Evaluation of corn planter under travel speed, working depth, pressure wheel and cone index

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Abstract: Compaction is one of the restricting factors in desirable seed germination and root growth. As a sign for soil compaction can be a criterion for optimal seed germination. Seeds require some compression of the surrounding soil at planting for optimum growth, which it is made by pressure wheels in planters. Travel speed and working depth affect the soil cone index. A field experiments were conducted to evaluate the effects of the speed and working depth in the beginning of the autumn season. Experiments were performed in the form of factorial split-plot based on a randomized complete block design with two factors, the travel speed (3, 4, and 6 km/h) and working depth (3, 6, 9, 12 and 15 cm) in three replication. Digital cone Penetrometer was used for measuring soil cone index of sandy-loamy soil at the depths ranging from 1 to 20 cm. The results showed that the cone index reduced by the increasing of average speed, also the cone index Increased with the increasing depth.

Keywords: Compaction, cone index, corn planter, depth, moving speed, pressure wheel

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1 Introduction

The compaction phenomenon in agricultural soils can be defined as an increase in its dry density and the close packing of solid particles or reduction in porosity (Mckyes, 1985). Compaction as evidenced by increased soil cone index and bulk density and reductions in soil porosity reduces the penetrability of the soil for roots (Botta et al., 2007). Patel and Mani (2011) directed a field study on sandy-loamy soil to quantify subsoil compaction at ranged wheel loads and multiple tire passages in terms of bulk density and penetration resistance. There are some factors significantly influence the compaction of agricultural soils. These factors are: soil type, soil moisture content, external load intensity, the area of the contact surface between the soil and the tire or track, shape of contact surface, and the number of passes (Biris et al., 2003).

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The quantity of bulk density and cone index commonly used to measure and describe soil compaction. Soil bulk density is expressed as mass per unit volume of soil. In the compaction phenomenon, soil bulk density increases due to constant mass and volume decreasing. The compaction rate changes by soil structure and type. For the compaction expression, the cone index has two main advantages than bulk density: First, the required data are obtained easily and so the required time for analysis of the soil profile is short. Second, cone index values for different soils are more comparable easily than bulk density.

The cone index defines as the value of force per area unit which is required for pressings the Penetrometer in soil (ASAE, 2005). Soil water content, bulk density and soil texture influence on the measurement value of soil resistance (cone index). The soil resistance index is obtained by the vertical penetration of Penetrometer in soil.

For best growth and development of rooting system in the soil, corn seed should be planted at a depth of 5 cm. This work causes to create deeper and healthy rooting system, increasing the ability of water absorbing, good crop production and eventually yield increases. Speed of corn planter depends on the planting conditions in the field, but it is typically less than 8 km/h. In the lower forward speeds; seeds could be planted at the proper depth and distance (Kinnison, 2013). Increasing planter speed influences the technical performance of planter and so product yield finally (Staggenborg et al., 2004).

Szymaniak et al (2003) was carried out an experimental investigation on the effects of reduced inflation pressure and variable ride velocity on soil vertical and longitudinal deformations. The vertical deformations of soil expressions rut. The experiment was run at three velocities: 5, 10 and 15 km/h and three inflation pressures: 0.6 (nominal), 0.5 and 0.4 MPa. Non-contact Opto-electronic method was used to measure both vertical and horizontal displacements. Their results showed that soil displacement is less with speed increasing and reducing of tire pressure, therefore soil rut and lateral deformation is reduced in contact area.

The pressure wheel is a component of corn planter that provides the optimum density for seedbed to have better germination and growth. In addition to speed, because the pressure wheel moves on plowed soil and the soil cone index is less in surface depths, so investigation about the cone index variation is important and will be useful in depths ranging from 40 to 65 mm of corn seed planting (Sirvastava et al., 2006).

In this study, cone index was selected as a criterion for defining the compacted soil and by this way the seed germination can be analyzed. So the main objectives of this work were, first, determination variance analysis of speed and soil depth effect on cone index; Second, investigate the main effects of speed and depth and the interaction effect.

2 Materials and methods

2.1 Cone index measurement

Topsoil compaction causes reduction in infiltration rate of the soil, root growth, rooting system and makes many problems for the product and its yield. Factors influencing soil compaction are wheel axle load, tire pressure, the number of wheel passes, soil moisture content, soil density, soil resistance and wheel slip (Mouazen et al., 2003). In this study, compaction resulting from pressure wheel crossing was evaluated. For this purpose, field experiments were conducted at the Khalaat-Poushan station University of Tabriz. For obtaining aggregation, soil samples were selected and transferred to the laboratory. Data results showed that the soil consisted of 70% sand, 15% loam and 15% silt, which is indicating that it is sandy-loamy soil. The initial density of soil was 1650 kg/m^3 which measured in the soil mechanics laboratory. This study was conducted in the autumn of 2014 and before the start of region monsoon rainfall. Soil moisture content was measured about 10% for these conditions. Density and moisture of the soil were measured and was assumed to be constant throughout the study. There are no measurements or changes for soil resistance criterion and wheel slip criterion.

For evaluation of compaction resulting from pressure wheel on soil, existing corn planter T63 in site were used. T63 corn planter was an advanced mechanical planter for row plants, such as cotton, rice, sunflower, melon, etc. The studied pressure wheel of four rowed corn planter is the wide rubbery type with a bulge in its middle. The wheel has the steel rim with a diameter of 42 cm and the total diameter of the wheel, including the rubber was measured 46 cm (Figure 1). These types of pressure wheels are pressing the seed directly in soil furrow by its central bulge. Pressure wheel compresses the soil during its movement which is critical for seed germination and growth. In this study, the applied load on the pressure wheel was considered 638 N (the amount of weight that is transmitted to the pressure wheel from a corn planter unit). Inflation pressure of wheel considered zero because the pressure wheel was chosen as a solid rubber. Number of passes was also once assumed.

Figure 1 Pressure wheel of corn planter T63 (Technohac Agricultural machinery Ltd, Israel).

Generally in the literatures cone index and bulk density are being used to quantify soil compaction levels, which in this study the cone index was used. For measuring soil compaction a digital penetrometer was used. For measurement of parameters, corn planter was pulled by john-deer 3410 tractor in 3 separate paths in length of 30 m and width of 5 meters and three speed levels of 3, 4 and 6 km/h. Cone index measurements were done in four locations of wheels crossing to a depth of 20 cm. The cone penetrometer with a cone angle of 60 degrees and constant velocity of 2 cm/s was inserted into the soil down to the depth of 20 cm and cone index data was recorded on the device memory, which then were transferred to a computer for analysis.

2.2 Tests execution and data analyzing

Experiments carried out at three speed levels (3, 4, and 6 km/h) and five depth levels (3, 6, 9, 12 and 15 cm). In this study the planting speed and depth levels are chosen in the range of the field working. Experiments were conducted in the form of factorial split-plot based on a randomized complete block design with three replication. SPSS21 and MSTATC software were used to perform the analysis of variance and comparison of means. As well as, the regression model of cone index was created in terms of working speed and depth with SPSS21.

3 Results and discussion

3.1 Effect of planter speed and wheel pressure depth on soil penetration resistance

To study the effect of selected independent variables on the soil cone index, statistical analysis was performed on the data. Evaluation of Kolmogorov-Smirnov test in SPSS21 software on cone index data showed that the data had normal distribution. Data for analysis were entered into MSTAT-C software in the form of factorial split-plot based on randomized complete block design. In the experimental design, the planter travel speed (V, km/h) and pressure wheel depth (D, cm) were on main and sub plots, respectively. The results of variance analysis for effect of corn planter speed (V) and soil depth (D) on cone index are given in Table 1.

Table 1 Variance analysis of speed effect and soil depth effect on cone index

Source of Change	Degree of freedom	Mean-square	F
R	2	0.038	1.5030^{ns}
V	2	0.064	2.5339^{ns}
Experimental error	4	0.025	
D	4	0.323	21.4905^{**}
V*D	8	0.038	2.5034^{*}
Experimental error	24	0.015	
total	44	–	

Note: **, * Significant at the 1% and 5% level respectively, ns Nonsignificant at the 5% level

V (km/h), D (cm) and R is speed, depth and replication respectively.

As a result of the variance analysis table 1 showed that the main effect depth was significant at the 1% level. The interaction effect (V*D) was significant at 5% probability level. But the main effect of speed (V) and replication (R) were not significant. Considering that the main effect of depth was significant, it can be concluded that the depth has a significant impact on compaction and compression of the soil and on the seed germination issue also it can be cited as a contributing factor. Also, the reaction effect of three speed levels and five depth levels (V*D) were studied by the comparing of means (Figure 2).

The results in Figure 2 showed that with increasing speed, the cone index decreased in the specific depth. Cone index values Between 3 and 6 cm depths are very close and the lines match together as shown in Figure 2. This shows that in the surface depths (3-6 cm), changing speed significantly doesn't affect on the cone index values. However, with increasing of depth the lines separate from each other (Figure 2). At the speeds of 3 and 4 km/h, the increasing of cone index is faster than 6 km/h. This means that in the lower speeds, the Weight of pressure wheel has more effect than the higher speed on soil compaction. In the speed 6 km/h and the depth 15 cm, the cone index reduced and this means that the higher speed has less effect on compaction and compression of the soil. These results were agreed with the reports of Aboaba (1969) and Carman (1994). They reported that travel speed influences soil compaction mainly at lower speeds and its effect decreases with increase in speed. In the other words, low velocities result in greater increases in soil cone index.

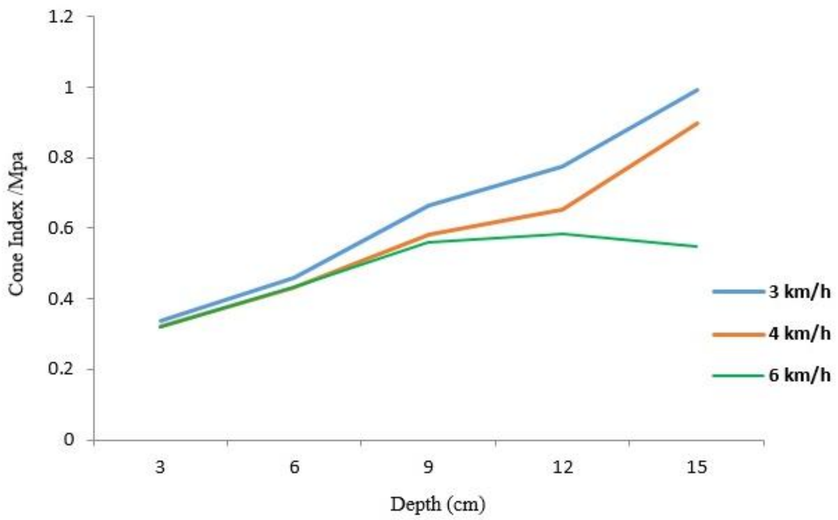

Figure 2 the reaction effect of corn planter speed and working depth on the cone index

Due to the reaction effect of corn planter speed and working depth，the cone index is the changes in value statically, so the main effect the working speed and depth must be studied (Figure 4). According to the Table 2 that shows the results of the mean comparison of the main effect speed and depth in the experimental design, it can be seen that the speed has a depressing effect on cone index.

The effect of three speed levels on cone index have not a significant difference, but what is understandable,

Table 2 Average values of cone index at different levels of speed and depth

Independent variable	Level of variables	Averages of cone index,MPa
Speed, km/h	3	0.6375[a]
	4	0.5618[a]
	6	0.5077[a]
Soil depth, cm	3	0.3264[d]
	6	0.4499[cd]
	9	0.5841[bc]
	12	0.6709[ab]
	15	0.8137[a]

increasing speed makes less compaction in soil (Figure 3). This issue can be looked at from various aspects; from an aspect of device performance, whatever increasing working speed, grows corn planter performance for planting, but in this situation because of increasing divider speed possibility of not planted seed and crushed seed between disks increases. On the other hand, excessive increase of the speed increases the possibility of not being properly compression level in soil bed and reduced germination amount. Crop yield for speeds of six and seven miles per hour were significantly less than speeds of three and four mile per hour, and with one mile per hour increasing in speed crop yield decreases with a rate of 0.086 cubic meters per hectare (Nielesen, 1993). So, according to previous researches can be seen that with too much speed increasing, the rate of field efficiency decreases. With increasing velocity, the terrain does not get sufficient time to be completely compacted and deformed to the high level (Xia, 2011).

The bulk density of the soil at a depth of 0-10 and 10-20 cm under the wheel track increased with increasing vertical load and inflation pressure, and decreased with increasing forward speed. In other words, Penetration resistance of soil increased with increasing wheel load and inflation pressure, but the penetration resistance decreased with increasing forward speed (Carman, 2008). However the optimal seeding speed for corn is typically less than 5 miles per hour, and use of the corn planter at optimum speed makes up for the planter to sow seeds in appropriate depth and distance (Kinnison, 2013). However, scientific sources are noted values between 2 and 10 miles per hour according to the type of soil, weather and plant type.

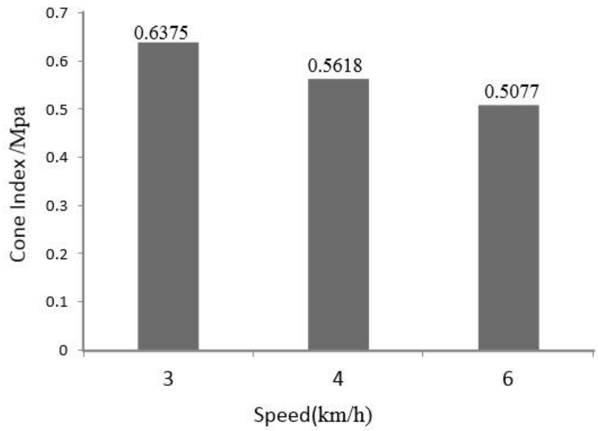

Figure 3 Effect of planter travel speed on soil cone index

At very low speed levels (3 km/h) that soil compaction rate is high; also, this can be mentioned that compaction and yield of field are imitative. By reducing the speed, seed planting rate per acre decreases. Lower traveling velocities increase contact time and therefore make more time for applying downward forces to producing soil compaction. In other words, because of decreasing speed the pressure wheel has this opportunity to increase the loading time and surface layers of soil surrounding the seed is too much pressure and this will reduce the germination.

According to the comparison of mean cone index values in Table 2, it can be concluded that with increasing depth, cone index increases also, which represents the increasing of compaction. Braunack et al. (2014) indicated that soil strength increased after traffic of either picker compared with before traffic and increases were detected to a depth of 0.6 meter. Effects of tillage treatments during (a) growing season and (b) the time of harvesting at four tillage practices (CT: conventional tillage; ZT: zero tillage; MT: minimum tillage; RT: reservoir tillage) showed that the cone index increased with increasing depth (Salem, 2015).

Of course, with increasing the depth up to 15 mm, cone index increased from 15 to 25 cm, but the soil compaction standard (cone index) initially increases and then decreases (Raper et al, 2007). But because in this study, shallow depths were studied, so this phenomenon is not visible here. The Increasing of cone index with depth is due to the soil resistance forces. These forces caused by the accumulation effect of applied downward forces and the weight of soil above depth. In the case of agricultural lands that have no traffic, weight of the soil above depth is also the reason for the increase of cone index with soil depth.

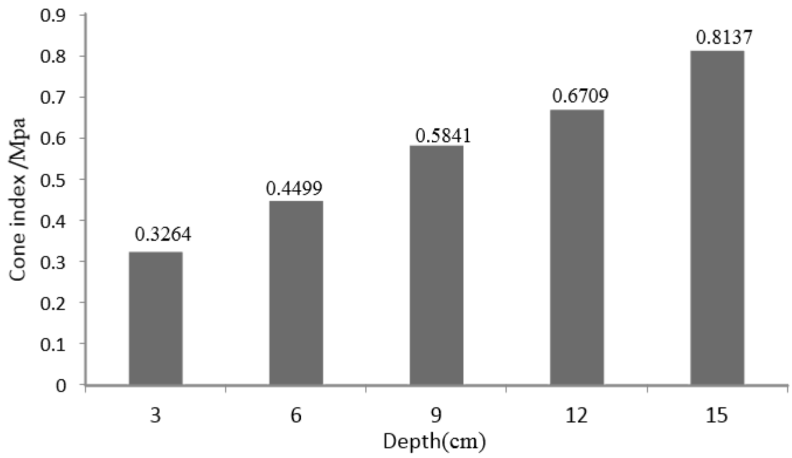

Figure 4 Effect of planter pressure wheel depth on soil cone index.

3.2 The regression model of cone index

The linear and exponential regression models were used to define the variation of cone index. The linear regression model showed a high correlation coefficient than exponential model. The results of the variance analysis are presented in Table 3. According to Standardized coefficients of the regression model in Table 3 for the cone index seen that the moving speed has reduced effect on cone index whereas the soil depth has an additive effect. Since Standardized coefficient of depth is more than the unstandardized coefficient of speed, the moving speed has greater impact than the depth on cone index. Of course, according to the papers, the cone index is reduced in the more depths. Standardized coefficients and unstandardized coefficients are presented in Table 3.

Table 3 Unstandardized and standardized coefficients of the linear regression model

Regression coefficient	Unstandardized coefficients	Standardized coefficients
Intercept	0.388	-
Moving peed	-0.041	-0.228
Soil depth	0.040	0.755

This linear model was significant in the cone index prediction at 1% level (Table 4). According to Table 4 the results showed that the model was able to predict cone index with variation of moving speed and soil depth. The degree of freedom and mean squares of the regression model in analysis of variance for linear regression model (Table 4) was 2 and 0.702 respectively.

Table 4 Analysis of variance for linear regression model

Model	Degree of freedom	Means squares	Sig.
Regression	2	0.702	0.00
Residual	42	0.020	
Total	44		

The regression model for cone index (Y-Mpa), moving speed (X_1 –km/h) and soil depth (X2 -cm) is equal to:

$$Y= -0.041\times(X_1) + 0.04\times(X_2)$$

Coefficient of determination (R2) was obtained 0.85 from this equation which expression the variation of cone index by means of two factors (cone index and moving speed). In accordance with more coefficient determination, this model is able to estimate cone index. For model validation, the measured value of cone index fitting than the predicted value which the result showed the more correlation (Figure 5).

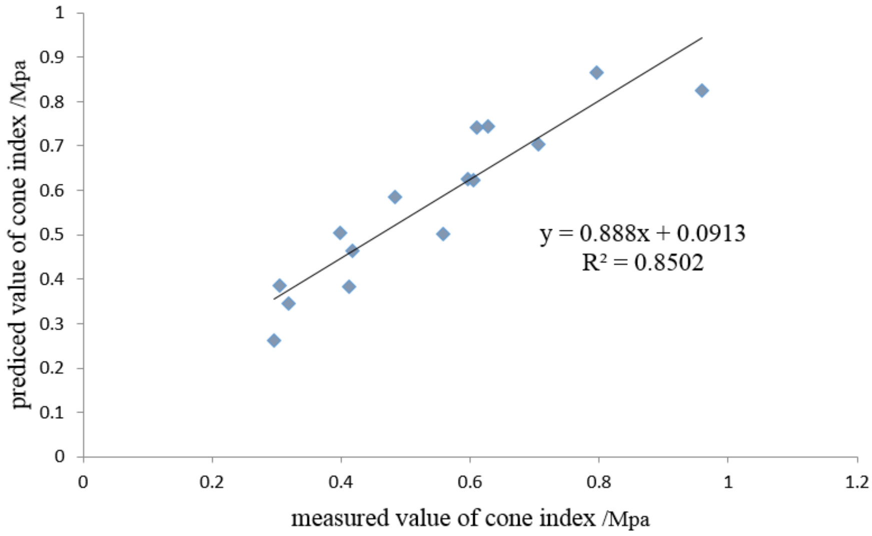

Figure 4 the accuracy of presented model for penetration resistance against measured values

4 Conclusions

In present work effect of travel speed (three levels) and working depth 3, 6, 9, 12 and 15 cm was evaluated on cone index under pressure wheel of corn planter and soil cone index of sandy-loamy soil was measured. The following results are achieved:

i) Velocity has a significant impact on compaction and compression of the soil and in seed germination.

ii) Increasing speed makes less compaction in soil.

iii) Variance analysis was used to determine the effects of working speed and depth on cone index. The results showed that the interaction effect of speed and depth significant in probability level of 5%. The reaction effect of corn planter speed and working depth on the cone index is the changes in value statically, so the main effects were examined. The means comparison showed that by increasing the levels of speed and depth, respectively the cone index decreased and increased.

A regression model was developed to measure the cone index in terms of working speed and depth. The model predicted the cone index values with a coefficient of 1 to determination 85%. The model coefficients showed the cone index changes correctly. So, the result of regression model and mean comparisons were similar.

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