Effect of the tine type on mechanical aeration of grassy sward

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Research Article

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ABSTRACT

The effect of mechanical aeration depending on the tine type was studied on a sandy soil of Tunisian golf green. Aeration was performed using an aerator Verti-drain of 1.6 m of width, at a perforation density of 250 holes/m². Two types of tines were used, hollow tines with outer and inner diameters of 12 and 10 mm respectively, and full tines with a diameter of 8 mm. Measurements focused on soil resistance to penetration and its bulk density. They were performed at initial state (E₀) and 6, 21, 40 and 53 days after aeration. Results showed that mechanical aeration as it was practiced progressively improved grassy soil structure by reducing its resistance to penetration and bulk density compared to initial state, especially with hollow tines perforation. However, this situation lasts only about ten days to see again the soil compaction. Indeed, measurements 6, 21 and 40 days after aeration, showed a continuous lowering of soil parameters and the optimum was recorded at 40 days. However, from 53 days after aeration, soil started to return to its initial state.

Keywords: golf green - grass - soil compaction - mechanical aeration - hollow tines - full tines - soil resistance - bulk density.

INTRODUCTION

The grassy swards compaction by players trampling and repeated passage of maintenance machinery, leads to aggregates crushing reducing the spaces between soil particles that contain water and air on which the roots depend (Martineau et al., 2008; Delage, 2009). According to Giroux et al., (2005), soil compaction increases its density by reducing especially the larger pores that are the origin of water and air percolation. This change leads to substantial yield losses and causes a reduction of the root system. Accordingly, the soil becomes poisonous and unfavorable to biological activity of microorganisms and plants.

Moreover, the turf success and its good density depend on the quality of its establishment as the quality and regularity of its maintenance. Mechanical maintenance operations of grassy swards are essential especially on frequently used grounds. They are necessary to obtain a green lawn, dense and homogeneous in order to improve the conditions of the game and ensure safety for users (Goëxes et al., 2008). However, there are often problems of soil permeability and insufficient rooting weakening the sports turf which is due, in most cases, to soil compaction from 15 to 20 cm of depth (Gouverneur, 1997). In addition, implanted turf on compacted soil has a poor rooting that promotes the development of weeds (Pepin, 2005).

However, if conventional tillage reduces soil density by increasing its porosity (Lahlou et al., 2005), aeration is a mechanical plowing method that allows soil loosening without damage by extraction of small soil cores. Aeration allows regenerating and restoring volume to compacted soil by mechanical work at more than 5 cm of depth (Laurent, 2007). This method can also be performed through the use of equipment with tips that make holes in the grassy sward (Wetmore and Browne, 2003).

Aerating grassy soils helps to promote root development, stimulate the soil life, promoting water penetration, air and fertilizer, and to fight against felting (Denayer, 2005; Goëxes et al., 2008; Seixas, 2010). Duclos (2008) reported that mechanical work was not only designed to aerate the soil, but also to facilitate the descent of the root in depth, evacuate water and improve soil structure. Hollow tines aerators are necessary to extract fine soil or felted and replace it by clean material. The full-tines aerators allow satisfactory results provided not to have impermeable layers in depth. The aeration efficiency is usually related to the number of holes performed. The minimum number should be 50 holes/m² (BNQ, 2001). To achieve beneficial effects of aeration, it is recommended to have an average of 200 holes/m² (Desjardins, 2003).
Extraction of soil cores with hollow tines allows air to descend in depth and keep it by penetrating a porous and draining material. The volume of disturbed soil for each intervention is considerable with 400 holes/m² and tines of 16 mm of diameter, more than 8% of the worked layer are exchanged (Boxx et al., 2008). However, during their penetration in soil, full tines slightly move the material laterally and compress the bottom. However, the operation is clean, there is less sand to bring, and the discomfort is minimal for the game (Cochard, 2004).

The present work aims to study the effect of the tine nature (hollow or full) on mechanical aeration of grassy sward.

MATERIALS AND METHODS

Principle of turf aeration

Aeration, also called “perforation”, “wedge” or “coring” is a mechanical operation which consists in perforating the soil by cores extraction, leaving holes on grassy soil (Fig. 1a). Aeration improves the structure and texture of the soil by contribution of sandy amendment. It is performed by a machine called aerator with tines mounted on a crankshaft (Fig. 1b). Equipped with full tines, this type of machine does not remove any soil particle during its passage. The tines aerator performs from 200 to 400 holes/m². It allows a better permeability by decreasing superficial compaction, good root development and fight against felting (Pepin, 2005).

Experimental conditions

Tests were conducted on a green golf course in Tunisia. The green has an average area of 250 m². Mechanical aeration work was performed by a machine of Toro brand equipped with straight tines, whose main characteristics are given in Table 1. Two types of tines were used, hollow tines of outer and inner diameters of 12 and 10 mm respectively, and full tines of 8 mm of diameter. In order to fill the holes and have a smooth surface, sanding was performed on the lawn followed by irrigation. The perforation density was 250 holes/m². The penetration depth of the tines into soil was 12 cm. Two soil treatments were therefore considered:

- Treatment 1: soil aeration by hollow tines;
- Treatment 2: soil aeration by full tines.

<table>
<thead>
<tr>
<th>Mark</th>
<th>Type</th>
<th>Working width (m)</th>
<th>Maximum working depth (mm)</th>
<th>Distance between tines (mm)</th>
<th>Propulsion</th>
<th>Training mode</th>
<th>Weight (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toro</td>
<td>Verti-drain</td>
<td>1.6</td>
<td>300</td>
<td>65</td>
<td>towed</td>
<td>PTO</td>
<td>670</td>
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<td>7316</td>
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</table>

Table 1: Technical characteristics of Verti-drain.
Characterization and modalities of measurements

The effect of mechanical work of the turf aeration by two types of tines is based on measurements of soil resistance to penetration and its bulk density, performed on grassy sward at initial state before aeration and after passage of the machine with hollow or full tines.

Soil resistance to penetration

Soil resistance to penetration was determined by a penetrometer. This tool offers a good potential for assessing the soil structural quality (Burgess et al., 1997; Vitlox and Loyen, 2002).

The penetrometer used is of the electronic type, also called penetrologger (Figure 2). Coupled to a recorder, this device allows the storage and immediate processing of data. It consists of a force sensor, a recorder, a drill pipe, a cone, and an ultrasonic depth gauge. The apparatus is run by two very ergonomic handles for easy access to various commands. The application of equal pressure on both handles pushes the cone vertically into the soil. A mechanism of integrated measuring allows recording the penetration resistance encountered during the phase of insertion of the cone. It is also possible to immediately display the results of measurements on the screen as a graph or table of numerical data.

![Electronic penetrometer or penetrologger](image)

Figure 2: Electronic penetrometer or penetrologger

Bulk density

Soil bulk density (g/cm³) was measured on a soil cylindrical core (diameter = 5 cm, height = 5 cm) using a cylinder densimeter, the sample was taken every 10 cm for a depth of 30 cm. Then we obtained the dry mass of the sample after drying it in a stove at a temperature of 105°C for 24 hours (Yoro and Godo, 1990).

Measurements of soil parameters were performed at initial state (E0) before aeration and 6, 21, 40 and 53 days after aeration.

Statistical Analysis

Statistical analysis of the different measurements was based on the analysis of variance (ANOVA) through the software SPSS 13. The comparison between means was performed according to the Duncan test at 5%.

RESULTS AND DISCUSSION

Soil resistance to penetration

According to Figure 1, the sit of soil resistance to penetration is growing from surface to depth, for all results. Indeed, six days after aeration (Figure. 3a), soil resistance at 5 cm of depth, was 2.36, 1.66 and 1.5 daN/cm² respectively for initial state, treatment 1 and treatment 2. At 10 cm of depth, values were 3.13, 2.9 and 2.7 daN/cm² respectively for initial state, and treatments T1 and T2. However, compared to the initial state, mechanical work as it has been practiced, has led to a soil loosening indicated by a decrease in its resistance to penetration. However, the plots worked by hollow tines were marked by lowest values of soil resistance.

Regarding measurements performed 21 days after aeration (Figure. 3b), they reflected a continuation of soil relaxation after aeration. Indeed, compared to the previous state, soil resistance recorded a decrease of
6.6% at 5 cm of depth for both treatments. Equally at 15 cm of depth, the reduction in soil resistance was 5.9 and 8.6% respectively for the treatments T1 and T2.

In addition, measurements performed 40 days after aeration (Figure. 3c) showed improvement in soil loosening state marked by lower soil resistance. Indeed, at 10 and 20 cm of depth, it respectively corresponded to 2 and 3.2 daN/cm² for treatment 1, and 2.5 and 3.5 daN/cm² for treatment 2. This represents a depletion compared to initial state of 36 and 39% for treatment 1, and 20 and 33% for treatment 2. It appears that the effect of mechanical aeration of grassy swards is not instantaneous, but it depends on time (Abrougui et al., 2012).

As for measurements performed 53 days after aeration, they revealed a return beginning of soil to its condition before aeration, indicated by increasing values of soil resistance for all considered horizons and for the two treatments. The curves gaits were similar, particularly on the horizon 0-10 cm. This may be related to the extension in depth of the pressure at surface by maintenance machinery and trampling of players.

It thus appears that mechanical work of grassy soil aeration led to its loosening, but with more efficiency of hollow tines compared to full tines. This may be due to the extirpation of soil cores, which leads to empty volume in elevated soil, without significant pressure exerted laterally and in depth, due to small thickness of the tines. Accordingly, the soil has more opportunities to relax later. However, with full tines, the aggregates are compacted in depth and laterally by the pressure exerted on soil by the tine which displaces a quantity of material equivalent to its volume embedded in soil.
Bulk density

Density obtained 6 days after aeration (Figure 4a), showed a marked decrease in its value compared to initial state for the two treatments. However, the hollow tines aeration has provided the best impact on all depths. Indeed, at initial state, the bulk density was 1.69, 1.75 and 1.71 g/cm$^3$ at 10, 20 and 30 cm of depth respectively. These values for the same depths were 1.57, 1.59 and 1.65 g/cm$^3$ for aerated plots with hollow tines, and 1.62, 1.69 and 1.69 g/cm$^3$ for perforated plots with full tines. It appears that mechanical aeration as it was practiced has the direct effect of improving soil structure by loosening the upper horizons.

Regarding results obtained 21 days after aeration (Figure 4b), they were marked by a significant decrease in bulk density over time. At a depth of 10 cm for example, we recorded a decrease of 2.5 and 2.4% compared to the previous state, respectively for treatments T1 and T2. This was equally valid for 20 and 30 cm of depth.

Regarding measurements 40 days after aeration (Figure 4c), they revealed a continuous decrease in bulk density, especially for hollow tines aeration. These tines provided for considered depths, a lower density than the previous state. Indeed, we recorded a decrease of 4 and 2% at 10 and 20 cm of depth. However, aerating with full tines has not proved a net decrease of bulk density.

Examination of results obtained 53 days after soil aeration (Figure 4d) showed a recovery of soil compaction for the two treatments and all studied depths. Indeed, we recorded an increase in soil bulk density compared to the previous state of 6.8, 2.6 and 3.8%, respectively at 10, 20 and 30 cm of depth for plots aerated with hollow tines. For the same depths, plots aerated with full tines were marked by an increase of soil bulk density of 1.3, 1.2 and 3.1% respectively. It is noted that the effect of soil mechanical aeration is temporary and decreases with time.

These results are consistent with those of Chehaibi and Abrougui (2012) and Chehaibi et al. (2012) who showed that mechanical aeration with hollow tines loosens the soil better than full tines, and that its effect is limited in time. They also confirm those of Martineau et al. (2008) and Delage (2009) who reported that grassy sward subjected to trampling and repetitive passages of maintenance machinery undergoes a compaction resulting from the reduction of the spaces between soil particles.
**Figure 4**: Soil bulk density at initial state and treatments 1 and 2, a: 6 days after aeration; b: 17 days after aeration; c: 40 days after aeration; d: 53 days after aeration

**CONCLUSION**

This work aimed to study the effect of the tine nature on mechanical aeration of grassy soil. It appears that mechanical aeration can improve soil structure by reducing its resistance to penetration and its bulk density compared to the initial state. However, hollow tines aeration has provided the best results. Indeed, measurements of soil physical parameters (resistance to penetration and bulk density) at four different dates after aeration allowed the following conclusions: the passage of the aerator has loosened the soil for the two types of tines; aerating with hollow tines is characterized by the lowest soil physical parameters; soil loosening was improved with time and the optimum was reached at 40 days after aeration; soil compaction recorded a recovery and a return to its original state from the fiftieth day after aeration.

**REFERENCES**