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WATER INFILTRATION AS AFFECTED BY TILLAGE METHODS, PLOWING DEPTH AND WHEEL TRAFFIC

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ABSTRACT

Field experiments were conducted in clay soil planted with sunflower crop during summer 2006 to determine interactive effects of tillage methods, plowing depths and wheel traffic (number of wheel passes) on water infiltration. The results showed that infiltration rates were affected significantly by tillage treatments, plowing depths and number of wheel passes over the soil. Average basic infiltration rate after 180 min was ranged from 7.8-9.1 mm/h for moldboard plow, 6.2-7.9 mm/h for chisel plow and 5.9-7.2 mm/h for rotary plow under different wheel passes and plowing depths. Among the various wheel passes, five-pass caused 10.75, 19.55 and 14.37% reduction in infiltration rate under moldboard, chisel and rotary plows, respectively when tillage was achieved at 9.7 cm plowing depth. A simple empirical model based on the Kostiakov equation was presented. This model will predict infiltration rate under soil mean weight diameter, number of wheel passes and plowing depth. Firstly, the values of empirical constants (k and n) of the Kostiakov equation could be determined then infiltration rate was computed. This could be useful to predict infiltration at any time interval in the studied rang of affecting variables. The results showed that the coefficient of determination (R^2) was 0.90 between measured and predicted basic infiltration rate. The developed model could provide valuable information for the effective design of surface irrigation system. Further, managers of irrigation systems can use it to modify management practices during season to conserve water.

INTRODUCTION

As our agricultural land and water resources are becoming more strained, conservation is becoming an increasingly important topic. There are different ways to conserve water and one of them by improving soil properties using alternative cropping systems and different practice farming systems. So, researchers are interested to determine whether practice-farming systems have a negative, positive or no effect on soil physical properties. However, management styles in Egypt differ from area to area depending on many factors. One of these factors is tillage practice. However, the most popular tillage implements to practice farming in Egypt are moldboard, chisel and rotary plows. On the other hand, wheel-traffic induced soil compaction has been shown to limit crop productivity, and its interaction with tillage method could affect soil physical properties. Soil compaction by wheel traffic from farm implements affects soil properties such as aggregate stability, erosion and water infiltration and drainage (Fuentes et al., 2004).

Subsoiling, deep plowing and chiseling can alleviate compaction, but it is suggested that these methods are only temporary as the soil settles back into place (Lal and Shukla, 2004). The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. An infiltration rate of 5 mm/h means that a water layer of 5 mm on the soil surface will take one hour to infiltrate. The basic infiltration rate for clay soil ranged from 1.02– 5.08 mm/h according to Hillel (1982). Water infiltration of rainfall or irrigation is an important topic of soil and water conservation in semiarid regions like Egypt. Infiltration is important because (1) it controls leaching, runoff and crop water availability (Franzluebbers, 2002) (2) for evaluation and management surface irrigation (Guirguis, 2005).

Infiltration rates of soil decrease over time until a steady state is reached. Infiltration is dependent on several factors, such as soil texture, structure, initial soil water content, pore size, soil metric potential and vegetation (Lowery et al., 1996). Soil crusting, compaction, vegetative cover, root and earthworm channels also influence the ability of water to move through (infiltrate) soil layers.

Management practices that affect soil crusting and compaction, vegetative cover and soil porosity will increase or decrease the rate of water infiltration. For example, slow infiltration could be caused by increased soil compaction (Abu-Hamdeh, 2004). Leaving crop residues on the soil surface or increasing the organic matter content in the soil surface may maintain aggregation and enhance infiltration (Abu-Hamdeh, 2004).

El Marazky (2005) showed that the seedbed preparation treatments had significant effects on water infiltration into the soil. Al-Ghazal (2000) conducted field experiments to study the effect of tillage practices and compaction on infiltration rate of sandy soils. Average infiltration ranged from 31.8-61.5 mm/h for roravator, 37.5-78.5 mm/h for moldboard plow and 60.2-136.2 mm/h for chisel plow under different compaction treatments. Among the various compaction treatments, three-passes treatment caused 12.5, 22.9 and 50.3% reduction in infiltration rate of soil under rotavator, moldboard and chisel plow respectively. Al-Ghazal (2002) evaluated the effect of tractor wheel compaction on infiltration rate of a loamy-sandy soil. Average water infiltration rate ranged between 15.3-57.9 mm/h in different compaction treatments. Among the various compaction treatments, the "4-passes" treatment caused 69 % reduction in infiltration rate of soil. The highest compaction treatment (8-passes of tractor wheel) caused up to 77 % reduction in infiltration rate of soil.

Abu-Hamdeh (2004) and Matula (2003) showed that infiltration rate in the field was strongly affected by tillage treatments in the topsoil. Bailey et al. (1988) mentioned that excessive compaction might cause such undesirable effects as decreased infiltration of water, restriction of root growth, and increased runoff. These detrimental effects can increase erosion. Attia et al. (1999) conducted field experiments to study the effect of three plowing depths on some soil-water characteristics in the calcareous soils at Nubaria area (Egypt). Results revealed that infiltration rate and cumulative infiltration rate increased with increasing plowing depth from 15 to 45 cm.

Ogunremi et al. (1986) indicated that the equilibrium infiltration rates were 0.43, 0.54 and 5.94 mm/h in compacted, plowed and no-till treatments, respectively. Rahman and Islam (1989) mentioned that infiltration rates were increased owing to increase in depth of tillage. Shafiq et al. (1994) reported that soil compaction changes the ability of soil to hold water, decreases infiltration rate. Thierfelder et al. (2005) reported that the change in superficial soil structure created a notable reduction in final infiltration from 92 to 42.2 mm/h. Abu-Hamdeh et al. (2000) reported that water infiltration rate into soil at the tire track centerline generally decreased as the static load increased and as inflation pressure increased. Akinyemi and Adedeji (2004) showed that there were significance differences between the tillage systems in terms of infiltration rate and accumulated infiltration. Ankeny et al. (1995) conducted study to show the effects of wheel traffic on infiltration rates in chisel-plow and no-till tillage systems. Wheel traffic reduced ponded infiltration rates in both tillage systems. Lipiec et al. (2006) reported that the relations between soil pore structure induced by tillage and infiltration play an important role in flow characteristics of water and solutes in soil.

Hamad et al. (1994) mentioned that increasing wheel traffic on soil from 1 pass to 3 passes had significant effect on soil bulk density but when increasing from 4 passes to 7 passes had no significant effect on bulk density increasing. Al-Ghobari (2003) modified a simple empirical model based on the Kostiakov equation. This model could predict soil infiltration rate as a function of soil characteristics and sequence of irrigation events. Adekalu et al. (2007) showed that mulching the soil surface with a layer of plant residue was an effective method of conserving water and soil because it reduced surface runoff, increased infiltration of water into the soil and retard soil erosion. Tripathi et al. (2007) showed that infiltration rate was lowest in conventional puddling and puddling by four passes of rotavator in the rice experiment with four levels of tillage as puddling by two passes of rotavator, conventional puddling, puddling by four passes of rotavator and direct seeding without puddling.

The aim of this research determines the interactive effects of tillage methods, plowing depths and levels of tractor wheel-traffic on infiltration of water into clay soil.

MATERIALS AND METHODS

Site and treatments description:

The present research was carried out in a farmer field in Research Farm of Rice Mechanization Center, Meet El Deeba, Kafr El-Sheikh during growing season of summer 2006. The field was previously cultivated with sunflower. The tested area extended over 1.2 feddan. Averages of some soil characteristics at the experiment site are shown in Table (1). The land was previously leveled before planting sunflower crop. It was irrigated and left to attain a moisture level range of 15-19 % db. The tillage methods were moldboard plow (M), chisel plow (Ch) and rotary plow (R) at two plowing depths (D1 and D2) under four levels of wheel passes (0,1,3 and 5 passes) on the cultivated soil.

The treatments combinations were labeled as T1-T24 as shown in Table (2). The specifications of tillage implements are shown in Table (3). However, compaction was done by moving the Deutz-Fahr tractor on the cultivated soil. The Deutz-Fahr tractor mass was 4840 kg and wheel dimensions of rear and front wheels were 18.4-34 and 14.3-24, respectively.

Table (1): Average of some soil characteristics at the experiment site.

Soil depth (cm)	Particle size distribution			Texture class	Soil bulk density
	Sand (%)	Silt (%)	Clay (%)	(--)	(g/cm^3)
0-15	20.90	24.30	54.80	Clay	1.12
15-30	23.65	21.20	55.15	Clay	1.21

Table (2): Treatments labels* at experiment site.

M-0-D1 (T1)	M-0-D2 (T2)	M-1-D1 (T3)	M-1-D2 (T4)	M-3-D1 (T5)	M-3-D2 (T6)
M-5-D1 (T7)	M-5-D2 (T8)	Ch-0-D1 (T9)	Ch-0-D2 (T10)	Ch-1-D1 (T11)	Ch-1-D2 (T12)
Ch-3-D1 (T13)	Ch-3-D2 (T14)	Ch-5-D1 (T15)	Ch-5-D2 (T16)	R-0-D1 (T17)	R-0-D2 (T18)
R-1-D1 (T19)	R-1-D2 (T20)	R-3-D1 (T21)	R-3-D2 (T22)	R-5-D1 (T23)	R-5-D2 (T24)

*** The treatment (M-0-D1) means tillage is conducted with moldboard plow + no pass of wheel on the cultivated soil + first plowing depth.**

Table (3): The specifications of tillage implements.

Item	Moldboard plow	Chisel plow	Rotary plow
Manufacture	USA	Local	Local
Type	Mounted (2 bottoms)	Mounted (7 shanks arranged in 3 rows)	Mounted
Working width (cm)	100	175	160
Model	USA	Behera	Military factories
Hitched tractor	Deutz-Fahr tractor (110 hp)	Nasr tractor (65 hp)	U 800 tractor (80 hp)

The total four soil compaction treatments were applied by repeatedly running the Deutz-Fahr tractor over the cultivated soil. These were: control (zero-pass), low (1-pass), medium (3-passes) and high (5-passes) compaction according to the total number of tractor passes over the area. During applying compaction treatments and plowing, the tractors speed was 4.5 km/h. Two plowing depths were achieved, the first one was D1 around 10 cm and the second one (D2) was around 20 cm.

In compaction intervals, the tractor was run without any implement behind it. The size of each experimental plot was 30 x 2.5 m with a 1 m space in between two plots as buffer zone to avoid overlapping of additional soil compaction by tractor during treatment application. In order to apply different treatments, the tractor was run over the land as many times the desired to complete the number of passes.

Three soil samples were randomly taken from each plot after completed the practice tillage treatments. A frame of 50×50 cm was used to collect soil samples to determine the soil mean weight diameter. However, the soil mean weight diameter (SMWD, mm) was calculated according to Van Bavell (1949) as follows:

$$SMWD=\sum_{i}^{n}\frac{X_i \times W_i}{W} \qquad \text{.......(1)}$$

Where X_i is mean diameter of i^{th} fraction (mm) ($X_i = \frac{\Delta_{i-1} + \Delta_i}{2}$), W_i is weight of the soil retained on i^{th} sieve (kg), Δ is sieve mesh (mm) and W is total weight of soil sample (kg).

Determination of infiltration rate:

The soil infiltration rate was measured from the piece of land runover by the tractor wheel to observe the impact of compaction on soil. Double ring infiltrometer was used to determine infiltration rate. The measurements were repeated three times in the same area. The infiltration rings were 45 cm long with a 30 cm inner diameter.

The infiltration rings were inserted into the soil up to 7 cm depth as vertical as possible to make a tight bond between the cylinder and the soil. Buffer rings were placed outside the infiltration rings to eliminate the effect of lateral movement of water. The water used for the measurement of infiltration rate of soil was the same as that used to irrigate the field. A constant water head of 20 cm was maintained in each ring and the measurements were recorded at 5 minutes interval. Readings were taken at specified time intervals for 3 hours (180 min).

Model development:

Numerous equations have been developed to represent the infiltration phenomena. They can be classified into three general categories of models: empirical, physical-based and numerical (Al-Ghobari, 2003). In each category, different approaches are made to calculate infiltration rate, and each method has advantages and disadvantages (Al-Ghobari, 2003). Most of these equations are empirical in nature and have been developed to match observed data sets. The empirical technique is used extensively more than the other techniques in irrigation system design. The mean reason for this is that it can be used practically in the field. The most widely used empirical equation is the Kostiakov equation, which is simple powerful one (Al-Ghobari, 2003). However, Kostiakov (1932) proposed the following equation for estimating infiltration:

$$I = kt^n \qquad \text{.......... (2)}$$

Where I is the infiltration rate at time t and k and n are empirical constants. They can be determined by curve fitting to experimental data for infiltration rate. As the infiltration rate was plotted versus time on log-log paper to find the intercept and the slop of the straight line.

The infiltration model used in this research was based on Kostiakov's equation. In developing the model the authors look into consideration that the soil mean weight diameter, plowing depth and the number of passes influence the infiltration rate.

The infiltration rate value is affected by the constant values for the Kostiakov equation. There is a functional relation between these constants and the soil mean weight diameter, the number of passes and plowing depth, because of their effect on the soil conditions. To determine this relationship a multiple linear regression analysis was performed to get the equation for each constant. Whereas, the form of relationships as follows:

$$k, n = \beta_0 + \beta_1 \times X1 + \beta_2 \times X2 + \beta_3 \times X3 \qquad \text{.............................. (3)}$$

Where X1 is the soil mean weight diameter (mm) in the range of 9.2-80.2 mm, X2 is the number of wheel passes (dimensionless) in the range of 0,1,3 and 5 passes and X3 is plowing depth (cm) in the range of 9.7-20.4 cm.

Statistical analysis:

The field data for infiltration rate and empirical constants Eq. (2) were statistically analyzed, using two-way analysis of variance (ANOVA) for the randomized complete design with three replicates. The used software was SAS (1986) using ANOVA procedure. Comparisons among treatment means, when significant, were conducted using least significant difference (LSD) at p = 0.05 level.

RESULTS AND DISCUSSION

Tillage methods, number of wheel passes over the soil (compaction level) and plowing depth had significant effect on basic infiltration rate (mm/h) after 180 min of clay soil, Table (4). Meanwhile, only tillage methods had significant effect on empirical constants (k and n) whereas P-values are greater than 0.05. The interactions among treatments had no significant effect on both basic infiltration rate (mm/h) and empirical constants (k and n) whereas P-values are greater than 0.05, Table (4).

Table (4): Source of variation, degree of freedom (DF) and probability (P-values) from ANOVA basic infiltration rate after 180 min and empirical constants of Eq. (2).

Source of variation	DF	P- values		
		Infiltration rate	Empirical constants	
			(k)	(n)
		(mm/h)	(mm/h)	(--)
T	2	0.0001	0.0001	0.0001
N	3	0.0001	0.1372	0.8983
D	1	0.0001	0.2789	0.7616
$T \times N$	6	0.0928	0.9994	1.0000
$T \times D$	2	0.2700	0.9874	0.9995
$N \times D$	3	0.7848	0.9999	0.9991
$T \times N \times D$	6	0.8361	1.0000	1.0000
Model Pr>F		0.0001	0.1105	0.0001
R^2		0.969	0.421	0.849
C.V, %		2.721	7.43	-0.94

T = Tillage methods; N = number of wheel passes and D = plowing depth

Average values of basic infiltration rate after 180 min were 8.4,7.8 and 6.6 mm/h for moldboard, chisel and rotary plows respectively. It is obvious that the moldboard plow gave higher values of infiltration compared to other plows, Table (5). However, average values of basic infiltration rate after 180 min were 7.9, 7.5, 7.2 and 6.8 mm/h for control (zero compaction), low (1-pass), medium (3- passes) and high (5-passes) compaction treatments, respectively. This suggested that extensive running of wheel tractor caused significant changes in infiltration in the upper 0-20 cm depth of the tested soil.

Fig. (1) shows the effect of tillage methods and number of wheel passes on average basic infiltration rate after 180 min of clay soil at two plowing depths. The labeled figure (a) is belonged to treatments with odd numbers and the labeled figure (b) is belonged to treatments with even numbers as shown in Table (2). It is clear that increasing compaction level decreases the basic infiltration rate under any plowing depth.

Fig. (2) shows the reduction is amounted up to19.55 % and 19.42 % in basic infiltration rate (mm/h) at treatment labeled by T15, which consisted of chisel plow + high compaction treatment (5-passes of tractor wheel) and 9.7 cm plowing depth than the control treatment (zero compaction). These results suggested that application of high compaction treatment (5-passes) caused significant reduction in the basic infiltration rate of clay soil than the control treatment. This result is in agreement with the findings by Al-Ghazal (2002) who reported significant reduction in infiltration rate due to tractor wheel compaction. However, the conclusion of Al-Ghazal (2002) based on this result was water could be achieved in this case if the soil compaction is possible with simple farm machinery such as tractor.

Table (5): Mean basic infiltration rate after 180 min and empirical constants as affected by tillage methods, number of wheel passes (compaction level) and plowing depths.

Treatments*	Infiltration rate (mm/h)	Empirical constants	
		(k) (mm/h)	(n) (--)
	Mean+	Mean	
M	8.4a	212.9a	-0.6213a
Ch	7.8 b	197.8b	-0.6421b
R	6.6 c	190.9b	-0.6487c
LSD$ (5%)	0.1	8.7	0.0035
Level-0	7.9 a	206.6a	-0.6368a
Level-1	7.5 b	202.1ba	-0.6371a
Level-3	7.2 c	197.8ba	-0.6374a
Level-5	6.8 d	195.6b	-0.6383a
LSD (5%)	0.1	10.0	0.0041
D2	7.6 a	202.5a	-0.6372a
D1	7.2 b	198.6a	-0.6376a
LSD (5%)	0.1	7.1	0.0029

*** M = moldboard plow; Ch = chisel plow; R = rotary plow ; D1 = 9.7 cm and D2 = 20.4 cm.**
+ Means followed by different letters in each column are significantly different at P = 0.05.
$ LSD = least significance difference.

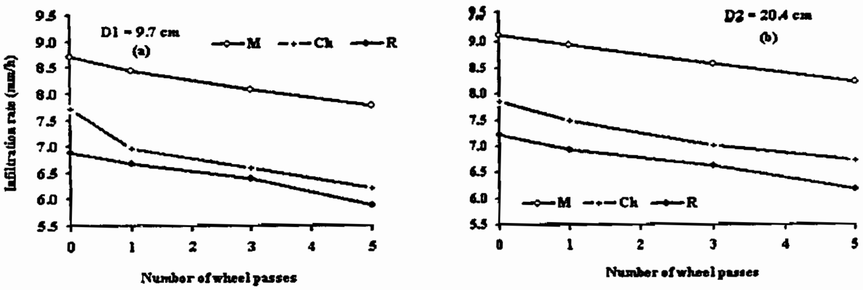

Fig. (1): Effect of number of wheel passes and tillage methods on average basic infiltration rate after 180 min of clay soil at two plowing depths.

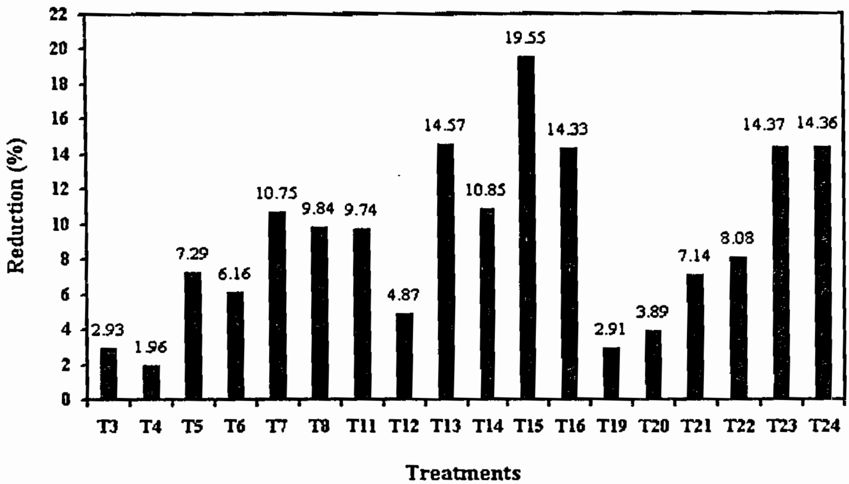

Fig. (2): Reduction (%) in basic infiltration rate after 180 min at different treatments compared to no compaction.

Fig. (3) shows the effect of plowing depth and compaction level on average basic infiltration rate after 180 min of clay soil for moldboard, chisel and rotary plows. It is clear that increasing plowing depth increases the basic infiltration rate under any compaction level. However, Table (6) shows the effect of combination of different treatments on average basic infiltration rate after 180 min. It is obvious that the maximum basic infiltration rate was 9.1 mm/h and occurred for moldboard plow at soil mean weight diameter of 80.20 mm, 19.60 cm plowing depth and no wheel passes.

To derive an equation to get infiltration rate as a function of soil mean weight diameter, number of wheel passes and plowing depth. Firstly, the empirical constants (k) and (n) of Eq. (2) were obtained corresponding to each case of infiltration measurements. Second, the corresponding empirical constants were analyzed using multiple linear regression to get the regression coefficients of Eq. (3). The results are shown in Tables (7 and 8).

Empirical constants (k) and (n) are functions of soil mean weight diameter (X1, mm) in the range of 9.2-80.2 mm, number of wheel passes (X2, dimensionless) in the range of 0,1,3 and 5 passes and plowing depth (X3, cm) in the range of 9.7-20.4 cm. To get infiltration rate, firstly, the values of (k,mm/h) and (n) could be determined as follows:

$$k = 175.076 + 0.479 \times X1 - 3.347 \times X2 + 1.067 \times X3 \quad \ldots\ldots\ldots\ldots (4)$$

$$n = -0.663 + 0.0006 \times X1 + 0.0032 \times X2 - 0.00026 \times X3 \quad \ldots\ldots\ldots\ldots (5)$$

The infiltration rate (I, mm/h) could be obtained after substituting of both (k,mm/h) and (n) values from Eqs. (4 and 5) and the corresponding time (t, min) in Eq. (2). To show the behavior of Eq. (2) in predicting the infiltration rates, measured and predicted infiltration rates were compared. Consequently, Fig. (4) shows average measured and predicted infiltration rates when the wheels of the tractor passed three times on the cultivated soil by moldboard plow, chisel plow and rotary plow at average plowing depth of 9.7 cm. Generally, there was good agreement between the predicted and the experimental infiltration rates for all cases.

Table (6): Average basic infiltration rate after 180 min as affected by combination of different treatments.

Treatments			Soil mean weight diameter (X1)	Infiltration rate
Tillage method	Number of wheel passes (X2)	Plowing depth (X3)		
	(----)	(cm)	(mm)	(mm/h)
M	0	10.5	75.97	8.7
Ch		10.6	43.30	7.7
R		10.2	20.35	6.9
M	0	19.6	80.20	9.1
Ch		19.9	45.71	7.9
R		19.7	21.49	7.2
M	1	10.3	63.81	8.4
Ch		10.8	36.37	7.0
R		10.8	17.10	6.7
M	1	19.7	68.97	9.0
Ch		20.4	39.31	7.5
R		19.7	18.48	6.9
M	3	10.4	47.22	8.1
Ch		10.2	26.92	6.6
R		9.7	12.65	6.4
M	3	19.4	52.42	8.6
Ch		19.4	29.88	7.0
R		19.4	14.04	6.6
M	5	10.1	34.47	7.8
Ch		10.3	19.65	6.2
R		10.3	9.23	5.9
M	5	19.6	39.84	8.2
Ch		19.8	22.71	6.7
R		19.1	10.67	6.2
Minimum		9.7	9.20	5.9
Maximum		20.4	80.2	9.1

M = moldboard plow **Ch = chisel plow** **R = rotary plow**

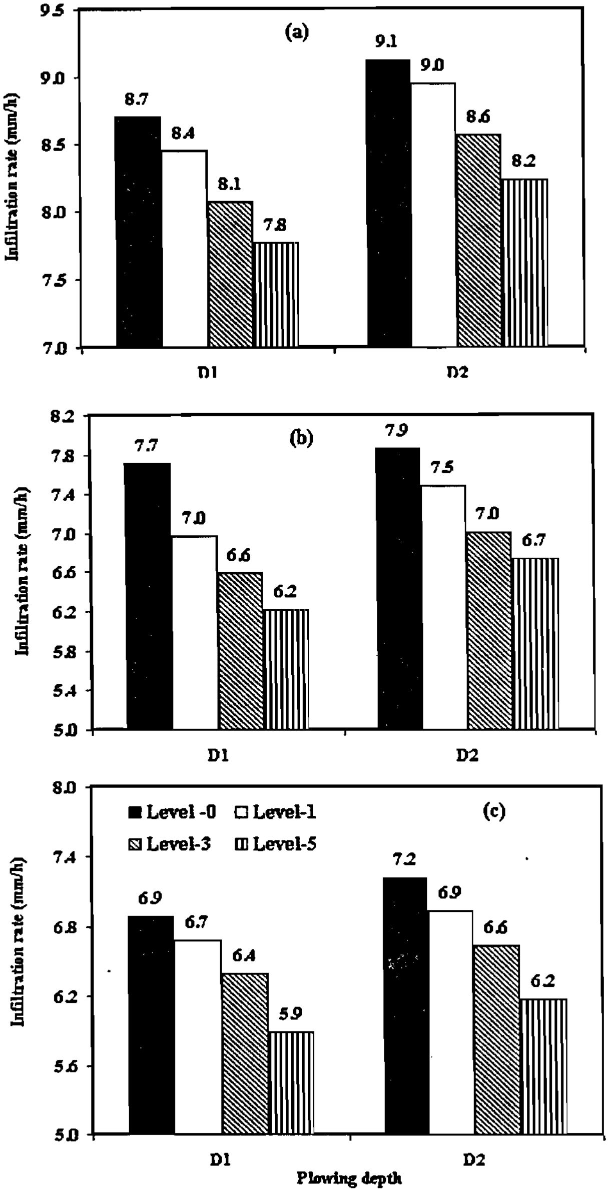

Fig. (3): Effect of plowing depth on average of basic infiltration rate after 180 min at different levels of wheel passes for moldboard plow (curve, a), chisel plow (curve, b) and rotary plow (curve, c).

Table (7): Regression statistics for the constants k and n.

Regression statistics	(k)	(n)
Multiple R	0.950	0.875
R^2	0.902	0.765
Adjusted R^2	0.897	0.754
Standard Error	5.162	0.0063
Observations	72	72

Table (8): Regression coefficients for the constants k and n.

Regression coefficients	(k)	(n)
β_0	175.076	-0.663
β_1	0.479	0.0006
β_2	-3.347	0.0032
β_3	1.067	-0.00026

Fig. (5) shows average measured versus predicted basic infiltration rate after 180 min for all combination treatments. Generally, there was good agreement between the experimental basic infiltration rate after 180 and the model. Also, an indication of how the developed model fits the measured basic infiltration rate after 180 min is given by the coefficient of determination (R^2) value for all treatments which was 0.90. This could be useful to predict infiltration at any time interval in the studied rang of affecting variables in this research.

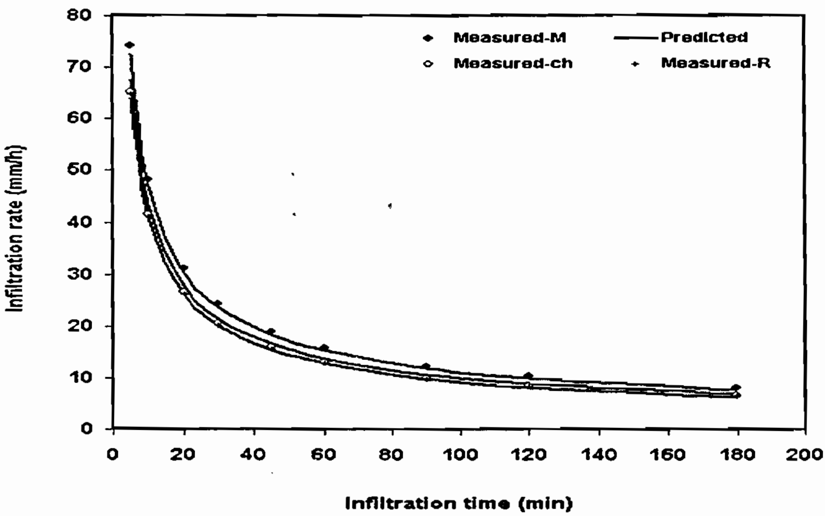

Fig. (4): Average measured and predicted infiltration rate when the wheel passed 3 times on the cultivated soil by moldboard plow (M), chisel plow (ch) and rotary plow (R) at average plowing depth of 9.7 cm.

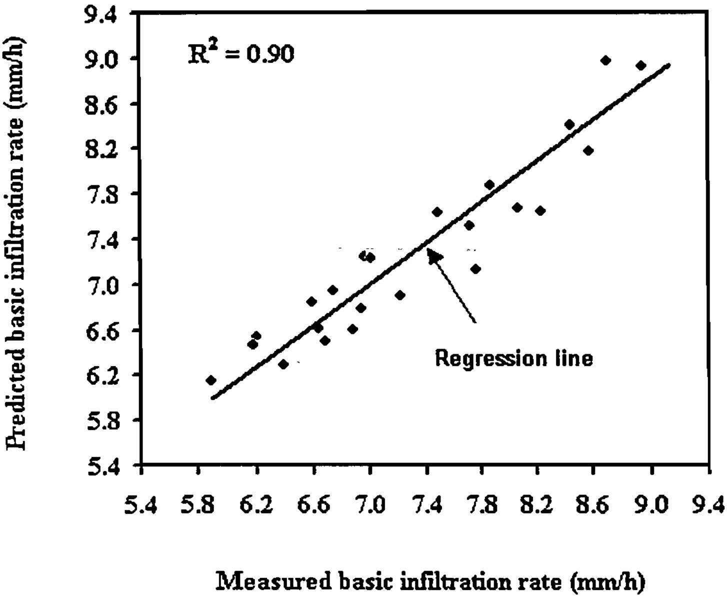

Fig. (5): Average measured vs. predicted basic infiltration rate after 180 min for all treatments.

CONCLUSION

Infiltration rate of soil were reduced significantly with tractor wheel compaction. This inferred that soil infiltration rate could be reduced significantly with tractor wheel compaction thus resulting in higher water use efficiencies. Soil compaction with tractor wheel appears to be a potential tool for changing the soil physical properties such as infiltration rate to conserve more water. The change in soil bulk density by wheel passing can significantly influence the infiltration rate of soil thus improving soil water holding capacity.

Average basic infiltration rate after 180 min was ranged from 7.8-9.1 mm/h for moldboard plow, 6.2-7.9 mm/h for chisel plow and 5.9-7.2 mm/h for rotary plow under different wheel passes and two plowing depths. Among the various wheel passes, five-pass caused 10.75, 19.55 and 14.37% reduction in infiltration rate under moldboard, chisel and rotary plows, respectively when tillage was achieved at 9.7 cm plowing depth. Mathematical model was derived from experimental data to get the infiltration rate in ease way by multiple regression analysis as empirical constants (k) and (n) of Kostiakov equation are functions of soil mean weight diameter, number of wheel passes and plowing depth. The measured versus predicted basic infiltration after 180 min using the developed models was correlated well by coefficient of determination (R^2) of 0.90.

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تأثر تسرب المياه بمعاملات الحراثة وعمق الحرث ومرور العجلة

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أجريت تجارب حقلية في تربة طينية كانت منزرعة عباد الشمس خلال صيف ٢٠٠٦ م لدراسة تأثير معاملات حراثة بأنواع محاريث مختلفة (حفار وقلاب مطرحي ودوراني) عند عمقي حرث حوالي (٩,٧ و ٢٠,٤ سم) ومرور عجلة الجرار فوق التربة المثارة بعدد ٥،٣،١،٠ مرة على معدل تسرب المياه في التربة، واستنباط علاقة رياضية تربط بين معدل تسرب المياه (نموذج كوستياكوف) وكلا من القطر المتوسط لحبيبات التربة، عدد مرات مرور العجلة فوق التربة المثارة وعمق الحرث. ويمكن تلخيص أهم النتائج المتحصل عليها كما يلي:

- تأثر معدل تسرب المياه النهائي داخل التربة (مم/س) بعد ١٨٠ دقيقة معنويا بنوع آلة الحراثة وعدد مرات مرور العجلة فوق التربة المثارة وعمق الحرث، بينما وجد أن التفاعل الثنائي والثلاثي بين المعاملات ليس لهم تأثير معنوي عليه، وكانت أعلى نسبة انخفاض له حوالي ١٠,٧٥ % عند استخدام المحراث القلاب المطرحي و ١٩,٥٥% عند استخدام المحراث الحفار و ١٤,٣٧% عند استخدام المحراث الدوراني في عمليات الحرث بعمق حرث متوسط حوالي ٩,٧ سم ومرور عجلة الجرار ٥ مرات فوق التربة المثارة.
- تأثر ثابتي معادلة كوستياكوف (k) و (n) لتقدير معدل تسرب المياه في التربة عند أي وقت وحتى ١٨٠ دقيقة معنويا بنوع آلة الحراثة، ولم يتأثرا معنويا بعدد مرات مرور العجلة فوق التربة المثارة وعمق الحرث، بينما وجد أن التفاعل الثنائي والثلاثي بين المعاملات ليس لهم تأثير معنوي عليهما.
- تراوح متوسط معدل تسرب المياه النهائي داخل التربة بعد ١٨٠ دقيقة من ٧,٨-٩,١مم/س للمحراث القلاب المطرحي، ومن٦,٢-٧,٩ مم/س للمحراث الحفار ومن٥,٩-٧,٢ مم/س للمحراث الدوراني وذلك تحت المعاملات المختلفة لعمق الحرث وعدد مرات مرور العجلة فوق التربة المثارة، كما انخفض هذا المعدل بزيادة عدد مرات مرور العجلة فوق التربة عند أي نوع آلة حراثة وأي عمق حرث، بينما زادت قيمته مع زيادة عمق الحرث من ٩,٧ إلى ٢٠,٤ سم عند استخدام أي نوع من آلات الحراثة وعند مرور العجلة فوق التربة المثارة بأي عدد من المرات (١ أو ٣ أو ٥) أو بدون مرور.
- تم استنباط نموذج رياضي يربط بين معدل تسرب المياه داخل التربة (مم/س) (نموذج كوستياكوف) وكل من القطر المتوسط لحبيبات التربة وعدد مرات مرور العجلة فوق التربة المثارة وعمق الحرث، وأوضحت النتائج توافق القيم المقاسة لمعدل تسرب المياه النهائي داخل التربة بعد ١٨٠ دقيقة مع القيم المتنبأ بها بمعامل ارتباط (R^2) قدرة ٠,٩٠. ويمكن من هذا النموذج معرفة معدل تسرب المياه داخل الأراضي الطينية عند أزمنة مختلفة وحتى ١٨٠ دقيقة من أجل الوصول إلى كفاءة ري متميزة، والمساعدة في تصميم نظم الري الحقلي عند الممارسات الزراعية المختلفة وخصوصا عند إجراء عمليات الحرث.