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Evaluation of Center Pivot Wheel Traffic and its Impact on Soil Compaction

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ABSTRACT

The machine wheel track is considered one of the essential factors affecting wheat crop yield and soil compaction. Therefore, the current investigation was implemented aiming at assessing the influence of center pivot wheel traffic on soil compaction and crop yield at center pivot wheel track and adjacent soil. The main results of the current study can be summarized as follows: 1-The highest soil penetration resistance was recorded at the wheel track between1.0-2.0cm depth. 2-The penetration resistance gradually reduced to 45.0cm on each side of the wheel track Thus, root depth and distribution area followed an opposite trend. 3-The plants grown adjacent to the track of the wheel (0-45cm apart from the wheel traffic) realized the spread of roots to a depth of 15cm.While the spread of wheat roots in the other areas was 18.0and20.0cm. 4-A decline in the density of roots of plants grown in the area adjacent to the wheel track compared to that of plants grown in other both areas. The average of root distribution area of plant grown of plant grown in the area adjacent to the wheel path (0-45cm apart from the wheel traffic) was approximately 320 cm^2/plant, while the average values were 550 and 600 cm^2/plant for other both areas (45-90and90-135cm apart from the wheel traffic, respectively). From the tabled data in this paper, it can be concluded that more care should be taken into consideration, in selecting the suitable system of seedbed preparation to avoid transporting pressure of the pivot wheel to adjacent soil.

Keywords: Soil penetration resistance and center pivot wheel traffic.

INTRODUCTION

In the newly reclaimed soils in Egypt, the irrigation process usually is done under center pivot irrigation systems. These fields were observed to have spatial variability in soil characteristics and crop yield (El Hamdi *et al.*, 2017).

Understanding and evaluating the spatial variability of soil attributes *e.g.*, soil compaction and their impact on yield is a crucial step toward the appropriate application of precision agriculture technology. Soil compaction is characterized as one of the key soil degradation processes. Soil compaction causes the decline in soil macro-pores and the raise in both soil density and soil strength. It imposes detrimental influences on crop production due to it creates a poor environment for plant root growth moreover reduces water infiltration and increases runoff, thus, soil erosion (Edrris *et al.*, 2020).

The detrimental impacts of soil compaction on performance of higher plants have been reported by many of researchers.

Wheel traffic from heavy vehicles *i.e.*, center pivot wheels can compress soils to varying degrees via the plant root zone, often causing increased mechanical strength and decreased both air and water permeability. These circumstances can impede root elongation and pronouncedly reduce plant growth and yield (Raper, 2005).

Al-Gaadi, (2013) stated that soil compaction caused as a result of the passage of vehicles led to an important economic and ecological consequences.e., poor crop productivity of both wheat and alfalfa due to problems of crop establishment and root growth and excessive soil erosion because of reduced water infiltrability.

Therefore, this current research work was conducted to determine the extent of the effect of the center pivot on soil compaction below and on both sides of the wheel and its impact on wheat crop productivity.

MATERIALS AND METHODS

1. Study Area.

The current study was implemented during winter season of 2020/2021 in Farafra Oasis, which located 170 km south of Bahariya Oasis and 627 km away from Cairo via the Cairo Al-Wahat Desert Road, Egypt. Geographic coordinates are between latitudes 26 0 00' and 27 0 30' N and longitude 27 0 20' and 29 0 00'E.

2. Soil and water analysis.

Initial soil sample which taken at depth of 0-30 cm as well as sample of groundwater of well used in irrigation process were analyzed according to Dane and Topp (2020) and Sparks *et al.*, (2020), where characteristics of both are presented in Tables1 and 2, respectively.

Table 1. Characteristics of initial soil of the studied area located in Farafra Oasis.

Initial soil characteristics									
Particle size distribution (%)				Texture class	Available soil nutrients (mg kg^{-1})			EC, dSm^{-1}	pH
C. Sand	F. Sand	Silt	Clay		N	P	K		
20.0	40.0	22.0	18.0	Sandy loam	48.95	8.10	250.1	2.25	7.82

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Table 2. Chemical analysis of groundwater of well in the studied area located in Farafra Oasis.

EC, dSm^{-1}	Cations, $meqL^{-1}$				Anions, $meqL^{-1}$			
	Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
0.22	0.6	0.4	0.4	0.8	0.0	0.3	1.3	0.6

3. Distribution of vertical pressure in the soil and measurements.

Fig1 show the distribution of vertical pressure in the soil under the front wheel of the tractor. Yield components *i.e.,* spike length (cm), spike weight (g) and No. of tillers plant^{-1} were measured three successive areas at dimensions of 0-45, 45-90 and 90-135 cm from the track. Also, soil resistance to penetration was measured at twenty points randomly distributed in the area of the track of the center pivot wheel irrigation device as well as on both sides of the track in three successive areas at dimensions of 0-45, 45-90 and 90-135 cm from the wheel track. Soil resistance to penetration was measured at all points in the four regions at four different depths: 0-15, 15-25, 25-35 cm, and deeper than 30 cm. The depth and distribution of wheat roots in the three regions adjacent to the path of the wheel of the center pivot irrigation system (Fig1).

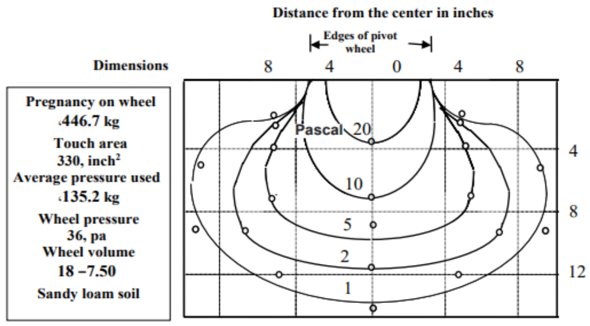

Fig. 1. Distribution of vertical pressure in the soil under the front wheel of the tractor.

RESULTS AND DISCUSSION

1.Yield components.

Table 3 shows the effect of center pivot wheel on wheat yield component *i.e.,* spike length (cm), spike weight (g) and No. of tillers plant^{-1}.

Table 3 shows the effect of center pivot wheel on wheat yield component (as mean value).The results show that the wheat plants grown adjacent to the track of the wheel (dimensions of 0-45 cm from the wheel track) recorded the lowest average values of wheat yield component *i.e.,* spike length (cm), spike weight (g) and No. of tillers plant^{-1} followed by that grown on the second area (dimensions of 45-90 cm from the wheel track), while the highest average values of wheat yield component *i.e.,* spike length (cm), spike weight (g) and No. of tillers plant^{-1} were realized in the third area (dimensions of 90-135 cm from the wheel track),

Table 3. Effect of center pivot wheel on wheat yield component (as mean value).

Parameters Dimensions	spike length, cm	spike weight, g	No. of tillers plant^{-1}
0-45 cm apart from the wheel traffic.	13.5	2.19	5
45-90 cm apart from the wheel traffic.	15.2	2.82	8
90-135 cm apart from the wheel traffic.	15.6	3.00	10

Accordingly, the average crop production in the vicinity of the wheel track of the center pivot irrigation system is very low relative to the average crop productivity compared to that of plants grown on other both areas (45-90 and 90-135 apart from the wheel traffic, respectively).

2.Depth, weight and distribution of wheat roots.

Table 4 shows the effect of center pivot wheel on depth, weight and distribution of wheat roots (as mean value). The results show that the area adjacent to the center pivot irrigation track was affected by the pressure of the wheel affecting the specifications of the root system of wheat plants grown in this area up to 45 cm from the track compared to other dimensions (45-90 and 90-135 cm apart from the wheel traffic). The plants grown adjacent to the track of the wheel (dimensions of 0-45 cm from the wheel track) recorded the spread of roots to a depth of 15 cm. While the spread of roots in the other areas was18 and 20 cm. The results also illustrate a decline in the density of roots of plants grown in the area adjacent to the wheel track compared to that of plants grown in other both areas. The average of root distribution area of plant grown in the area adjacent to the wheel path (dimensions of 0-45 cm from the track) was approximately 320 cm^2 / plant, while the average values were 550 and 600 cm^2 / plant for other both areas (dimensions 45-90 and 90-135cm, respectively).

Table 4. Effect of center pivot wheel on depth and distribution of wheat roots (as mean value).

Parameters Dimensions	Root depth, cm	Root weight , g	Distribution area , cm^2
0-45 cm apart from the wheel traffic.	15	14	320
45-90 cm apart from the wheel traffic.	18	30	550
90-135 cm apart from the wheel traffic.	20	32	600

Accordingly, it is clear that the plants grown in the vicinity of the center pivot wheel track were clearly affected by the pressure generated by the pivot irrigation system and the frequency of passage of the device during the growing season compared to plants grown on other both areas (dimensions 45-90 and 90-135cm, respectively).

3.Soil penetration resistance.

Table 5 illustrated the effect of center pivot wheel on soil resistance to penetration below and on both sides of the Wheel track at different soil depths.

Table 5. Effect of center pivot wheel on soil resistance to penetration below and on both sides of the Wheel track at different soil depths.

	Soil penetration resistance, kg cm^2			
Depths Dimensions	0-15, cm	15-25, cm	25-35, cm	Deeper than 30 cm
0-45 cm apart from the wheel traffic.	32	34	31	28
45-90 cm apart from the wheel traffic.	30	31	29	28
90-135 cm apart from the wheel traffic.	27	29	28	26

The obtained results showed that the highest value of soil resistance to penetration was recorded in the area of the track of the wheel of the pivot irrigation device, as it reached 34 kg / cm^2 at a depth of 15-25 cm from the surface of the soil. The results also show that the area adjacent to the Wheel's track was affected up to a distance of 45 cm from both sides, where the maximum value of the penetration resistance was recorded at the same depth, which was 30 kg/cm^2. Whereas, the average soil resistance to penetration in the following areas was stable at 25 kg/cm^2 at the same depth. Repeated passage during the planting season led to clear compaction of the soil below the Wheel track and encroachment into the adjacent area up to a distance of 45 cm laterally from the wheel traffic.

CONCLUSION

From the tabled data in this paper, it is clear that the traffic movement of the center pivot irrigation system has a clear effect on the decrease in the crop productivity, where the movement of the center pivot irrigation system affects no less than 2.5% of the total cultivated area. Therefore, it can be concluded that more care should be taken into consideration, in selecting the suitable system of seedbed preparation to avoid transporting pressure of the pivot wheel to adjacent soil.

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تقييم جهاز الري المحوري وتاثيرة على محصول انضغاط التربة

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الملخص

يعتبر مسار عجلة المعدات الزراعية أحد العوامل الأساسية التي تؤثر على محصول القمح وانضغاط التربة. لذلك، تم تنفيذ الدراسة الحالية لتحديد تأثير حركة عجل جهاز الري المحوري على إنتاجية محصول القمح وانضغاط التربة أسفل وعلى جانبي مسار العجل. يمكن تلخيص النتائج الرئيسية للدراسة الحالية على النحو التالي؛ 1-تم تحقيق أعلى مقاومة لاختراق التربة في منطقة مسار عجل المحور عند عمق ما بين 15 -25 سم. 2- تقلصت مقاومة الاختراق تدريجياً كلما ابتعدنا جانبياً عن مسار العجل حتى مسافة 45سم وبالتالي، مساحة انتشار الجذور وعمقها وإنتاجية المحصول تسلك اتجاهاً عكسياً. 3-سجلت النباتات المزروعة بمحاذاة مسار العجلة (0-45 سم بعيدًا عن العجلة) انتشار الجذور حتى عمق 15 سم. بينما كان انتشار الجذور في المناطق الأخرى 18 و20 سم. 4- انخفاض كثافة جذور النباتات المزروعة في المنطقة المجاورة لمجرى العجلة مقارنة بالنباتات المزروعة في المنطقتين الأخريين. كان متوسط مساحة توزيع الجذور للنبات المزروع في المنطقة المجاورة لمسار العجلة (0-45 سم بعيدًا عن مسار العجلة) حوالي 320 سم ^{2} / نبات، بينما كان متوسط القيم 550 و600 سم ^{2} / النبات لكلا المنطقتين الأخريين (45-90 و90-135 سم بعيدًا عن مسار العجلات، على التوالي). من البيانات المجدولة في هذه الورقة البحثية، يمكن الاستنتاج أنه يجب زيادة الاهتمام باختيار وتطبيق نظم إعداد مرقد البذرة المناسبة لتجنب انتقال الضغط الناتج عن عجل جهاز الري المحوري جانبياً بقدر الإمكان