Yield components of sweet corn (*Zea mays*) and some soil physical properties towards different tillage methods and plant population

Hosseinali Shamsabadi[1*], Desa Ahmad[2], Azmi Yahya[3], W. Aimrun[2]

(1. *Department of Biological and Agricultural Engineering, Faculty of Engineering, University Putra Malaysia, Malaysia; Department of Mechanics of Bio-system Engineering, University of Agricultural Sciences and Natural Resources, Gorgan, Iran*;
2. *Department of Biological and Agricultural Engineering, Faculty of Engineering, Smart Farming Technology Research Centre, University Putra Malaysia, Malaysia*;
3. *Department of Biological and Agricultural Engineering, Faculty of Engineering, University Putra Malaysia, Malaysia*)

Abstract: A field experiment was conducted to investigate the effects of three tillage systems and three corn plant populations on selected soil physical properties and yield components of sweet corn for Serdang soil series (*Typic Paleodults*) at the research farm of University Putra Malaysia (UPM) in Malaysia. The experimental design with three replications was a 2×3 factorial treatments based on randomized complete block design (RCBD) for soil analysis and a 3×3 factorial treatments based on RCBD for yield and yield components analysis of sweet corn (*Zea mays*). The three tillage systems were moldboard plow followed by once disc harrowing (MPD), disc plow followed by once disc harrowing (DPD) and rotary cultivator (RC) only, as control on soil physical properties at two depths of 0-10 cm and 20-30 cm; and also their effects on yield and selected yield components of sweet corn at three seeding rates or seed spacing of 20, 30 and 40 cm. The results showed that the measured soil physical properties were homogeneous at three plots and the two depths. Although *WI* (water infiltration) was higher and resistance to penetration (*RP*) was lower in RC plot at the upper layer, this condition had no influence on crop yield. The highest and minimum value of crop yield at given seed spacing occurred in DPD plot and MPD and RC plots, respectively. Interaction effects of the two factors, tillage and planting density were found to be significant on row length of kernels on cob corn, yield of sweet corn and total weight of dry matter.

Keywords: land preparation, soil physics, sweet corn, yield

Citation: Hosseinali, S., D. Ahmad, A. Yahya, W. Aimrun. Yield components of sweet corn (*Zea mays*) and some soil physical properties towards different tillage methods and plant population. Agricultural Engineering International: CIGR Journal, 19(3): 56–63.

1 Introduction

Tillage operation plays an important role in the yield of crop, energy consumption and soil structure. Hence, it is important to choose a proper method among the different tillage systems. Generally, tillage systems also can be evaluated by the physical-chemical and biological characteristics of soil, energy, fuel consumption, and grain yield of crops. The temperature, water content, bulk density, porosity, penetration resistance and aggregate size distribution are some physical properties of soil which are affected by tillage systems (Dam et al., 2005; Fabrizzi et al., 2005). The physical properties of water infiltration and water retention aerosol physical properties are also influenced by conservation tillage (Osunbitan et al., 2005).

Bulk density of the soil is related to soil structure (Sung and Talib, 2006). The soil with fine-textured soil structure has the lower bulk density and the higher porosity, and the soil with massive-textured soil structure has the higher bulk density and the lower porosity. It was reported that organic matter content affected bulk density (Lipiec et al., 2006). Compared with conventional tillage, soil bulk density is greater under conservation tillage (Ferreras et al., 2000); whereas Lal et al.(1994) reported the opposite view. This result has been due to the

Received data: 2016-10-18 **Accepted date:** 2017-05-28
*** Corresponding Author: Hosseinali Shamsabadi,** Email: Hshamsabadi@yahoo.com, Phone: 00989112738186, Fax: 0098175547721

presence of residue layer on the soil surface, compared to conventional tillage. The conventional tillage methods in semi-arid areas of Iran where has 350-500 mm per year rainfall has negative effects on soil physical characteristics and lead to soil degradation and soil erosion (Barzegar et al., 2003).

Soil physical characteristics are improved by tillage practices. The studies conducted on root growth and distribution (Merrill et al., 1996), porosity (Kay, 1990), water distribution (Waddell and Weil 1996), dry bulk density revealed the importance of tillage practices (Salinas-Garcia et al., 1997; Tapela and Colvin, 2002). Topsoil losses through surface runoff have a serious influence on farmers, as well as surrounding ecosystems and water bodies (Larsen et al., 2014).

Soil Moisture Content of volumetric basis (*MC*, v v^{-1}) is one of the properties of the soil, which is affected by tillage practices due to produced changes in infiltration, evaporation from the soil surface and runoff (Zhai et al., 1990). It can be measured simultaneously when the soil is sampled in the core ring (Bayer et al., 2016). The soil compaction causes reduction of the moisture and oxygen penetration of the soil, and increases energy consumption for soil disturbance and pulverization (Tebrugge, 2003). However, the efficiency of C sequestered in soil is different among crop systems (Yan et al., 2013, Chen and Weil, 2011).

Zea mays (Corn) is one of the most demanded, valuable and strategic crops worldwide. Besides being used as food for mankind and animal, it is used in industry too. It makes seeds produced the required protein. If it is possible to make a 200 kg ha^{-1} improvement, and it can produce a considerable increase in yield (Liu et al., 2016; Hubbard et al., 2013). Planting density is a major and important factor which determines the degree of competition between the plants for absorption of water, nutrients and light. The yield per plant increases, if the plant density decreases and vice versa. However, the total yield maybe increases due to greater number of the plants (Moreira et al., 2016; Hosseini et al., 2016; Nguetnkam and Dultz, 2011).

The purposes of this study were to evaluate the effects of the three tillage systems for land preparation (moldboard plow followed by one time disc harrowing (MPD), disc plow followed by one time disc harrowing (DPD) and rotary cultivator (RC) only as control) on some selected soil physical properties (dry bulk density (BD_d), total porosity (P_t) and volumetric moisture content (*MC*, v v^{-1}), water infiltration (*WI*) and resistance to penetration (*RP*); and their influences on yield and some yield components of sweet corn (*Zea mays*). Moreover, interaction effects of two factors (tillage and planting density) on yield and some yield components of sweet corn was reviewed.

2 Materials and methods

2.1 Experimental site

The experiments were conducted at the research farm of University Putra Malaysia (UPM), Serdang Selangor, Malaysia, during cropping season in 2008, which was a sandy clay loam soil texture (60% sand, 32% clay and 8% loam) with an EC of 33 μS cm^{-1}, pH of 5.2 and cation exchange capacity (CEC) of 9.80 cmol kg^{-1}. The experimental site was under corn and corn rotation with longitude 101°42.722′E, latitude 2°58.990′N, and an altitude of 31m above sea level. Average annual rainfall of the experimented region was 2548.5 mm. The maximum and minimum temperatures were 33.1°C and 23.0°C, respectively.

2.2 Experimental design

The experimental design was arranged with a 2×3 factorial treatment, based on randomized complete block design (RCBD) with three replications for soil analysis. The main plots were attributed to tillage systems, namely moldboard plow (MP) and disc plow (DP) with plowing depth of 25 and 30 cm, respectively and then once tandem disc harrowing with the depth of 10 cm were followed, and also rotary cultivator (RC) as control with 10-12cm plow depth. Samplings were taken by auger and core ring from two depths of 0-10 and 20-30 cm to determine soil parameters. The other experimental design was arranged with a 3×3 factorial treatment, based on randomized complete block design (RCBD) with three replications for crop analysis including the yield and yield components of Thai Super Sweet Corn as follows: Ear diameter, row length of kernel on cob corn, number of kernel per row on cob corn, number of kernel row, weight of Fresh husked, and yield. Pulling machine (tractor) was with 70 hp engine power.

2.3 Measurements

Soil texture was determined and adapted by the pipette method (Gee et al., 1986). Bulk Density which includes the volume of the solids and pore spaces should be undisturbed soil samples and were taken in a container of a constant and known volume (Blake et al., 1986). It was calculated with the following Equation (1) :

$$BD = (W_{ds(105)}) \div (V_{scr}) \qquad (1)$$

In obove equation $W_{ds(105)}$ and V_{scr} is Weight of dried soil at 105°C and Volume of soil inside the core ring, respectively.

Total Porosity (P_t) which is a measure of the void spaces in a soil was calculated from the particle density (PD) and the bulk density (BD) using the following Equation (2):

$$P_t = [1 - BD \div PD] \times 100 \qquad (2)$$

It is expressed in % or $m^3 \cdot m^{-3}$ (Aimrun et al., 2002).

To determine the relation between water infiltration and yield of sweet corn to tillage treatment, water infiltration test was carried out by double-ring method in the field.

To determine the soil resistance to penetrationn after plowing and its influence on yield of sweet corn, cone index test was carried out by penetrometer method in the field.

After soil preparation with different tillage machines, the Thai Super Sweet Corn seeds (*Zea mays*) with germination rate of 90%, purity rate of 80% and 160 g for weight of 1000 seeds, were sown by a four rows crop planter with pneumatic metering system with row spacing of 80 cm and three seed spacing of 20, 30 and 40 cm. Fertilizing practice was carried out at three stages which were including N-P-K green, 20 g per plant while seeding; N-P-K blue, 20 g per plant at two weeks after seeding and N-P-K blue, 20 g per plant while tasselling or anthesis. Other crop protection (maintenance) practices were weed control three times by manual, sprinkler irrigation and breaking crust layer by hoe.

In the present study, there were 4 rows for each treatment of tillage and density. The length was 20 m and the width or row spacing was 0.8 m. For measurement of the crop parameters, the two middle rows were harvested (Balkcom and Reeves, 2005). After omitting the borders (2 m from the first and the end of each row crop) all the ear corns from the two middle rows were harvested for yield per hectare, and 5 m length of the mentioned rows were considered as the harvest area for yield components (ear diameter of cob corn, row length of kernel on cob corn, nomber of kernel per row, nomber of kernel row on cob corn, weight of fresh husked).

2.4 Statistical analysis

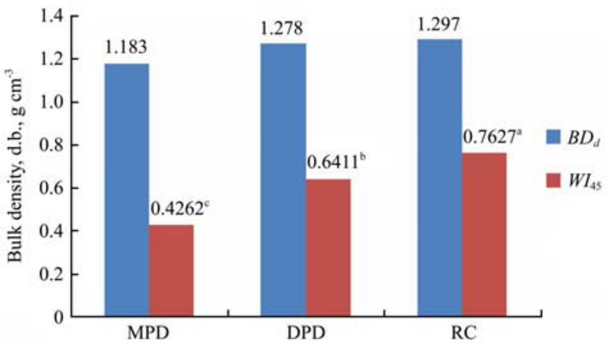
The analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) were used to analyze the data, and that was performed by SAS software (SAS Institute, 2003).

3 Results and discussion

3.1 Soil physical properties

The relation of total water infiltration during 45 minutes (WI_{45}) and BD_d against the three tillage treatments was based on the reverse order at the depth of 0-15 cm, as observe in Figure 1. As long as BD_d increased, WI_{45} decreased and vise versa. When the value of BD_d was reduced from 1.297 to 1.183 g cm^{-3}, the afore-mentioned result became in reverse order. For example, when BD_d reduced from 1.297 to 1.183 g cm^{-3}, WI_{45} increased from 42.67 to 76.27 L. Consequently, the soil ploughed by RC had the lowest BD_d and the highest WI_{45} at the depth of 0-15 cm. Although the value of water infiltration test was higher for RC, but this condition (downward movement of water with high velocity) might be improper for the plants, particularly for shallow rooted plants.

Figure 1 shows the results of water infiltration test after 45 min (WI_{45}) in the field for different tillage treatments. The greatest value of WI_{45} occurred in the RC plots (47.625 L) and decreased to 39.003 L of DPD and 23.445 L of MPD, respectively. This result could be related to higher aggregates and bulk density (BD) and lower total porosity (P_t), and higher macro porosity at the depth of 0-15 cm as compared to other tillage treatments; owing to intensive operation and mixing at upper layer by RC which led to more breaking, mixing and powdering, and granular. On the other hand, the value of WI_{45} in the sandy clay loam soil texture had higher aggregates more than 2 mm, higher BD_d and lower P_t. Although it could be a function of working depth of tillage implements, however it was not accordingly. The afore-mentioned results also could be due to other parameters such as soil texture, soil structure, amount of organic matter, depth of soil layer to hard pan or plough pan, amount of water in the soil, soil temperature and compaction (Teh and Jamal, 2006). The present study revealed that soil structure and depth of soil layer of hard pan or plough pan had been effective in the afore-mentioned result. Nevertheless, the fine-textured soil structure with large water-stable aggregates (granular structure) under RC had higher infiltration rate than massive (structureless) soil under DPD and MPD, respectively. Consequently, total porosity (P_t) increased and soil bulk density (BD_d) decreased, except BD_d in the second layer of RC. This result was in contrary with the obtained results by Fabrizzi et al.(2005) , Lipiec et al.(2006) who observed that the soils with lower BD_d or higher P_t had higher WI_{45}. They concluded that soil had lower bulk density and greater porosity versus different tillage treatments. Consequently, this condition could affect WI and increased it.



Note: Means with different letters are significantly different at P<0.001.

Figure 1 Relation of total water infiltration in m^3 during 45 minutes and bulk density to tillage treatments at the depth of 0-15 cm

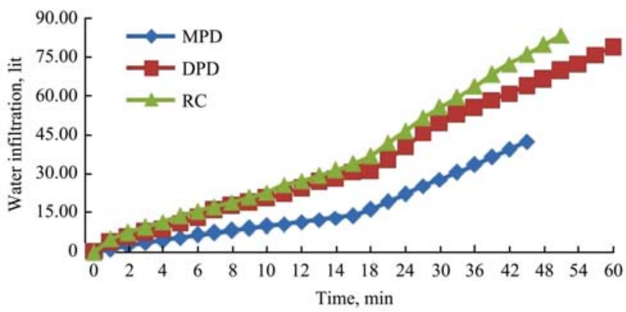


Figure 2 Water infiltration during the test as affected by various tillage treatments

The soil resistance to penetration (RP) was affected by both tillage methods and depth treatment at P<0.01. This result could be due to various soil disturbance and pulverization or soil structure which was created by various tillage implements with different plough depths (Teh and Jamal, 2006; Miller and Donahue, 1990).

The soil RP in Figure 3 shows that hardpan layer with soil RP (between 1.7 to 2.8 MPa) was presented at the depths of 25 to 50 cm, which was restrictive to the growth of sweet corn (*Zea mayz* L.) root. The highest value of soil RP of DPD was 2.73 MPa and occurred at the depth of 50 cm. At the depth of 20 cm, the highest value of RP of RC was 1.80 MPa and decreased to 1.41 MPa of MPD and 1.25 MPa of DPD, respectively. These results show reaction of root growth development and crop yield of sweet corn. When the soil below 40 cm depth, the values of RP decreased from 2 to 1.5 MPa for RC plot and 2.15 to 1.75 MPa for MPD plot, but it would increased from 2.25 to 2.665 MPa for DPD plot. This result could be due to moisture content, working depth and needed draught force of each tillage implements during soil tillage practices.

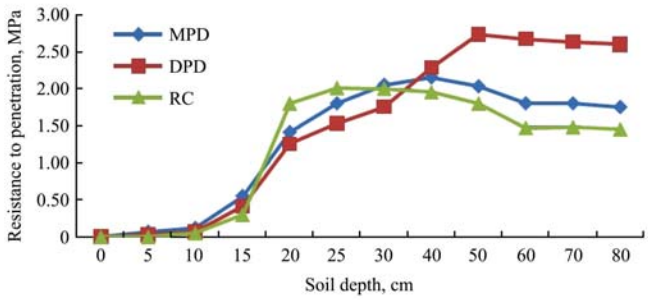


Figure 3 Resistance to penetration at different depths vs various tillage methods

Table 1 shows analysis of variance for the measued traits of sweet corn yield and its components under different tillage methods. Interaction effects of the two factors, tillage method and planting density showed significant effects for row length of kernel of cob corn, yield of sweet corn, and total weight of dry matter. Figure 4 shows the highest values of row length of kernel of cob corn (RL) attributed to T1 (MPD plot) and T2 (DPD plot) under low planting density of D3 (seed spacing of 40 cm times row spacing of 80 cm), while The lowest value of RL attributed to T3 (RC plot) under high planting density of D1 (seed spacing of 20 cm by row spacing of 80 cm).

About 74% difference between the highest and the lowest values of RL could be due to the distance of plants, as that led to lower competition for light, moisture and nutrients in big spaces of the plants. Depth of ploughing and different soil structure as affected by various tillage methods and this could be the other reasons for this result. For example, higher bulk density of the soil under RC plot at the root zone area led to reduction in root growthand crop traits.

Comparison of means for the measued traits of sweet corn yield and its selected components versus different tillage methods were shown in Table 2. This table inferred the highest and lowest values of ear diameter of corn and that atributed to DPD and RC, respectively. Also, the highest and lowest values of Fresh weight unhusked ear was allocated to DPD and RC, which was under the seed spacing of 40 and 20 cm, respectively. These results could be the soil conditions which ploughed by different tillage machines and distances of the plants. Seed spacing of 40 cm produced lower competition between the plants, consequently, that was created good condition for corn production.

Table 1 Analysis of variance (ANOVA) for measured traits of yield and its components of sweet corn versus different treatments in 2009

Sources of variation	DF	Ear diameter unhusked		Row length		Fresh weight unhusked ear		Yield of sweet corn		Total weight of dry matter ha^{-1}	
		MS	F	MS	F	MS	F	MS	F	MS	F
Replication (R)	2	0.592	16.72**	0.287	0.38^{ns}	3698.08	0.77**	6627436	7.13*	84196	0.638^{ns}
Tillage (Till)	2	0.111	1.70*	10.572	9.13*	3361.42	4.64**	6368008	3.18*	129438	1.060*
R×Till (E_a)	4	0.015	-	6.986	-	493.28	-	617999	-	691314	-
Density (Den)	2	0.033	1.68^{ns}	3.177	2.63*	1700.86	2.32*	64785269	71.39***	68456735	218.34**
Till×Den	4	0.042	0.897^{ns}	70.789	5.89*	1343.79	1.51^{ns}	18225696	10.15*	17939382	88.99**
Error	18	0.035	-	0.754	-	343.28	-	929726	-	501582	-
Total	26	-	-	-	-	-	-	-	-	-	-

Note: *** Significant at 0.001probability level; ** Significant at 0.01 probability level; * Significant at 0.05 probability level; ^{ns} Not significant.

Table 2 Comparison of means for measured traits of sweet corn versus different treatments

		Ear dia, cm	Row length, cm	Fresh wt. corn, g	Corn yield, kg ha^{-1}	Total wt. of dry matter ha^{-1}, kg ha^{-1}
Tillage	MPD	4.92ab	15.11a	226.95ab	9580ab	3300a
	DPD	4.98a	15.85a	243.37a	10550a	3600a
	RC	4.76b	13.49b	204.85b	8880b	2850b
Density	D20	4.82a	14.14b	210.34b	12520a	3960a
	D30	4.92a	14.70ab	227.27ab	9300b	2730b
	D40	4.93a	15.32a	237.57a	7190c	2690c

Note: Means between treatments followed by similar letters do not differ significantly (p>0.05). D_{20}= seed spacing of 20 cm; D_{30}= seed spacing of 30 cm; D_{40}= seed spacing of 40 cm.

Interaction effect of tillage and planting density on fresh yield of sweet corn was shown in Figure 4, and which indicates that the highest value of sweet corn yield (13,890 kg ha^{-1}) attributed to the soil prepared by DPD under high planting density (seed spacing of 20 cm by row spacing of 80 cm, or 62,500 plant ha^{-1}), while the lowest value of sweet corn yield (6,920 kg ha^{-1}) was belonged to the soil prepared by RC under low planting density (seed spacing of 40 cm by row spacing of 80 cm, or 31,250 plant ha^{-1}). The difference between the two values (100% increased sweet corn yield) could be due to the afore-mentioned reasons for RL.

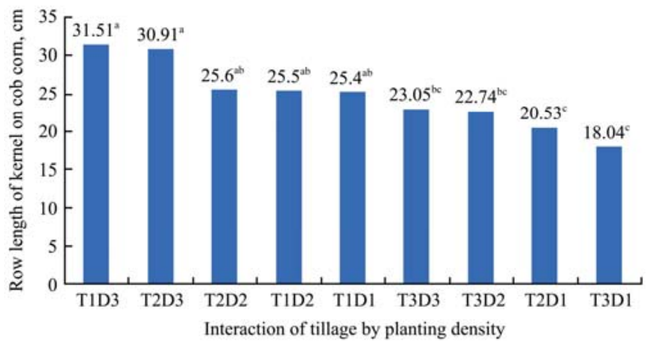


Figure 4 Interaction of tillage by planting density on row length of kernel on cob

The afore-mentioned results in yield and TWDM indicate that the optimal use has been done in the cases of high planting density and deeper plough depths, according to higher products of the land. From Table 1 it can be concluded that ear diameter of cob corn (*ED*) was affected by tillage method. Therefore with reference to Table 2 (comparison of means), under various tillage methods, the highest value of *ED* (4.98 cm) occurred in DPD plot, and decreased to 4.92 and 4.76 cm in MPD and RC plots, respectively. This result could be different depth of ploughing and soil physical characteristics was affected by various tillage methods. The soil under DPD plot created the best condition for RL of kernel of cob corn at any given planting density.

Fresh weight of unhusked ear corn (*FWE*) was affected by both tillage methods and planting density, separately, as shown in Table 1. Comparison of means in Table 2 indicates that the highest value of *FWE* yielded in DPD plot under large spacing of the plants or low planting density whilst, and the lowest value of *FWE* recorded in RC plot under short spacing of the plants or high planting density. Although *FWE* was higher under DPD plot with seed spacing of 40 cm, however because of number of plant per hectare in this case, the sweet corn yield was not higher, as shown in Figure 5.

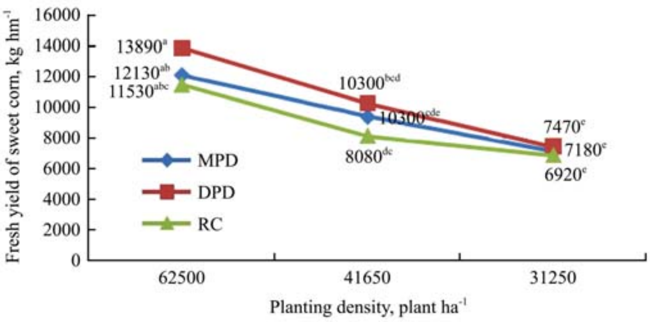


Figure 5 Interaction of tillage by planting density on fresh yield of sweet corn

Interaction effect of tillage and planting density on fresh yield of sweet corn was shown in Figure 2, which indicates that the highest value of sweet corn yield (13,890 kg ha^{-1}) attributed to the soil prepared by DPD under high planting density (seed spacing of 20 cm by row spacing of 80 cm, or 62,500 plant ha^{-1}), while the lowest value of sweet corn yield (6,920 kg ha^{-1}) belonged to the soil prepared by RC under low planting density (seed spacing of 40 cm by row spacing of 80 cm, or 31,250 plant ha^{-1}). The difference between the two values (100% increased sweet corn yield) could be due to the afore-mentioned reasons for RL. The soil under DPD plot created the best condition for RL of kernel of cob corn at any given planting density.

From Table 1 it can be concluded that ear diameter of cob corn (*ED*) was affected by tillage method. Therefore with reference to Table 2 (comparison of means), under various tillage methods, the highest value of *ED* (4.98 cm) occurred in DPD plot, and decreased to 4.92 and 4.76 cm under MPD and RC plots, respectively. This result could be different depth of ploughing and soil physical characteristics as affected by various tillage methods.

Fresh weight of unhusked ear corn (*FWE*) was affected by both tillage methods and planting density, rseparately, as shown in Table 1 Comparison of means in Table 2 indicates that the highest value of *FWE* yielded in DPD plot under large spacing of the plants or low planting density whilst, the lowest value of *FWE* recorded in RC plot under short spacing of the plants or high planting density. Although *FWE* was higher under DPD plot with seed spacing of 40 cm, however because of number of plant per hectare in this case, the sweet corn yield was not higher, as shown in Figure 2.

From the afore-mentioned results it can be deduced that when the water or rainfall and sunshine hour were higher (after tillage), the vegetative growth of sweet corn was increased up to 32% and 75% between the highest and lowest plants, respectively. While in reproductive growth of sweet corn (yield) was increased up to 28% between the highest values, and up to 1% between the lowest values. Also it can be inferred that when the climate condition improved, in terms of amount of rainfall and sunshine hours; the reproductive and vegetative growths of sweet corn increased up to 28% and 32%, respectively, in the case of high planting density. Whilst in the case of low planting density, the vegetative growth produced considerable increase (75%) proportion to reproductive growth of sweet corn (1%). In other words, when rainfall and sunshine hour increased vegetative growth of sweet corn was much greater than reproductive growth when plant population was lower or in the bigger spacing of the plants. The above described results are summarized in Table 3.

Table 3 Differences of corn yield and total weight of dry matter before and after tillage

Crop trait	$Yield_{max}$, kg ha^{-1}	$Yield_{min}$, kg ha^{-1}	Difference, %	$TWDM_{max}$, kg ha^{-1}	$TWDM_{min}$, kg ha^{-1}	Difference, %
Output	13,890	6920	100	4,110	2,775	67

Note: 13,890 max.and 6920 kg ha^{-1} Fresh yield of sweet corn; and 4110 and 2775 kg ha^{-1} $TWDM_{max}$ occurred in the plots which plowed with DPD and RC, respectively.

4 Conclusion

Soil physical conditions in terms of soil dry bulk density, soil resistance to penetration and water infiltration were significantly affected by depth and tillage treatments. Tillage practices decreased bulk density and increased total porosity.

The highest values of row length of kernel of cob corn (RL) was attributed to T1 (MPD plot) and T2 (DPD plot) with low planting density of D3 (seed spacing of 40 cm times row spacing of 80 cm), while the lowest value of RL was attributed to T3 (RC plot) with high planting density of D1 (seed spacing of 20 cm by row spacing of 80 cm).

Interaction effect of tillage and planting density on fresh yield of sweet corn indicates that the highest value of sweet corn yield was attributed to the soil prepared of DPD under high planting density. Also, it concluded that ear diameter of cob corn (*ED*) was affected by tillage method.

The yield of sweet corn and total weight of dry matter (TWDM) were increased at any given planting densities and tillage treatments.

When plant population was lower or there was the bigger spacing of the plants, and there was adequate light, moisture and nutrients for all the plants, in contrast, Y and TWDM were higher in the case of high planting density. It infers that the influence of factor ofplanting density) was greater than the other factor of tillage method for yield of sweet corn, as stated before.

Importance or influence of each one of the two factors; tillage method and planting density for sweet corn yield was in accordance with this order: planting density> tillage method.

References

Aimrun W., M. Amin, M. Mokhtaruddin, and S. Eltaib. 2002. Determination of soil physicalproperties in lowland rice area of Tanjung Karang irrigation scheme Malaysia. In *Proc. 2nd World Engineering Congress*, *Barcelona, Spain*: 363–368.

Balkcom, K. S., and D. W. Reeves. 2005. Sunn-hemp utilized as a legume cover crop for corn production. *Agronomy Journal*, 97(1): 26–31.

Barzegar, A., M. Asoodar, A. Khadish, A. Hashemi, and S. Herbert. 2003. Soil physical characteristics and chickpea yield responses to tillage treatments. *Soil and Tillage Research*, 71(1): 49–57.

Bayer, C., J. Gomes, J. A. Zanatta, F. C. B. Vieira, and J. Dieckow. 2016. Mitigating greenhouse gas emissions from a subtropical Ultisol by using long-term no-tillage in combination with legume cover crops. *Soil and Tillage Research*, 161(2): 86–94.

Blake, G. R., K. H. Hartge, and A. Klute. 1986. *Methods of Soil Analysis: Part I. Physical and Mineralogical Methods.* American Society of Agronomy, Inc.

Chen, G., and R. R. Weil. 2011. Root growth and yield of maize as affected by soil compaction and cover crops. *Soil and Tillage Research*, 117(2): 17–27.

Dam, R. F., B. B. Mehdi, M. S. E. Burgess, C. A. Madramootoo, G. R. Mehuys, and I. R. Callum. 2005. Soil bulk density and crop yield under eleven consecutive years of corn with different tillage and residue practices in a sandy loam soil in central Canada. *Soil and Tillage Research*, 84(1): 41–53.

Fabrizzi, K., F. Garc, J. Costa, and L. Picone. 2005. Soil water dynamics, physical properties and corn and wheat responses to minimum and no-tillage systems in the southern Pampas of Argentina. *Soil and Tillage Research*, 81(1): 57–69.

Ferreras, L. A., J. L. Costa, F. O. Garcia, and C. Pecorari. 2000. Effect of no-tillage on some soil physical properties of a structural degraded Petrocalcic Paleudoll of the southern "Pampa" of Argentina. *Soil and Tillage Research*, 54(1): 31–39.

Gee, G. W., J. W. Bauder, and A. Klute. 1986. Particle-size analysis. Methods of soil analysis. Part I. In *Physical and Mineralogical Methods*, 383–411.

Hosseini, M., S. A. M. Naeini, A. A. Dehghani, and Y. Khaledian. 2016. Estimation of soil mechanical resistance parameter by using particle swarm optimization, genetic algorithm and multiple regression methods. *Soil and Tillage Research*, 157(5): 32–42.

Hubbard, R. K., T. C. Strickland, and S. Phatak. 2013. Effects of cover crop systems on soil physical properties and carbon/nitrogen relationships in the coastal plain of southeastern USA. *Soil and Tillage Research*, 126(6): 276–283.

Kay, B. D. 1990. Rates of change of soil structure under different cropping systems. In *Advances in Soil Science*

12, pp. 1–52. New York: Springer.

Lal, R., A. Mahboubi, and N. Fausey. 1994. Long-term tillage and rotation effects on properties of a central Ohio soil. *Soil Science Society of America Journal*, 58(2): 517–522.

Larsen, E., J. Grossman, J. Edgell, G. Hoyt, D. Osmond, and S. Hu. 2014. Soil biological properties, soil losses and corn yield in long-term organic and conventional farming systems. *Soil and Tillage Research*, 139(7): 37–45.

Lipiec, J., J. Kus, A. Nosalewicz, and M. Turski. 2006. Tillage system effects on stability and sorptivity of soil aggregates. *International Agrophysics*, 20(3): 189.

Liu, Q. J., J. An, G. H. Zhang, and X. Y. Wu. 2016. The effect of row grade and length on soil erosion from concentrated flow in furrows of contouring ridge systems. *Soil and Tillage Research*, 160(12): 92–100.

Merrill, S., A. Black, and A. Bauer. 1996. Conservation tillage affects root growth of dryland spring wheat under drought. *Soil Science Society of America Journal*, 60(2): 575–583.

Moreira, W. H., C. A. Tormena, D. L. Karlen, Á. P. da Silva, T. Keller, and E. Betioli. 2016. Seasonal changes in soil physical properties under long-term no-tillage. *Soil and Tillage Research*, 160: 53–64.

Nguetnkam, J. P., and S. Dultz. 2011. Soil degradation in Central North Cameroon: Water-dispersible clay in relation to surface charge in Oxisol A and B horizons. *Soil and Tillage Research*, 113(1): 38–47.

Osunbitan, J., D. Oyedele, and K. Adekalu. 2005. Tillage effects on bulk density, hydraulic conductivity and strength of a loamy sand soil in southwestern Nigeria. *Soil and Tillage Research*, 82(1): 57–64.

Salinas-Garcia, J., J. Matocha, and F. Hons, 1997. Long-term tillage and nitrogen fertilization effects on soil properties of an Alfisol under dryland corn/cotton production. *Soil and Tillage Research*, 42(1): 79–93.

SAS Institute. 2003. *Statistics*, 8th Ed. Cary, N.C.: SAS Inst. Inc.

Sung, C. T. B., and J. Talib. 2006. Soil and Plant Analyses, *Soil Physics Analyses*.

Tapela, M., T. S. Colvin. 2002. Quantifying seedbed condition using soil physical properties. *Soil and Tillage Research*, 64(3): 203–210.

Tebrugge, F. 2003. No-tillage visions-protection of soil, water and climate and influence on management and farm income. In *Conservation Agriculture*, 327–340. Netherlands: Springer.

Waddell, J., and R. Weil. 1996. Water distribution in soil under ridge-till and no-till corn. *Soil Science Society of America Journal*, 60(1): 230–237.

Yan, X., H. Zhou, Q. H. Zhu, X. F. Wang, Y. Z. Zhang, X. C. Yu, and X. Peng. 2013. Carbon sequestration efficiency in paddy soil and upland soil under long-term fertilization in southern China. *Soil and Tillage Research*, 130(6): 42–51.

Zhai, R., R. Kachanoski, and R. Voroney. 1990. Tillage effects on the spatial and temporal variations of soil water. *Soil Science Society of America Journal*, 54(1): 186–192.