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EFFECTS OF MECHANICAL AERATION ON THE COMPACTION AND PERMEABILITY OF A GRASSY SWARD

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ABSTRACT In a golf course located at El Kantaoui, Sousse, Tunisia, many trials were carried out over a sandy soil grassy sward to investigate the effects of mechanical aeration on its compaction and permeability. For this purpose, many soil cores were extracted using a 1.6 m effective width Verti-Drain aerator equipped with hollow spades spaced 65 mm apart. Aeration was performed at a rate of 350 holes /m^2. Soil resistance to penetration and permeability were determined at the initial state before aeration as well as 10, 20, and 30 days after aeration. Compared to the initial state, the results showed that mechanical aeration positively affects the grassy sward ground by reducing its resistance to penetration as 35 and 43% decrease in penetration resistance were noticed at 5 cm depth 10 and 20 days after aeration, respectively. Also, resistance to penetration decreased by 41 and 48% at 15 cm depth during the same two periods of time. However, soil resistance to penetration at 5 and 15 cm depths only decreased by 21 and 26%, respectively. Regarding the soil permeability measured after aeration, a significant improvement was observed compared to that at the initial state (4.9 cm/h). Indeed, the permeability was 12.5, 13, and 14.1 cm/h 10, 20, and 30 days after aeration, respectively.

Keywords: Grassy sward, soil compaction, mechanical aeration, soil resistance, permeability.

INTRODUCTION The ground soil under our feet is not an inert agglomerate of mineral particles, but rather a support and a nutritional resource for lots of living beings such as plants (Musy and Scuter, 1991). Plants need a lot of nutriments, in particular water and oxygen (Beauchamp, 2002). However, the degradation of soil structure (ground surface compaction, hardened soil layers, etc.) alters its aeration and affects plants development. Moreover, the soil compaction reduces water infiltration and limits the growth of the roots because of the lack of water and air in the vicinity (Allen and Musick, 1997). The root growth limitation due to the soil compaction has been investigated by many researchers (Voorhees, 1977; Gaultney et al., 1982; Schuler and Lowery, 1984).

It is well known that compaction affects the soil structure by altering its physical characteristics, in particular the reduction of hydraulic conductivity (Vitlox andt Loyen, 2002). The extent of compaction mainly depends on the soil mechanics stability (Gysi, 2001). Repeated passages of heavy machinery and tire-soil contact pressures result in an increase of the soil compaction level (Raghavan et al., 1979, Angiboust, 1983). Trudging also represents an important source of compaction (Yoro and Assa, 1986). One of the main objectives of soil tillage is to favour the growth of the roots in this constraining medium. In this case, soil resistance to root penetration is reduced by improving its structure. Also, soil aeration is improved allowing therefore better gas exchanges at the root level. According to Charreau and Nicou (1971) and Nicou (1977), ploughing favourably affects the root system. It particularly enhances both the growth at the beginning of the cycle and a deep soil colonization following the improvement of the soil physical properties.

The success in establishing a grassy sward is highly related to the structural and textural states of the soil (Schut, 2001). Nevertheless, major maintenance operations carried out on grassy swards mostly aim at continuously improving aerial quality of the turf. This is however mainly related to the behaviour of the root layer which is greatly subject to golf players stamping and maintenance machinery circulation (Chehaibi et al., 2007).

Mechanical soil tillage or aeration of grassy swards represents one of the main methods used to remedy to compaction problems affecting the roots. It aims at lowering the incidence of repetitive passages of maintenance machineries and of stamping. This leads to easier water and air circulation into the soil which favours the building of an adequate water reserve, stimulates the development of the turf root system, enhances the microbial life in the ground soil, and allows a quick decomposition of organic matter (Schut, 2001).

The main objective of this research study was to explore the effects of mechanical aeration by extracting soil cores from a grassy sward on the resistance to penetration and permeability of a golf course.

MATERIELS AND METHODS Trials were carried out over a sandy soil grassy sward of a golf course located at El-Kantaoui, Sousse, Tunisia. Many soil cores were extracted using a 1.6 m effective width Verti-Drain aerator equipped with hollow spades spaced 65 mm. This tool could be operated at a maximum depth of 300 mm. The spades were subject to an alternate movement from a slider-crank mechanism operated by the power take off of a tractor. When penetrating the ground soil, the spades extirpate soil cores. Going back to the ground allows the spades ejecting previous soil cores on the ground surface to be picked up later. Aeration was always followed by a sand supply on the perforated surface.

Mechanical soil tillage was achieved on a 500 m^2 sandy sward at a rate of 350 holes /m^2. The sward was split into three plots. Compaction states before (E0) and 10, 20, and 30 days after aeration were evaluated through soil resistance to penetration and water infiltration speed or permeability measurements.

Soil resistance to penetration was evaluated using a direct reading static penetrometer (Billot, 1989). Measurements of soil resistance were taken every five centimetres for a total depth of 20 cm. Permeability measurements were based on the determination of the permeability coefficient "K" of Darcy laws (Musy and Scuter, 1991). This coefficient is strongly linked to soil properties, mainly its structure (Hillel, 1988).

RESULTS AND DISCUSSIONS Compared to the initial state before mechanical soil tillage, analysis of the penetrometric profiles shows a reduction of soil resistance after the passage of the aerator (Figure 1). This confirms the beneficial effect of soil tillage.

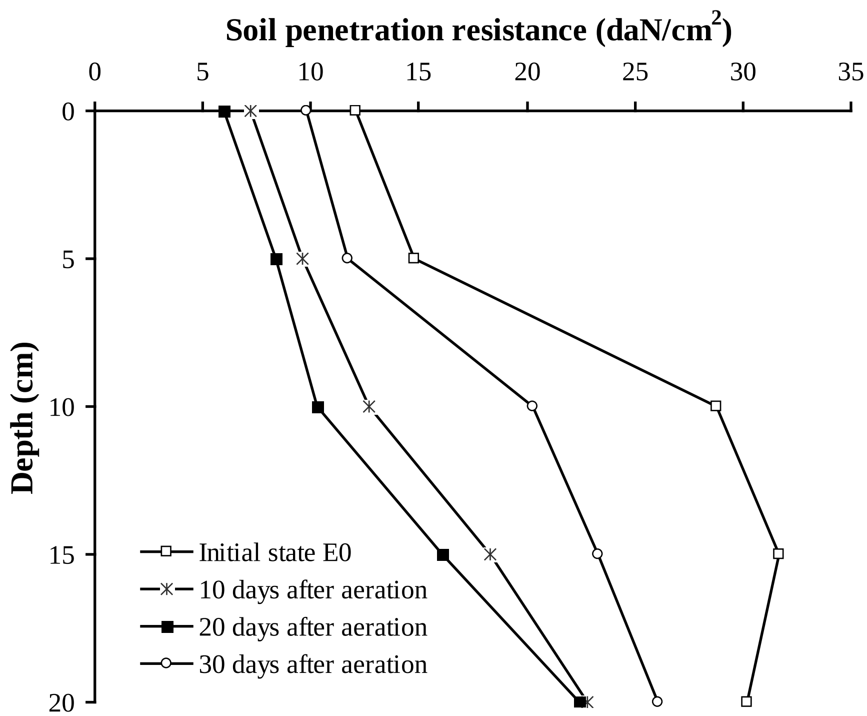

Figure 1: Penetrometric profiles of the initial states and 10, 20, and 30 days after aeration.

Ten days after aeration, soil resistance to penetration is 9.6 and 18.3 daN/cm^2 at 5 and 15 cm depths, respectively. Compared to the initial state, this represents 35 and 42% reductions in soil resistance. It appears that the mechanical tillage well improved the structure of the ground soil by reducing the penetration resistance. This agrees with the results of Chopart (1994) indicating that work made on soil improves its porosity and reduces its mechanical resistance.

Twenty days after aeration, results show a less compacted soil along with less resistance to soil penetration compared to the initial state. At 5 and 15 cm depths, resistances to penetration are 8.4 and 16.1 daN/cm^2, respectively, representing 43 and 49% reductions in soil resistance. This shows that mechanical soil tillage alleviates the compaction and brings the compacted soil into a new, loose equilibrium state.

On the other hand, results reveal that soil compaction 30 days after aeration is higher than that 10 and 20 days after. However, soil resistance to penetration remains below that at the initial state. At 5 and 15 cm depths, for example, 21 and 26.5% resistance to penetration reductions, respectively, were observed compared to the initial state.

Statistical analyses of the data show highly significant effects of the depth and the date of measurements on the soil resistance (Table 1).

Table 1 ANOVA results for the soil penetration resistance data

Source of variation	D.F.	M.S.
Block	2	3.47NS
Depth	4	578**
Date	3	364**
Depth * date	12	21**
Error	38	1.532

NS: not significant; **: significant at the 1% level.

Soil resistance significantly differs for all measurement dates. The higher resistance corresponds to the initial state whereas the lowest occurs 20 days after aeration (Figure 2).

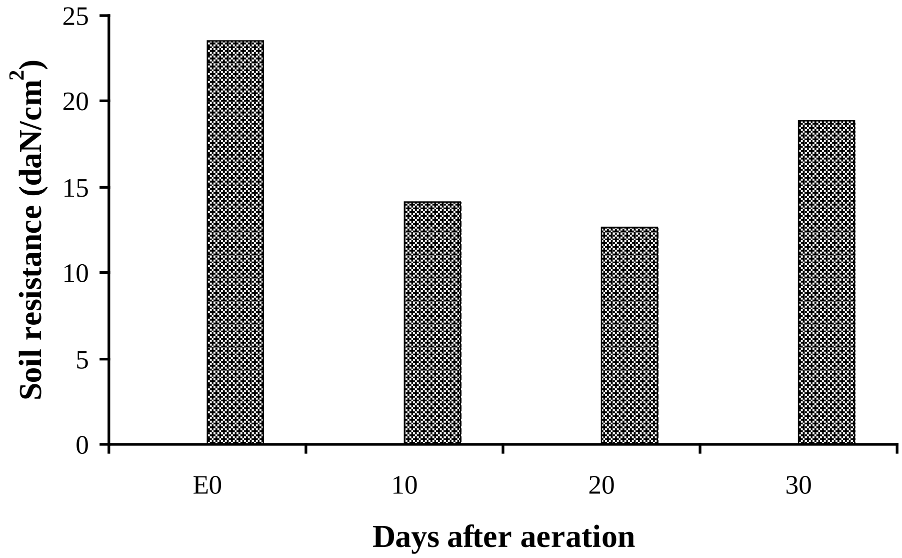

Figure 2: Evolution of soil resistance with time after aeration.

Soil resistance also significantly differs from one depth to another as shown on figure 3. This indicates that compaction of the ground surface by stamping and machinery circulation deeply spreads in the soil to generate dense horizons. The resistance of the soil increases with increasing the depth.

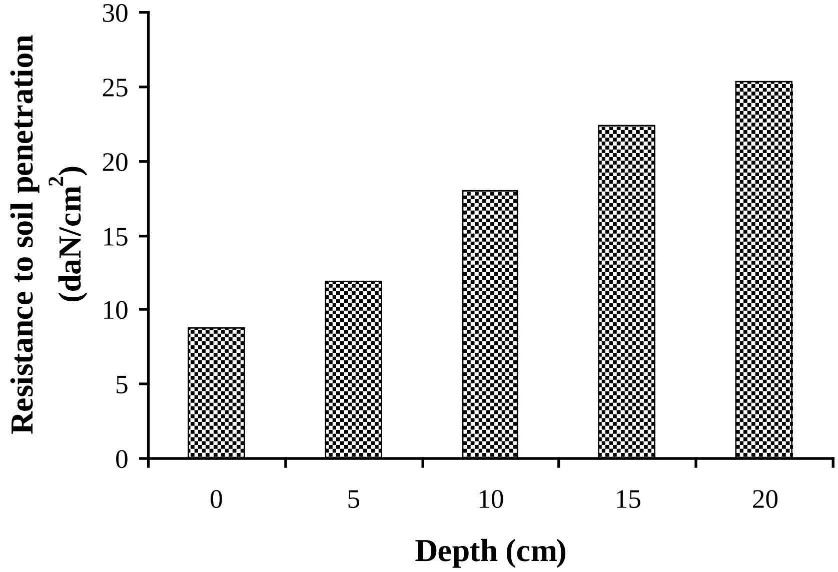

Figure 3: Evolution of the soil resistance with depth.

It appears that the soil undergoes a progressive alleviation of compaction after mechanical tillage. This alleviation slows down after a certain time and the soil gets compacted again. This shows that the effect of mechanical aeration is temporary. These results agree with those of Ouattara et al. (1998) which show that soil tillage contributes to increasing its porosity but this latter decrease with time. Chehaibi et al. (2007) also showed that mechanical aeration of turf grass reduces the compaction of the soil over a certain period of time and then the soil becomes compacted again.

Regarding the permeability, figure 4 shows that it increases with time after aeration. At the initial state, the soil is not very permeable as the soil permeability is only 4.9 cm/h. This proves that the soil was indeed compacted before aeration and that this compaction has a direct effect on water infiltration as mentioned by Musy and Scuter (1991). However, the “K” value obtained 10 days after aeration shows a clear improvement of the permeability with a speed of 12.5 cm/h. This represents a 60% increase compared to the initial state. This increase in permeability is attributed to the alleviation of soil aggregates compaction after aeration which is a good sign of a porous medium.

20 days after soil aeration, a small improvement in permeability is observed compared to that obtained after 10 days. It appears that the soil permeability undergoes a net improvement following the soil mechanical tillage. The most notable improvement compared to the initial state occurs 10 days after aeration. This results from the modification of the soil structure following the mechanical aeration.

Soil permeability measured 30 days after aeration is higher than that obtained after 10 or 20 days but the increase is not noticeable. This increase is however very significant compared to the initial state as the permeability was improved by 65%.

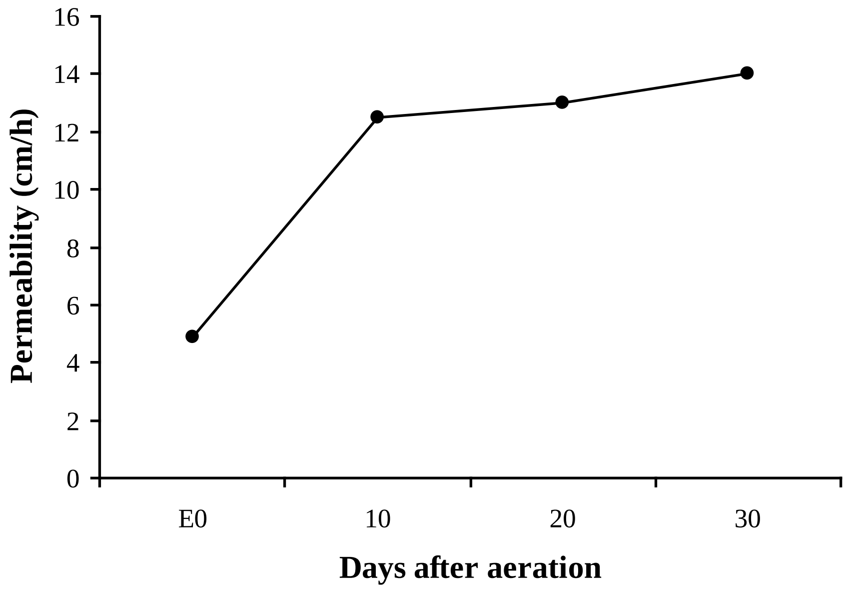

Figure 4: Evolution of the soil permeability after aeration.

Statistical analyses show a high significant effect of the measurement dates on the soil permeability (Table 2). However, the permeability measured 10 days after aeration is comparable to that measured after 20 days as shown on figure 4.

Table 3 ANOVA results for the soil permeability data

Source of variation	D.F.	M.S.
Block	2	0.052NS
Date	3	52.4**
Error	6	0.096

NS: not significant; **: significant at the 1% level.

Obtained results confirm those of Monnier et al. (1986), Casta et al. (1989), and Vauclin and Chopart (1992) which showed that soil tillage has an immediate positive effect on the soil permeability resulting from an improvement of its structure. This also agrees with the results obtained by Chehaibi et al. (2007) who demonstrated that mechanical soil aeration improves its permeability.

CONCLUSIONS Results of this research study show that soil mechanical tillage reduces its compaction as the penetration resistance decreased in all the studied horizons. Compared to the initial state, the decrease was 35 and 42% at 5 and 15 cm depths, respectively. Twenty days after aeration, 43 and 49% decrease in soil compaction were observed for the same depths. This is not the case 30 days after aeration as soil resistance was higher than those measured 10 and 20 days after aeration. Nevertheless, a reduction in soil compaction by 21 and 26.5% at 5 and 15 cm depths was noticed compared to the initial state.

Soil permeability improvement was remarkable in particular during the first few days following soil mechanical tillage. Indeed, 60% permeability increase was observed 10 days after aeration compared to the initial state. This increase slowed down thereafter as only 62 and 65% were noticed 20 and 30 days after aeration, respectively, compared to the initial state.

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