

Yield and Yield Components of Sweet Corn (*Zea Mays* L.) Grown Under Different Tillage Methods

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Abstract: Field experiment was conducted to investigate the effects of three tillage systems on sweet corn yield and selected its components for Serdang soil series (*Typic Paleodults*) at the Research Farm of University Putra Malaysia (UPM). The three tillage systems were mouldboard plough followed by once disc harrowing (MPD), disc plough followed by once disc harrowing (DPD), and rotary cultivator (RC) only as control. Crop yield and its components of sweet corn was investigated at three planting densities (high, medium and low) with seed spacing of 20, 30 and 40 cm. They were ear diameter, row length, weight of ear, and total weight of ear per hectare (yield). The experimental design was a 3×3 factorial treatments based on Randomized Complete Block Design (RCBD) with three replications. Results showed that the highest value of crop yield (10850 kg/ha) was recorded in MPD plot and decreased to 9800 and 9075 kg/ha in DPD and RC plots, respectively. Although the size of ears (yield components) were higher in big spacing of the plants (low planting density) at any given tillage methods, however it was not affected positively on crop yield, because of number of plants per hectare.

Key words: Mouldboard plough, disc plough, rotary cultivator, bulk density, porosity, corn, tillage

INTRODUCTION

The population of the world is increasing, and subsequently, food demand also increases. Therefore considering limitation in sources of crop production such as land, water and nutrient elements for agriculture, making the vast efforts to increase agricultural production seem necessary to meet this food demand. Among the cereals, corn (*Zea Mays* L.) is one of the most demanded, valuable and strategic crops worldwide after wheat, barley and rice. There are several ways to maximize crop yield in unit area. Two of them are tillage method and planting density. Tillage operation has an important role on the crop yield and soil structure. Hence, it is important to choose a proper method among the different tillage systems or land preparation methods.

Generally, tillage operation can also be evaluated based on the physical-chemical and biological characteristics of soil, energy and fuel consumption, and grain yield of crops. Soil temperature, water content,

bulk density, porosity, resistance to penetration and aggregate distribution are some of the physical properties which are affected by tillage systems (Fabrizzi et al., 2005). Some soil physical properties studied by Reynolds et al. (2007) were dry bulk density, porosity, available water holding capacity, air capacity, organic carbon content and hydraulic conductivity. The research conducted by Knapen et al. (2007) and Gobin et al. (2004) indicated that the soil erosion and soil formation are function of geophysical parameters such as topography, climate, coverage on the soil and soil characteristics.

Bulk density of a soil varies with soil structure (Teh and Jamal, 2006). The soil with fine-textured soil structure has the lower bulk density and the higher porosity and vice versa the soil with massive-textured soil structure has the higher bulk density and the lower porosity. These soil conditions often created with various tillage methods or systems. The conventional tillage methods in semi-arid areas of Iran which has 350-500

mm rainfall has negative effects on soil physical characteristics and led to degradation of soil and soil erosion, subsequently it could led to crop yield reduction (Barzegar et al., 2003).

Soil compaction describes the conditions of soil bulk density and porosity, and it can affect on final yield. Traffic with agricultural machinery for different operations can also create soil compaction. During soil tillage operation (ploughing) plough pan layer is existed. This compacted layer impede root growth, consequently it can lead yield reduction, particularly for deep rooted plants. The results recorded by Hamza and Anderson (2005), proved that soil compaction caused by sheep-trampling and was based on animal weight and soil moisture content.

Soil physical characteristics can be improved by tillage practices. The studies conducted by Merrill et al. (1996) on root growth and distribution, Kay (1990) on porosity, Salinas-Garcia et al. (1997) and Tapela and Colvin (2002) on dry bulk density revealed the importance of tillage practice.

One of the disadvantages of tillage implements is creating of the plough pan layer below the ploughed horizon. The soil compaction causes reduction of the moisture and oxygen penetration inside the soil and increasing energy consumption (Tebrugge, 2002).

Plant density is a major and important factor which determines the degree of competition between the plants. Depending on the soil structure, available water and nutrients, it can be different. Yield per hectare increases if the plant density per unit area decreases and vice versa, if the plant density per unit area increases, the yield per hectare can decrease due to competition between the plants for light, moisture and nutrients (Shamsabadi et al., 2009).

The purposes of this study were to evaluate the effects of various tillage methods (tillage) for land preparation on some soil physical properties at two depths of 0-15 and 20-35 cm. Tillage methods were T1= mouldboard plough with 25 cm plough depth followed by one time tandem disc harrowing with 10 cm depth (MPD), T2=disc plough with 35 cm plough depth followed by one time tandem disc harrowing with 10 cm depth (DPD), and T3=rotary cultivator only (RC) as control at about 20 cm plough depth. Soil physical properties were dry bulk density (BD_d) and total porosity (P_t). At the end yield and its components of

sweet corn (*Zea mays* L.) with three planting densities (high, medium and low), with planting pattern, row spacing of 80 cm and seed spacing of 20, 30 and 40 cm, respectively, investigated.

MATERIAL and METHODS

The experiments were conducted at the Research Farm of University Putra Malaysia, Serdang Selangor, Malaysia, in 2008 cropping season (March-May) on a sandy clay loam soil texture (60% sand, 32% clay and 8% loam) with pH of 5.2. The experimental site was under corn-corn rotation, with longitude of $101^{\circ} 42.722' E$, latitude of $2^{\circ} 58.990' N$. and an altitude of 31m above mean sea level. Average annual rainfall of the experimented region was 2548.5 mm and the maximum and minimum temperatures were 33.1 and $23.0^{\circ} C$, respectively.

The experimental design was arranged with a 3 (planting density) \times 3 (tillage) factorial treatment, based on randomized complete block design (RCBD) with three replications for crop analysis including; ear diameter, row length of kernel on cob corn, weight of fresh ear unhusked and yield of *Thai Super Sweet* corn. The main plots were allocated to tillage treatments, namely MPD, DPD and RC. The sub plots were allocated to the three planting densities. After soil tillage, soil samplings were taken by core ring from two depths of 0-15 and 20-35 cm to determine soil bulk density, dry basis (BD_d) and total porosity (P_t).

Soil texture was determined and adapted by the pipette method (Gee and Bauder, 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 and Hartge, 1986). Then weight of the oven-dried soil inside the core ring divided to its volume.

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 (BDd) using the following formula (Aimrun *et al.*, 2002):

$$P_t = \left(1 - \frac{BD_d}{PD} \right) \quad (1)$$

where; P_t is in % or m^3/m^3 .

After soil preparation with different tillage machines and soil sampling, the Thai Super Sweet corn seeds (*Zea mays* L.) with germination rate of 90%, purity rate of

80% and 160 g for weight of 1000 seeds were sown by a four row crop planter with pneumatic seeder with row spacing of 80 cm and a tractor with three seed spacings of 20, 30 and 40 cm. Fertilizing practice was carried out at three stages, comprising N-P-K green, 20 g per plant while seeding; N-P-K blue, 20 g per plant, two weeks after seeding and N-P-K blue, 20 g per plant while tasselling or anthesis. Other crop protection (maintenance) practices were three times manual weed control, sprinkler irrigation and breaking crust layer by hoe.

In each level of tillage, there were four rows and three rates of planting density with three replications. The length was 20 m and the width or row spacing was 0.8 m. For measurement of the crop traits, the two middle rows were harvested (Balkcom et al., 2004). After omitting the borders (2 m from the first and the end of each row crop) all the ear cobs from the two middle rows were harvested for yield per hectare, and 5 m length of the afore-mentioned rows were considered as the harvesting area for yield components (ear diameter of cob corn, row length of kernel on cob corn and weight of fresh ear unhusked). The analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) were conducted to analyze the data using SAS software (SAS, 2003).

RESULTS and DISCUSSION

The highest value of bulk density, dry basis (BD_d) occurred in RC plot at the depth of 0-15 and 20-35 cm. While the lowest value of BD_d concluded in MPD plot at the depth of 0-15 cm, as shown in Table 1. These results could be due to different ways of fracturing and pulverization and also indicate that lower layer (20-35 cm) had been compacted as compared to the upper layer (0-15 cm). The results obtained were consistent with the achieved results by Tapela and Colvin (2002) and Pietola et al. (2005). They recorded that lower layer (plough pan) had higher bulk density and lower porosity. In this regards, Griffith et al. (1977) reported that the value of dry bulk density between 1.4-1.5 g/cm³ shortens root growth. But the obtained values of dry bulk density in the current study were below the mentioned range, except for the plot ploughed by rotary cultivator (1.511 g/cm³) which occurred at the depth of 20-35 cm. According to the formula 1, total porosity (P_t)

calculated and the result was shown in Table 1. As observed when BD_d increased, P_t decreased. Meaning that the relation between BD_d and P_t was in reverse order. At the depth of 0-15 cm, the highest value of P_t (55.33 m³/m³) yielded in MPD plot and decreased to 53.59 and 50.30 m³/m³ by DPD and RC, respectively. But at the depth of 20-35 cm, the highest value of P_t recorded in DPD plot and decreased by MPD and RC, respectively. This finding could be due to different plough depths and geometry of implements, subsequently different soil structure or disturbance and pulverization as a result of various tillage methods.

Table 2 shows interaction effects of tillage methods by planting density that was significant for row length of kernel on corn cob, weight of fresh unhusked ear corn and sweet corn yield per hectare ($P < 0.01$). This finding expresses that both two factors, tillage methods and planting density independently could affect on the measured characteristics. The MPD and DPD tillage methods created better seedbed as compared to the RC. Figure 1 demonstrates the definite beneficial and significant effects of tillage and planting density on yield of sweet corn. The highest value of sweet corn yield (10850 kg/ha) was found in the MPD plot in high planting density of 62500 plant ha⁻¹ (with seed spacing of 20 cm and row spacing of 80 cm), and the lowest value of yield (6850 kg/ha) recorded in the RC plot in low planting density of 31250 plant ha⁻¹ (with seed spacing of 40 cm and row spacing of 80 cm), as control method. This finding revealed that the yield increased at about 60% for MPD plot as compared to RC, as control method.

Table 1. Comparison of means for the measured soil physical properties versus the different tillage treatments at two depths

Soil traits	Means			
	BD_d (g/cm ³)		P_t (m ³ /m ³)	
Dep (cm)	0-15	20-35	0-15	20-35
Tillage				
T1=MPD	1.183	1.398	55.33	48.00
T2=DPD	1.278	1.230	53.59	52.70
T3=RC	1.297	1.511	50.30	45.30

BD_d = dry bulk density; P_t =total porosity;
 MPD=mouldboard plough + disc harrow
 DPD=disc plough + disc harrow; RC=rotary cultivator.

Table 2. Analysis of variance (ANOVA) of different factors for traits measured

Sources of variation	DF	Mean Squares			
		Ear dia	Row length	Fresh wt. Ear	Yield of corn
Replication	2	0.043 ^{ns}	0.297 ^{ns}	229.44 ^{ns}	3563421 ^{ns}
Tillage (T)	2	0.046 ^{ns}	4.75 [*]	4051.44 ^{**}	5826546 [*]
Density (D)	2	0.132 ^{**}	7.504 [*]	3554.60 ^{**}	14854681 ^{**}
T×D	4	0.053 ^{ns}	6.09 ^{**}	2623.83 ^{**}	8544583 ^{**}
Error	16	0.022	0.131	32.365	461532
Total	26	-	-	-	-

** Significant at 1% level * Significant at 5% level ns Not significant.

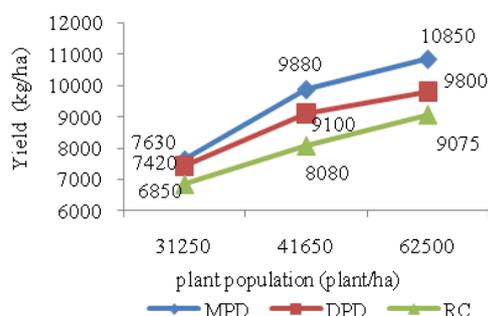


Figure 1. Yield of sweet corn against three tillage methods and three planting densities

The sweet corn yield responses to various tillage methods and different planting densities could be due to different soil structure caused by various tillage methods, different seed-soil contact and competition between the plants for light, water and nutrients. However the water and nutrients elements considered were equal for all treatments. The obtained result in the present study was agreed with French and Ewing (1989) where they stated that pea and chick pea grown as well in the Australian fine-textured soil structure.

The negative effects of higher BD_d and or lower P_t under RC plot concluded the lowest sweet corn yield at any given planting density, as shown in Figure 1. Interaction effect of the two factors, tillage and planting density on sweet corn yield in Figure 1 also appears that as planting density per hectare increased, and /or distance between the plants reduced, sweet corn yield increased too. This result revealed that water and nutrients were proper for high planting density, however the light might not to be adequate.

Figures 2 and 3 show interaction effects of tillage by planting density for row length of kernel on corn cob and weight of unhusked fresh ear corn,

respectively. The highest and the lowest values of row length of kernel on cob corn and weight of fresh unhusked ear corn concluded in T1D2 and T3D2 for MPD and RC plots, respectively with seed spacing of 30 cm. Meaning that mouldboard plough followed by disc harrowing (MPD) and rotary cultivator (RC) created the best and the worst soil structure and seedbed for the two traits mentioned at seed spacing of 30 cm.

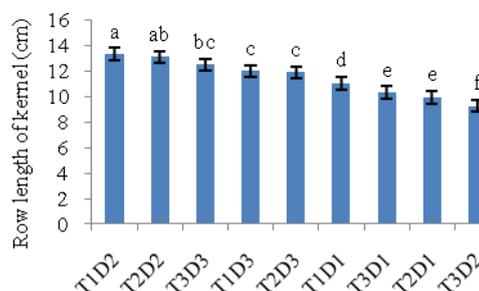


Figure 2. Interaction of tillage and planting density in row length of kernel on cob corn (T1=MPD, T2=DPD, T3=RC, D1, D2 & D3= seed spacing of 20, 30 & 40 cm, respectively)

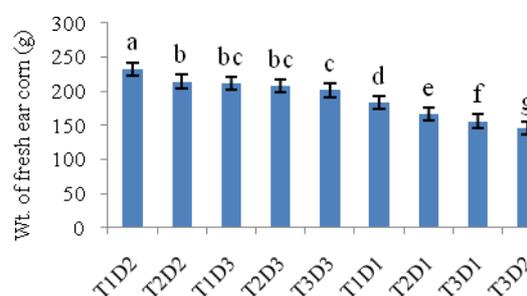


Figure 3. Interaction of tillage by planting density on fresh weight of unhusked ear corn (Means with the same letters on the bar charts do not have significantly difference)

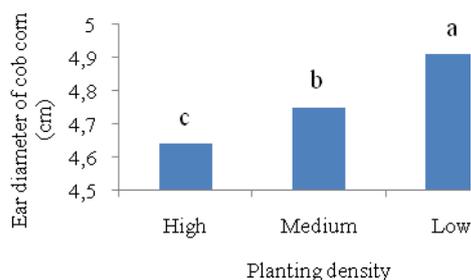


Figure 4. Ear diameter of unhusked corn against the different seeding rates (Means with different letters on the bar charts are significantly different at $P < 0.05$)

For the three yield components of sweet corn (ear diameter, row length and weight of ear), seed spacing of 20 cm (high planting density, D1) yielded the lowest and it increased for seed spacing of D2=30 and D3=40 cm, at any given tillage methods. However for sweet corn yield per hectare, seed spacing of 20 cm was the best. These results could be because of number of plant per hectare and stress or competition between the plants for light, water and nutrients, when the plants were close to each other.

Ear diameter was only trait that affected by planting density (Table 2). As shown in Figure. 4, when number of plant per hectare increased (seed spacing of 20 cm), ear diameter reduced. The highest value of ear diameter occurred in low planting density plot (seed spacing of 40 cm) and decreased in medium and high planting densities (seed spacing of 30 cm and 20 cm), respectively. This result indicates that when seed spacing was bigger (low planting density), competition between the plants reduced; consequently the plants could achieve more nutrients, water and light. As a result, the ear corn will grow better. From the economical and beneficial aspects, seed spacing of 20

REFERENCES

- Aimrun, W., M.S.M. Amin, M.M. Mokhtaruddin and S.M. Eltaib, 2002. Determination of soil physical properties in lowland rice area of Tanjung Karang irrigation scheme, Malaysia. 2nd World Engineering Congress, Sarawak, Malaysia: 363-368.
- Balkcom, K.S., D.W. Reeves, J.M. Kemble, and R.A. Dawkins, 2004. Winter annual grazing and tillage systems effects on sweet corn. 26th Southern Conservation Tillage Conference. 203-207.
- Barzegar, A.R., M.A. Asoodar, A. Khadish, A.M. Hashemi and S.J. Herbert, 2003. Soil physical characteristics and chickpea yield responses to tillage treatment. *Soil Till. Res.*, 71: 49-57.

and 30 cm were the best. Although yield components of sweet corn were lower at any given tillage methods and under short spacing of the plant (seed spacing of 20 cm), however for yield of sweet corn was the best at any given tillage methods.

CONCLUSIONS

Tillage methods decreased bulk density and increased total porosity. These results have been due to fracturing of soil or percentage of soil pulverization by different tillage implements. Relation of dry bulk density and total porosity was in inverted order. The soil with lower bulk density or higher total porosity was the best condition for sweet corn production. In this regards, mouldboard plough followed by disc harrowing (MPD) yielded lower soil bulk density in upper and lower layers, consequently, led to higher sweet corn yield, while rotary cultivator (RC) concluded opposite result.

The greater values of yield were obtained with high planting density of 62,500 plant/ha with seed spacing of 20 cm and row spacing of 80 cm, due to number of plant or ear corn per hectare. But the size of ear diameter of cobs was smaller and row length of kernel on cob was proportionally shorter.

Although there was competition between the plants in order to assess to moisture, light and nutrients when the plants were close to each other, but the highest and the lowest values of sweet corn yield per hectare occurred in MPD plot with seed spacing of 20 cm and RC plot with seed spacing of 40 cm. Therefore in terms of sweet corn yield per hectare, seed spacing of 20 cm was recommended.

For maximum benefits and optimum use of production resources (land, water, sunlight and nutrients), combination of MPD soil tillage with seed spacing of 20 cm was recommended.

- Blake, G.R., Hartge, K.H., 1986. Bulk density. In: Klute A. (Ed.), *Methods of soil analysis. Part 1. Agronomy 2th ed.* American Society of Agronomy, Madison, WI, USA: 363-375.
- Fabrizzi, K.P., F.O. Gacia, J.L. Costa, L.I. Picone., 2005. Soil water dynamic, physical properties and corn and wheat responses to minimum and no-tillage systems in the southern Pampas of Argentina. *Soil and Tillage Research*. 81:57-69.
- French, R.J. and Ewing, M.A., 1989. Soil type influences the relative yields of different cereals and crop legumes in Western Australia wheat belt. *Aust. J. Exp. Agric.*, 29:829-835.

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- Gee, G.W. and Bauder, J.W., 1986. Particle size analysis. In Klute, A. (ed). Methods of soil analysis. Part 1. Physical and mineralogical methods. 2nd ed. ASA-SSSA, Wisconsin, 383-411.
- Griffith, D.R., Mannering, J.V., Moldenhauer, W.C., 1977. Conservation tillage in the Eastern Corn Belt. *J. Soil Water Conservation*, 32: 20-28.
- Gobin, A., R. Jones, M. Kirkby, P. Campling, G. Govers, C. Kosmas and A.R., 2004. Gentile, Indicators for pan-European assessment and monitoring of soil erosion by water, *Environ. Sci. Policy*, 7: 25-38.
- Kay, B.D., 1990., Rate of change of soil structure under different cropping systems. *Adv. Soil Sci.*, 12:1-52.
- Knapen, A., J. Poesen, G. Govers, G. Gyssels and J. Nachtergaele, 2007. Resistance of soils to concentrated flow erosion: A review, *Earth Sci. Rev.*, 80: 75-109.
- Merril, S.D., Blake, A.L., Bauer, A., 1996. Conservation tillage affects on root growth of dry land spring wheat under drought. *Soil Sci. Soc. Am. J.*, 60:575-583.
- Pietola, L., R. Horn and M. Yli-Halla, 2005. Effects of trampling by cattle on the hydraulic and mechanical properties of soil, *Soil Till. Res.* 82: 99-108.
- Reynolds, W.D., C.F. Drury, X.M. Yang, C.A. Fox, C.S. Tan and T.Q. Zhang, 2007. Land management effects on the near-surface physical quality of a clay loam soil, *Soil Tillage Res.*, 96: 316-330.
- SAS Institute. 2003. SAS user's guide: Statistics. SAS Inst. Cary, NC.
- Salinas-Garcia, J.R., Matocha, J.E., Hons, F.M., 1997. Long-term tillage and nitrogen fertilization effects on soil properties of an Alfisol under dryland corn/cotton production. *Soil Till. Res.*, 42:79-93.
- Shamsabadi H.T., Abbas Biabani and Desa Ahmad. 2009. Effects of tillage methods and sowing rates on the grain yield and yield components of rain fed wheat, *Pertanika J. Sci. and Technol.* 17 (2): 325-336.
- Teh, B s.Ch. and Jamal T., 2006. *Soil Physics Analyses*. UPM press. 1:1-41.
- Tapela, M., and Culvin, T.S., 2002. Quantifying seed bed condition using soil physical properties. *Soil Till. Res.* 64:203-210.
- Tebrugge, F., 2002. Conservation tillage as a tool to improve soil-water and air quality. In: *Proceedings of the Eighth International Congress on Mechanization and Energy in Agriculture*, Kusadas1. Turkey.