replications. Total area was divided into twelve plots (60 m × 20 m). Three randomly selected plots were treated as conventional tillage (CT), three as minimum tillage (MT), three as zero tillage (ZT) and three were treated as controlled traffic farming (CTF). Maize was sown in the month of November 2012 using 25 kg seed ha^{-1} and repeated in March 2013 at the same seed rate. The plant to plant distance was kept 20 cm and row to row space was kept 75 cm. For the collection of agronomic data, ten plants from middle rows of each plot were selected and outer rows on both sides of treatment were kept as buffer zone to reduce the effect of edge and plot interferences. The parameters recorded were seedling emergence, plant growth, root development and yield of maize crop.The soil was clay loam at the experimental site. Statistical analyses were done using the statistical software Statistix (Version 8.1).

Emergence percentage

The emergence percentage was calculated using following formula:

$$\text{Emergence } \% = \frac{\text{Number of seeds emerged}}{\text{Number of seeds sown}} \text{ X } 100$$

Harvesting

Ten physiologically mature plants were selected from each plot at random for harvesting. Plants were used to measure height (cm) and number of leaves per plant. Cobs of harvested plants were separated out with chopper. Grains on each cob were counted and weighed to determine 1000-grain weight and grain yield per plant.

Root length and root weight

Length and weight of roots were measured from randomly selected plants from each plot at harvesting (Rowell, 1994).

RESULTS AND DISCUSSION

Seedling emergence percentage

The seeding emergence percentage was significantly affected by tillage systems. The results of seeding emergence for the autumn 2012 and spring 2013 are given in the Table 1. The highest emergence percentage (88.0%) was recorded from conventional tillage, followed by minimum tillage (86.7%), zero tillage (81.0 %) and controlled traffic system (84.0%) plots. Similar trend was observed during the year 2013.

Table 1. Effect of tillage systems on seedling emergence (%) of maize crop

Tillage systems	**Seedling emergence (%)**	
	Year 2012	**Year 2013**
Conventional tillage (CT)	88.0 a	88.6 a
Minimum tillage (MT)	86.7 a	86.9 a
Zero tillage (ZT)	81.0 c	81.6 c
Controlled traffic farming (CTF)	84.0 b	84.2 b

The means (LSD at 0.05) with same letters are not significantly different from each other.

Plant height

The results on plant height for the autumn 2012 and spring 2013 under different tillage systems are shown in the Table 2. The maximum height of plants was recorded under CT (181.5 cm), followed by MT (173.3 cm), and CTF (172.8 cm), while minimum plant height was recorded under ZT (166.6 cm). Similar trend was observed during the year 2013.

Table 2. Effect of tillage systems on the height (cm) of maize plants

Tillage systems	**Plant height (cm)**	
	Year 2012	**Year 2013**
Conventional tillage (CT)	181.5 a	181.6 a
Minimum tillage (MT)	173.3 b	173.6 b
Zero tillage (ZT)	166.6 c	167.1 c
Controlled traffic farming (CTF)	172.8 b	173.0 b

Table 3. Effect of tillage systems, on number leaves plant^{-1} of maize crop

Tillage systems	**Leaves (plant $^{-1}$)**	
	Year 2012	**Year 2013**
Conventional tillage (CT)	14.3 a	14.7 a
Minimum tillage (MT)	13.3 b	13.7 b
Zero tillage (ZT)	11.7 c	12.0 c
Controlled traffic farming (CTF)	13.0 b	13.3 b

Leaves plant^{-1}

The results on the number of leaves per plant in maize during the autumn 2012 and spring 2013 are given in Tables 3. We recorded 14.3, 13.3 13.0 and 11.7 leaves per plant under CT, MT, CTF and ZT, respectively. Similar trend was observed during spring 2013.

Grains cob^{-1}

The results on number of grains per cob are shown in Table 4. On an average 338.9 grains cob^{-1} were recorded under CT, 324.3 grains cob^{-1} under MT, 320.2 grains cob^{-1} under CTF and 308.9 grains cob^{-1} under zero tillage. The maximum grains per cob were observed under CT while minimum under ZT. There was no significant difference in the results of 2012 and 2013, while significant differences were observed for tillage systems for both the years. During 2013, 339.1 grains cob^{-1} were recorded under CT, 324.7 grains cob^{-1} under MT, and 321.3 grains cob^{-1} under CTF and 309.1 grains cob^{-1} under zero tillage.

Table 4. Effect of tillage systems on number of grains cob^{-1} of maize crop

Tillage systems	**Grains (cob^{-1})**	
	Year 2012	**Year 2013**
Conventional tillage (CT)	338.9 a	339.1 a
Minimum tillage (MT)	324.3 b	324.7 b
Zero tillage (ZT)	308.9 c	309.1 c
Controlled traffic farming (CTF)	320.2 b	321.3 b

1000-grain weight

The difference between tillage treatments for 1000-grain weight for 2012 and 2013 are given in Table 5. The difference between tillage treatments for 1000-grain weight was significant. The grains obtained from plants grown in conventional tillage system were heavier than the grains obtained from plants grown in minimum tillage system. The maximum 1000-grain weight was observed under CT (226.1 g), followed by MT (217.8 g) and CTF (215.9 g) whereas, the minimum (209.9 g) 1000-grain weight was recorded when crop was planted through zero tillage system. There was non-significant difference between the years (2012 and 2013). As compared to 2012, similar results were observed during 2013. During this year, conventional tillage system produced heavier grains than the minimum tillage, controlled traffic and zero tillage. The maximum 1000-grain weight was observed under CT (226.7 g), followed by MT (218.1 g) and CTF (216.5 g). However, the least (210.1 g) 1000-grain weight was noted under zero tillage system.

Grain yield

The results on grain yield under different tillage treatments for 2012 and 2013 are given in Table 6. Conventional tillage system gave maximum grain yield compared to zero tillage, minimum tillage and controlled traffic. The grain yield of 5359.3 kg ha^{-1}, 4939.2 kg ha^{-1}, 4907.2 kg ha^{-1} and 4321.4 kg ha^{-1} was obtained under CT, MT, CTF and ZT, respectively. However, slightly higher grain yield was obtained during 2013 than during 2012. In the year 2013, the grain yield of 5378.0 kg ha^{-1}, 4963.4 kg ha^{-1}, 4961.2 kg ha^{-1} and 4331.7 kg ha^{-1} was obtained under CT, MT, CTF and ZT, respectively. The maximum grain yield was observed under CT while minimum under ZT for 2012 and 2013.

Table 5. Effect of tillage systems on 1000- grain weight (g) of maize crop

Tillage systems	1000- grain weight (g)	
	Year 2012	Year 2013
Conventional tillage (CT)	226.1 a	226.7 a
Minimum tillage (MT)	217.8 b	218.1 b
Zero tillage (ZT)	209.9 c	210.1 c
Controlled traffic farming (CTF)	215.9 bc	216.5 bc

Table 6. Effect of tillage systems on grain yield (kg ha^{-1}) of maize crop

Tillage systems	Grain yield (kg ha^{-1})	
	Year 2012	Year 2013
Conventional tillage (CT)	5359.3 a	5378.0 a
Minimum tillage (MT)	4939.2 b	4963.4 b
Zero tillage (ZT)	4321.4 c	4331.7 c
Controlled traffic farming (CTF)	4907.2 b	4961.2 b

Table 7. Effect of tillage systems on root length (cm) of maize crop

Tillage systems	Root length (cm)	
	Year 2012	Year 2013
Conventional tillage (CT)	23.5 a	24.0 a
Minimum tillage (MT)	18.8 b	19.0 b
Zero tillage (ZT)	16.8 c	16.9 c
Controlled traffic farming (CTF)	18.7 c	19.6 b

Root length

The results regarding root length (cm) for 2012 and 2013 are given in Table 7. Lengthy roots were observed under CT (23.5 cm), followed by MT (18.8 cm), CTF (18.7cm) and ZT (16.8 cm). Though the root lengths were slightly higher during 2013 as compared to 2012, these differences were non-significant between years.

Relationship between root length and grain yield

The regression test was performed to determine the relationship between root length (cm) and grain yield (kg ha^{-1}) and the results are shown in Figure 1. The coefficient of determination (R^2 = 0.84), for the year 2012 showed 84% variation in the grain yield (kg ha^{-1}). Similarly, for the year 2013, the coefficient of determination (i.e. R^2 = 0.86) showed 86% variation in the grain yield (kg ha^{-1}) that was associated to change in root length.

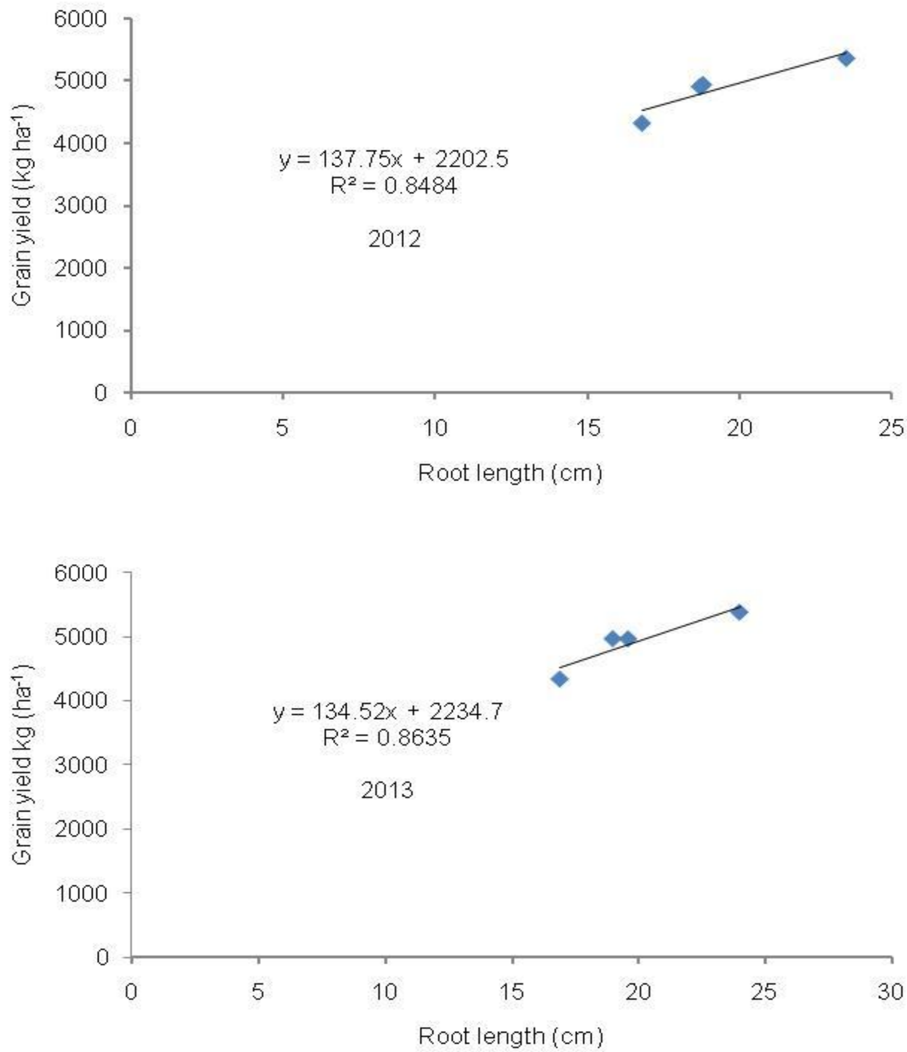

Figure 1. Relationship between root length and grain yield under different tillage systems

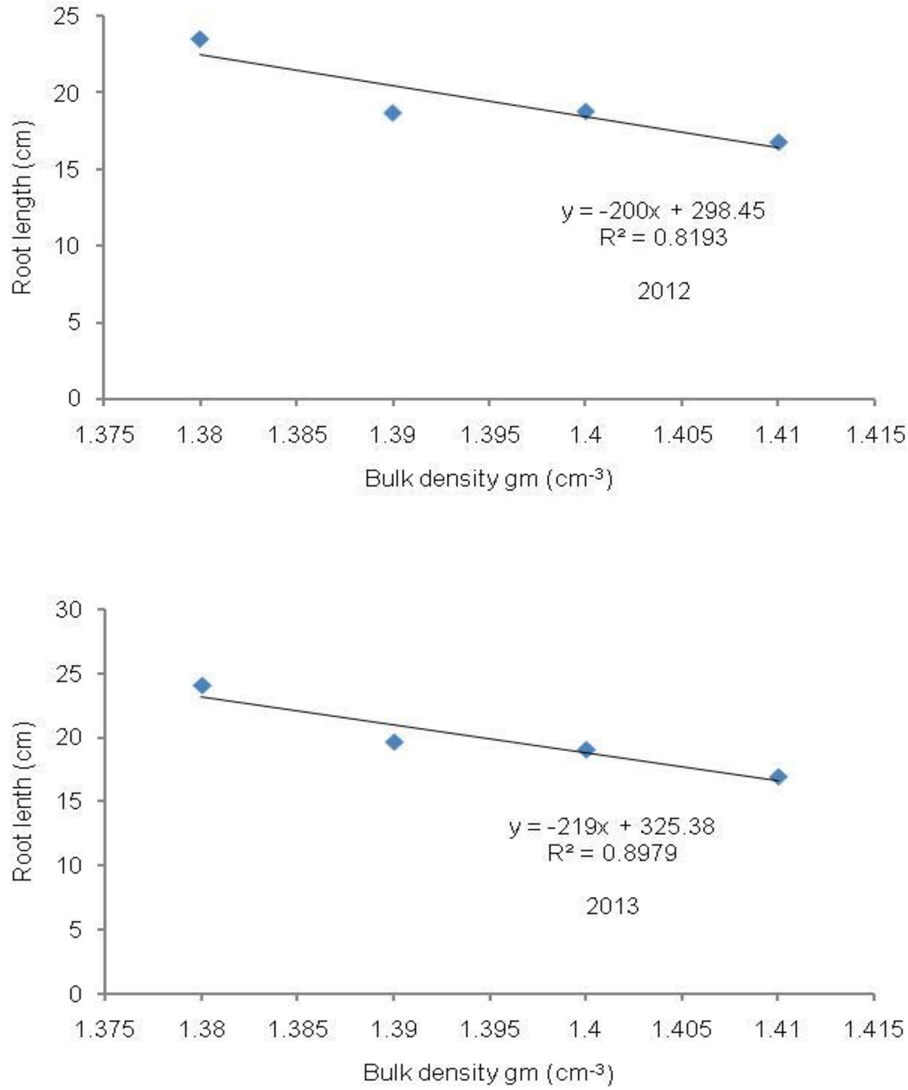

Figure 2. Relationship between bulk density and root length under different tillage systems during 2012 and 2013

Relationship between bulk density and root length

The regression analysis was performed to establish relationship between bulk density and root length and results are shown in Figure 2. The coefficient of determination (R^2 = 0.81), for the year 2012 showed 81% variation in the root length. Similarly, for the year 2013, the coefficient of determination (i.e. R^2 = 0.89) showed 89% variation in the root length that was associated to change in bulk density.

Root weight

The results on fresh and dry root weights of maize under different tillage treatments are given in Table 8. The fresh root weights obtained during 2012 from CT, MT, ZT and CTF treatments were 89.6, 70.4, 55.8, and 67.2 (g plant^{-1}), respectively, whereas, 90.8, 71.7, 56.7 and 69.5 (g plant^{-1}), respectively, for the respective treatments during 2013. While, the dry root weights for the year 2012 were 28, 22, 17.1, and 21.2 (g plant^{-1}) under CT, MT, ZT and CTF treatments, respectively whereas; 28.4, 22.4, 17.7 and 21.7 (g plant^{-1}), were for the respective treatments for 2013. No significant differences, in fresh and dry root weights per plant, between 2012 and 2013 were observed. It could be noted that the highest fresh as well as dry root weights per plant were observed in the plots treated by conventional tillage, whereas lowest fresh as well as dry root weights per plant were pragmatic under zero tillage during both the study years.

Table 8. Effect of tillage systems on fresh and dry root weights (g plant^{-1}) of maize crop

Tillage system	Fresh root weight (g plant $^{-1}$)		Dry root weight (g plant^{-1})	
	Year 2012	Year 2013	Year 2012	Year 2013
Conventional tillage (CT)	89.6 a	90.8 a	28.0 a	28.4 a
Minimum tillage (MT)	70.4 b	71.7 b	22.0 b	22.4 b
Zero tillage (ZT)	55.8 c	56.7 c	17.1 c	17.7 c
Controlled traffic farming (CTF)	67.2 b	67.5 b	21.7 b	21.7 b

DISCUSSION

The seedling emergence (%), plant height, leaves per plant^{-1}, grains per cob^{-1}, grain yield, root length and root weight were significantly affected by different tillage systems. The higher emergence was obtained from conventional tillage system as compared to minimum tillage, controlled traffic, and zero tillage. The significant difference was observed between CT and ZT at $P<0.05$. There was no difference in the spring 2013 for emergence percentage in comparison with emergence percentage in the autumn 2012. These findings are in agreement with those of Máthé-Gáspár and Rátonyi (2008). They pointed out that plowing methods alter soil temperature, moisture of upper soil surface, seed-soil contact and crop residue that ultimately vary seed germination. They further suggested that tillage systems also alter soil bulk density, water holding capacity of soils and ultimately the seedling emergence. The obtained results are further supported by the findings of Dam *et al.* (2005) who reported that spring corn emergence was slower under no-tillage as compared to reduced tillage and conventional tillage. Shoot height generally determines plant growth. The height of maize plants grown in different tillage treatment plots during autumn 2012 and spring 2013 was recorded. The maximum height of plants was recorded under CT, followed by MT, and CTF, while the shortest plants were observed under ZT. The obtained results indicated marked ($P<0.05$) differences in plant height among tillage systems. Almost identical results were recorded during spring 2013. These findings are supported by those of Khurshid *et al.* (2006) who observed tallest plants under conventional tillage than minimum tillage. The results of leaves plant^{-1} for the autumn 2012 and spring 2013 revealed that on average basis the maximum leaves plant^{-1} were observed for CT as compared to MT, CTF and ZT, the trend was similar for both the seasons. The results of number of grains on average revealed that maximum grains cob^{-1} were recorded under CT, followed by MT, CTF and lowest under ZT. The maximum grains per cob were observed under CT while minimum under ZT. There was non-significant difference in the results of autumn 2012 and spring 2013, while significant difference observed for tillage systems for both the seasons. The obtained results are supported by Khurshid *et al.* (2006) who observed the highest number of grains per cob and weight of 1000-grains under conventional tillage than minimum tillage. Furthermore, Halvorson *et al.* (2005) revealed that grains per cob were affected by tillage systems. Similar results were observed by Sainju and Singh (2001) and Dinnes *et al.* (2002). The results are further supported by Monneveux *et al.* (2006) who revealed that conventional tillage produced maximum number of maize grains per cob over zero tillage. The results of 1000-grain weight were observed for the autumn 2012 and spring 2013. The heavier grains were observed under CT as compared to MT, ZT and CTF. The significant difference was observed at ($P<0.05$) between CT and ZT. The maximum weight of 1000-grains was observed under conventional tillage, while minimum under zero tillage. No significant difference was observed for autumn 2012 and spring 2013. The observed results are supported by the findings of Ahmad *et al.* (2010) who observed that conventional tillage gave maximum grain yield as compared to zero tillage. The grain yields under various tillage treatments were measured during autumn 2012 and spring 2013. The conventional tillage resulted in maximum grain yield compared with zero tillage, minimum tillage and controlled traffic. The maximum grain yield was observed under CT while minimum under ZT for autumn 2012 and spring 2013. The tillage systems differed significantly ($P<0.05$) for grain yields. The obtained results are supported by the findings of Halvorson *et al.* (2006) and Simes *et al.* (1998), who harvested higher grain yield of maize with pre-plant tillage. They also obtained higher corn yield under conventional tillage than zero tillage. Similarly many other researchers (Vetsch and Randall, 2002; Al-Kaisi and Licht, 2004; Vetsch and Randall, 2004; Halvorson *et al.* 2006) have observed that conventional tillage produced greater grain yield. In another study, Pederson and Lauer (2003) recorded 5% more corn yield under conventional tillage practice than zero tillage.

The results regarding root length (cm) for autumn 2012 and spring 2013 under different tillage systems revealed that root length for CT was greater as compared to MT and CTF while minimum under ZT. Though the root lengths were slightly higher during spring 2013 as compared to autumn 2012 but differences were non-significant between the seasons. The longer roots were observed under conventional tillage, while shortest roots under zero tillage. There were significant differences ($P<0.05$) for root length between tillage systems. The observed results are supported by the findings of Stone and da Silveira (1999), who concluded that roots can be developed better under deep tillage. In another study, There was non-significant difference in the results of fresh and dry root weights per plant between autumn 2012 and spring 2013. While, the maximum fresh as well as dry root weights per plant were recorded under CT, whereas, the lowest fresh and dry root weights were observed under zero tillage during both the seasons i.e. autumn 2012 and spring 2013.

CONCLUSION

The results on seedling emergence, root development, plant height, seeds per cob, grain weight and yield remained significantly better under conventional tillage, followed by controlled traffic and minimum tillage, while they were poor under zero tillage. The conventional tillage provided better seed bed for germination, hence significantly higher seed emergence was recorded under this system. Similarly soil was pulverized down to deeper depths that in turn offered better environment for root growth and its development. Hence plants attained greater heights and yields more cobs with added seed weight and they produced higher yields as compared to those under minimum tillage, controlled traffic and zero tillage. It is concluded on the basis of obtained results that maize yield was obtained maximum under conventional tillage (CT).

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