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Effect of Tillage Practices and Compaction on Infiltration Rate of Sandy Soils

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Abstract: A filed study was conducted to determine the effect of tillage prqctices arid compaction on infiltration rate of a sandy soil. Mean cumulative infiltration ranged from 3.18-6.15 cm hr^{-1} for rotavator, 3.75-7.85 cm hr^{-1} for moldboard plow and 6.02-13.62 cm hr^{-1} for chisel plow under different compaction treatments. Whereas, mean infiltration rate of soil was 6.53 cm hr^{-1} for rotavator, 7.59 cm hr^{-1} for moldboard plow and 12.36 cm hr^{-1} for chisel plow. Among the various compaction treatments, three-pass treatment caused 12.5, 22.9 and 50.3% reduction in infiltration rate of soils under rotavator, moldboard and chisel plow, respectively. However, the reduction in infiltration rate of soil under high compaction treatment (five-passes) was 35, 45 and 58% under rotavator, moldboard and chisel plow, respectively. The difference in infiltration rate of soil was significant among one-pass, three-pass and five-pass treatments than the control treatment (zero-pass). This study has highlighted an excellent potential for water conservation in sandy soils if simple conventional agricultural implements such as tractor, planters etc. alongwith different tillage practices are used for soil compaction.

Key words: Agricultural implements, tractor, compaction, tillage practices, infiltration rate, rotavator, moldboard plow, chisel plow, Al-Hassa

Introduction

Saudi Arabia is an arid country with a total land area of 2.253×10^6 km^2. Majority of agricultural soils in Saudi Arabia are coarse textured and have low productivity due to poor water holding capacity, low organic matter contents, initial low soil fertility, high infiltration rate and the presence of appreciable amounts of calcium carbonate and gypsum (Bashour *et al.,* 1983). All these factors constitute a potential management problem of arid zone soils. Simultaneously, it is difficult to obtain uniform application of water by surface irrigation resulting in poor irrigation efficiency. Application of different types of organic and inorganic materials (polymers, gels, sewage sludge, dairy manures etc) has caused significant improvement in these soil properties (Patil *et al.,* 1972; El-Hady *et al.,* 1981; Tayel and El-Hady, 1981; Johnson, 1984; Al-Gosaibi *et al.,* 1987; Fitch *et al.,* 1989; Al-Gosaibi, 1994). Recently, some investigators have observed that machinery traffic and adoption of different tillage operations greatly influence the physical properties of coarse textured soils under varying plant growth management systems (Douglas and McKyes, 1978; Gaheen and Kjas, 1978; Akram and Kemper, 1979; Abo-Abda *et al.,* 1997; Abo-Abda and Hussain, 1991).

Recently, researchers have stated that soil compaction with farm machinery decreased the hydraulic conductivity of the cultivated soils, the lowest values were found after one and four passes of the rubber-tracked tractor in the range of 1.5 and 0.08 mm hr^{-1}, respectively (Marsili *et al.,* 1998; Lowery and Schuler, 1994). As such, owing to poor physical and chemical properties, the management of coarse textured soils in an arid environment is very difficult. An extensive review of literature indicates that very little has been accomplished on this topic under the existing local soil, water and crop management conditions. The present study was, therefore, undertaken to determine the effect of tillage practices and machinery compaction on infiltration rate of sandy soils and also to highlight the magnitude of water conservation by adopting certain common management practices.

Materials and Methods

Selection of Site: The study was carried out at King Faisal University, Research and Experimental Station, Al-Ahsa, Kingdom of Saudi Arabia. The research station is situated on the Main Hofuf-Qatar Highway about 20 km from the main Hofuf Town. Four donnums of a sandy soil were selected under the command of well No. 8 in field No. 2. The soil was non-saline and non-sodic with a pH value of saturation paste as 7.78, EC, (electrical conductivity of saturation paste extract) less than 4 dS m^{-1}, Sodium Adsorption Ratio (SAR) of 4.52, field capacity of 8.50% and a bulk density of 1.65 g cm^{-3}. The land was precisely levelled, irrigated and left for 5 to 6 days to attain a moisture level of 6.5% (weight basis) which ranges between field capacity (FC) and permanent wilting point (PWP) of this soil for application of tillage practices and compaction treatments.

Procedure

Treatments

Tillage Practices	= 3 (rotavator, Moldboard and Chisel plow)
Compaction Rates	= 4 (0, 1, 3, 5 passes of tractor)
Replication	= 3
Total No. of treatments	= $3 \times 4 \times 3 = 36$

Rotavator was used to loosen the top 25-30 cm depth of soil. Moldboard plow was used to pulverize the soil. Chisel plow with long blades was used to open the soil to increase water penetration into the hard soil where hardpan is within 30 cm depth of soil.

The experiment was laid out by following A Randomized Complete Block Design. The experimental soil was tilled with the selected tillage implements in each treatment. The soil was compacted with a 2500 kg tractor (Klockner-Humbolder Bentz AG, Koln DZ 80) with standard 50 cm tires. The soil compaction force was determined by a soil penetrometer resistance (digital force gauge) to 25 cm depth and the force applied was 890 kPa (rotary), 975 kPa (chisel) and 750 kPa (rotavator) for one pass of tractor. The soil compaction rates were control (zero-pass), low (1-pass), medium (3-passes) and high (5-passes of tractor) according to the compaction force applied. Zero compaction force means that the soil was cultivated with the respective implements and not compacted by running over the tractor. Similar methods were used to calculate compaction forces for other treatments.

Measurement of Infiltration Rate: The infiltration rate of soil was measured by "Double Ring Infiltrometer" according to a method described by Aronovici (1955) and replicated thrice. The infiltration rings used were 45 cm long with an inner diameter of 30 cm. The infiltration rings were inserted into the soil upto 25 cm depth as vertically 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 having a total dissolved solids (TDS) of 1060 mg L^{-1} and sodium adsorption ratio ISAR) of 3.25. A constant water head of 15 cm was maintained in each ring and the measurements were recorded at 5 minutes interval. The data were reported as mean values. The experimental data were subjected to analysis of variance techniques according to Snedecor and Cochran (1973).

Results and Discussion

Cumulative Infiltration Rate of Soils: Rotavator: Machinery compaction caused a significant reduction of cumulative water infiltration in soil. Mean values were 6.15, 5.18, 4.79 and 3.18 cm for zero, low, medium and high compaction treatments, respectively (Table 1, Fig. 1). The decrease in water infiltration in soil was higher in compaction treatments than the control treatment ($LSD_{0.05}$ = 0.69). The difference in cumulative water infiltration was not significant between low and medium compaction treatments. However, the high compaction treatment (5-passes) caused significant reduction in the cumulative infiltration rate of soils than the control treatment.

Moldboard plow: Depending upon different compaction treatments, mean cumulative water infiltration of soil was affected significantly by the different tillage practices and compaction treatments (Table 1, Fig. 2). Mean values were 7.85 for zero, 6.25 for low, 5.50 for medium and 3.75 cm for high compaction treatments. Mean Soil cumulative water infiltration was significantly less in the compacted treatments than the control treatment (zero compaction, which means simple cultivation) [$LSD_{0.05}$ = 0.77]. The difference in cumulative water infiltration of soil was not significant between low and medium compaction treatments.

Chisel Plow: Mean cumulative water infiltration of soil was affected significantly by the different machinery compaction and tillage Practices (Table 1, Fig. 3). Mean values were 13.62 for zero, 8.23 for low, T37 for medium and 6.03 cm for high compaction treatments. Mean Soil cumulative water infiltration was significantly less in the compaction treatments than the control treatment ($LSD_{0.05}$ = 2.19). The difference in cumulative water infiltration was significant among different compaction treatments except low and medium treatments where it was not significant.

Infiltration Rate of Soil: Rotavator: Depending upon different compaction treatments, the mean infiltration rate of soil decreased significantly with an increase in compaction force ($LSD_{0.05}$ = 0.514). Mean values were 7.52, 7.14, 6.58 and 4.89 cm hr^{-1} for zero, low, medium and high compaction treatments, respectively (Table 2, Fig. 4). The difference in the infiltration rates of soil was significant among the different compaction treatments. The research findings suggest that the infiltration rate of soils can be suppressed by using simple mechanical means i.e. by passing conventional agricultural equipments such as Tractor, planter etc. over a land under cultivation for productivity improvement. The results indicate that approximately 5-35% savings of applied water can be achieved if such farm management practices are adopted in sandy soils.

Moldboard Plow: Depending upon different compaction treatments, the mean infiltration rate of soil decreased significantly with an increase in compaction force ($LSD_{0.05}$ = 0.556). Mean values were 9.60. 8.12, 7.40 and 5.24 cm hr^{-1} for zero, low, medium and high compaction treatments, respectively (Table 2, Fig. 4). The difference in the infiltration rates of soil was significant among different compaction treatments. The research findings suggest that the infiltration rate of soils can

Table 1: Effect of Compaction Treatments on Mean Cumulative Water Infiltration in Soils (cm)

Compaction	Rotavator Plow	Moldboard Plow	Chisel Treatment
0-pass	6.15	7.85	13.62
1-passes (low)	5.18 (15.8)	6.25 (20.4)	8.23 (39.61
3-passes (Medium)	4.79 (20.3)	5.50 (29.9)	7.37 (45.9)
5-passes (high)	3.18 (48.3)	3.75 (52.3)	6.02 (55.8)
$LSD_{0.05}$	0.69	0.77	2.19

Figures in brackets show the percent decrease in cumulative water infiltration from the control treatment (0-pass)

Table 2: Effect of Tillage Treatments on Mean Infiltration Rate of Soils (cm h^{-1})

Compaction Treatment	Rotavator Plow	Moldboard Plow	Chisel
0-Pass	7.52	9.60	19.80
1-Passes (low)	7.14 (5.1)	8.12 (15.4)	11.52 (41.8)
3-Passes (medium)	6.58 (12.5)	7.40 (22.9)	9.84 (50.3)
3-Passes (high)	4.89(35.0)	5.24 (45.4)	8.28 (58.2)
Mean	6.53	7.59	12.36
LSD (0.05)[a]	0.514	0.556	0.991

Figures in brackets show the percent decrease in mean infiltration rate of soil from the control treatment (zero-pass)

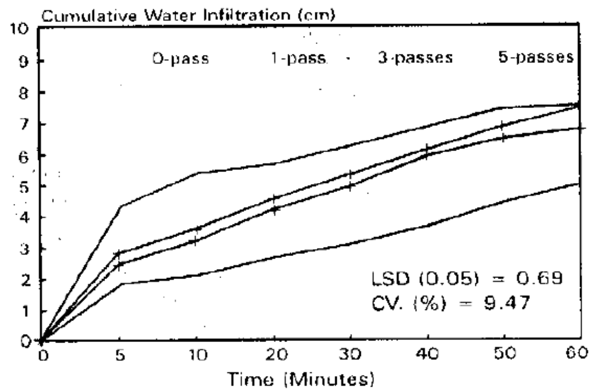

Fig. 1: Effect of compaction on cumulative infiltration of soil under rotavator tillage

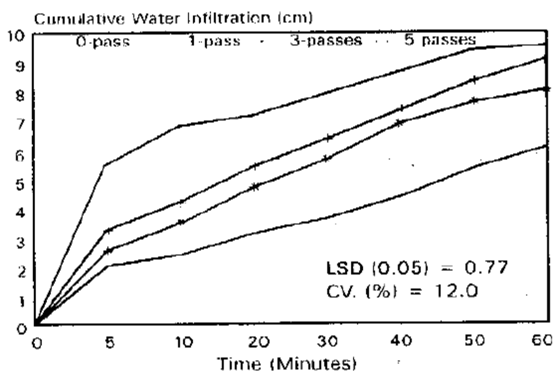

Fig. 2: Effect of compaction on cumulative infiltration of soil under moldboard tillage

be suppressed by using simple mechanical means i.e. by passing conventional agricultural equipments such as tractor, planters etc. over the land under cultivation for productivity improvement. The results indicated 15-45% savings in water by simply passing agricultural implements (tractor in this case) five times over the land under cultivation. The results are in agreement with those of Kemper *et al.* (1982) and Elliott *et al.* (1983) who reported 20 to 40% reduction in infiltration rate of soil by tractor wheel compaction.

Chisel Plow: Results indicate that compaction treatments and the tillage practices had significant effect on the infiltration rates of soil. Mean values were 19.80, 11.52, 9.84 and 8.28 cm hr^{-1} for zero, low, medium and high compaction treatments, respectively (Table 2, Fig. 4). The difference in the infiltration rates of soil was significant among different compaction treatments ($LSD_{0.05}$ = 991). The results indicated 42-58% savings in irrigation water by passing agricultural implements (tractor in this case) five times over the land under cultivation. The results are in agreement with those of Kemper *et al.* (1982) and Elliott *et al.* (1983) who reported 20 to 40% reduction in infiltration rate of soil by tractor wheel compaction.

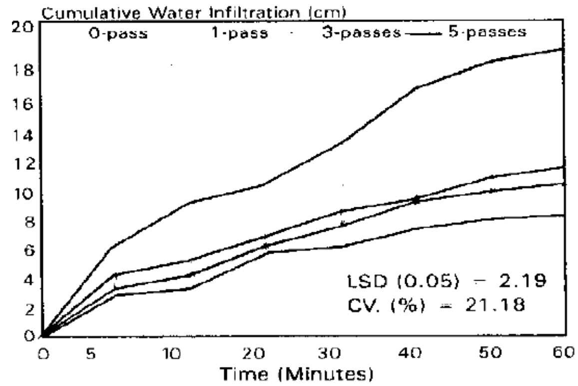

Fig. 3: Effect of compaction on cumulative infiltration of soil under Chisel tillage

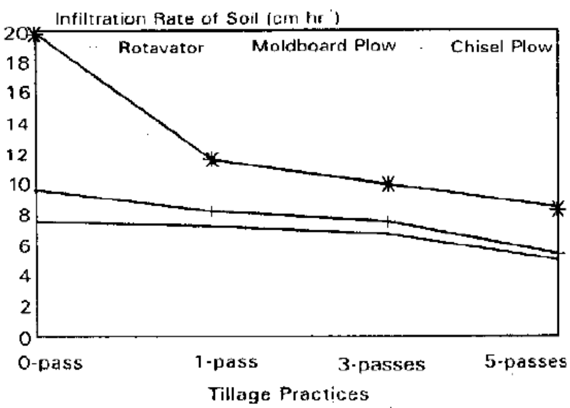

Fig. 4: Effect of tillage practices and compaction on infiltration rate of soil

Comparison between Different Implements: Comparison of results in Fig. 4 and Table 2 shows that mean infiltration rate of soil at the highest rate of compaction rate (5-passes of tractor) was significantly higher in chisel plow (12.36 cm hr^{-1}) followed by moldboard plow (7.59 cm hr^{-1}) and rotavator (6.53 cm hr^{-1}) in that order. The higher infiltration rate of soil under chisel plow may be attributed to increased soil disturbance than moldboard and rotavator implements.

Conclusion: Infiltration rate of soil was reduced significantly with a simple compaction by using conventional agricultural implements such as tractor etc. The results further indicated that irrigation losses through deep percolation could be reduced upto 58% by compacting the sandy soils and ultimately could result in achieving higher water use efficiencies. Soil compaction appears to he a potential tool of water conservation for the development of coarse textured soils in an arid environment. Further experiments are needed for test and evaluation of all kinds of conventional/non-conventional agricultural equipments currently in use in the Kingdom of Saudi Arabia to determine the effect of compaction and tillage practices on soil physical properties for improved water management by increasing irrigation efficiency through crop response and yields.

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