DEVELOPMENT AND EVALUATION OF A TURFGRASS AERATION MACHINE

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ABSTRACT

Turfgrass aeration involves the removal of small soil plugs or cores out of turfgrass. Most aeration is done mechanically with a machine having hollow tines or spoons mounted on a disk or drum. The objective of this study is to development, evaluation and manufactures an aeration machine for turfgrass. The evaluation study focused on measurements of soil bulk density, void ratio, soil porosity and energy consumption. The first three parameters were measured before and after turfgrass aeration with three tine diameters (1.27, 1.9 and 2.54 cm) under two depths (5 and 8 cm) with three working forward speeds (1.5 , 2 and 2.7 km/h.). Results showed that reduction in bulk densities in all treatments and the effective treatment was 0.78 at 8 cm depth, tine diameter 1.27 cm and forward speed 1.5 km/h. The void ratio increased for all treatments, while the highest increase value was 1.95 at 8 cm depth, tine diameter 1.27 cm and forward speed 1.5 km/h. and Soil porosity increased for all treatments, and the effective treatment from variance analysis was 66.09 % with same treatment.it noticed that The highest values of field capacity was 0.687 fed/h with third diameter 2.54 cm at 5 cm depth with 2.7 km/h. It was found that the higher treatment in consumed fuel was the third diameter (2.54 cm) at 8 cm depth and 2.7 km/h (5.78 L/h). It was found that $T_1 d_1 s_3$(tine diameter 1.27 cm, depth 5 cm and forward speed 2.7 km /h) had the lower value energy consumption 22.84 kW.h./fed.

INDROUTION

Turfgrass plants are normally perennial which grow through tillering, stolon and rhizomatous growth, and ideally, develop new vegetative shoots continually throughout the year. **(Lodge et al., 1990)**.

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Hillel (1980) described compaction as the process of soil densification or compression, which leads to the reduction of air volume in an unsaturated soil or water in a saturated soil Traffic from mowers, sprayers, golfers, and golf carts compact fairway soils. This traffic usually compacts the top 5 to 7.5 cm in turf situations with the top 2.5 cm being the most severely compacted **(Beard, 1973).**

Soil compaction is a problem in many turf areas **(Sills and Carrow, 1983).** Research has shown that soil compaction reduces water, heat, reduces root penetration, and gas exch0ange **(Linn and Doran, 1984).** Compacted soil restricts air and water movement to roots (**Bruneau et al., 2004). (Meek et al., 1992)** stated that a reduction in compaction can be achieved by applying traffic to the soil when it is as dry as possible. Compaction leads to decreased soil infiltrability **(Akram and Kemper, 1979).** decreased saturated hydraulic conductivity **(Dawidowski and Koden, 1987)** and decreased air entry values, while increased saturated water content **(Libardi et al., 1976).**

Cultivation/aeration is briefly defined as mechanically disturbing the rootzone or thatch layer by punching or slicing various types and depths of holes or fissures into turf surface to improve overall rootzone quality and turfgrass performance without destroying the turf **(Bunnell et l., 2001)**.

Among other benefits, the two main objectives in aeration turfgrass systems are to remove thatch-mat and organic matter, to improve soil physical properties such as soil aeration, air-soil gas exchange, saturated hydraulic conductivity, and to reduce soil compaction **(Sorokovsky et al., 2007)**.

Turgeon (2002) stated that Coring or core cultivation is the practice by which hollow tines or spoons are used to extract cores from the soil. Core size varies from 0.635 and 2.54 cm in diameter, depending on the size of the tine. The vertical length of the cores varies with soil strength and penetration capacity of the coring apparatus. Since soil strength is proportional to bulk density and moisture content, increasing soil moisture facilitates deeper penetration of the tines. Core lengths are 7.62 cm.

McCarty et al. (2007) reported that organic matter increased from 19 to 25 g kg-1, a 32% increase, in the surface 5.1 cm of an uncultivated turfgrass system. Organic matter content was reduced from 20 to 18 g kg-1, a 10% reduction, when turfgrass was core cultivated four times annually.

Abrougui et al. (2013) found that bulk density decreases after the aerator passage aeration, after aeration, the bulk density recorded a decrease compared to the initial state of 9 and 8%. Soil resistance recorded a decrease compared to the initial state by 53 and 58%.

MATERIALS AND METODS

The aim of this study is to development, evaluation and manufactures aeration machine for turfgrass with vertical motion to reduce turfgrass soil compaction. The machine depends on producing round vertical holes.

MATERIALS:

a- The agricultural tractor:

The characteristics of the agricultural tractor, used in this study as mobile power are 45Hp engine at 2200 r.p.m. and 2*4 wheeled typed.

b- Hand digital tachometer:

The rotational speed of the machine was measured for the main shaft of the machine it was measured by using a hand digital photo / contact tachometer, The specifications of selected tachometer according to its instruction manual were with range 0.5to 19,999 r.p.m and accuracy 0.05% + 1 Digit.

c- Soil resistance to penetration:

The soil cone penetrometer is recommended as a measuring device to provide a standard uniform method of characterizing the penetration resistance of soils. The force required to press the 300 deg. circular cone through the soil, expressed in kilopascals **(ASABE Standards, 2006).** The specifications of selected tachometer according to its instruction manual are with Memory1500 measurements and Maximum penetration force 1000 N.

d- Design of Aeration machine:

The design of the aeration machine consist of the following main component as shown (fig.1), The machine consists of four parts including, frame and hitch (A), transmission system from tractor to machine with crankshaft and connecting rod(B), flexible linkage (C) and tines holder (D) . The overall dimensions of aeration machine were 119×55×60 cm.

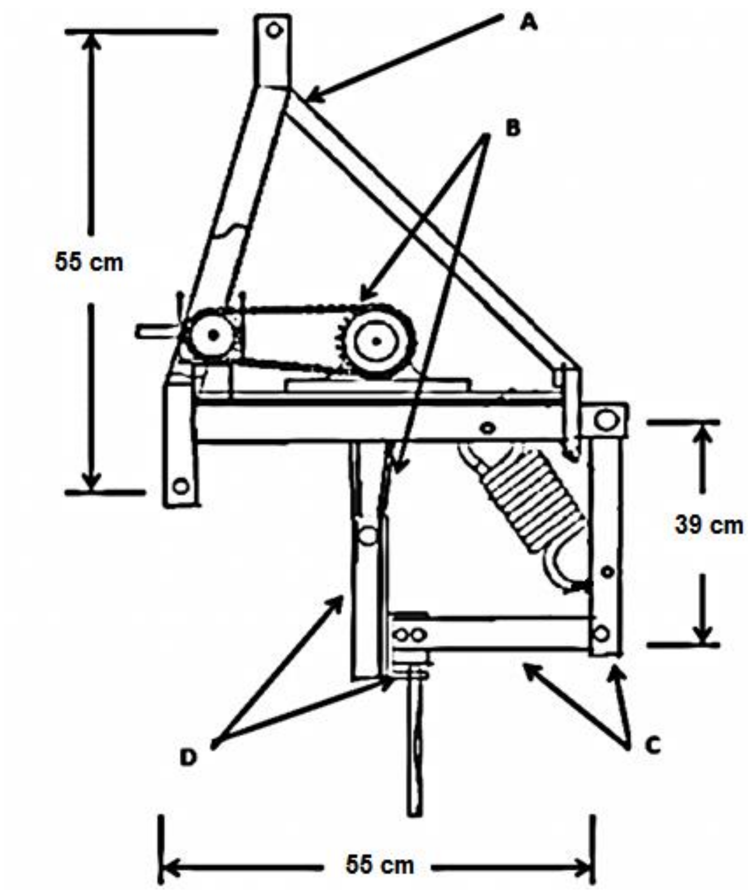


Fig.1.Side view of aeration machine.

The designing of turfgrass aerator machine depended on the results gathered from penetrating force and calculation for items of turfgrass aerator machine then manufacture the machine with bevel gear system, chain and sprocket, crank shaft, connection rod, bearing, tine holder, flexible linkage and core tine.

1- Chain and sprocket:

The chain transmits power between two rotating shafts by meshing with toothed sprockets was Calculated sprocket Diameter was by using the following formula according to **(Shippen, 1980):**

$$\frac{N_2}{N_1} = \frac{R_1}{R_2} \qquad (1)$$

N_1 = Rotating velocity of driving sprocket, r.p.m.

N_2 = Rotating velocity of driven sprocket, r.p.m.

R1= radius of driving sprocket, cm.

R2=radius of driven sprocket, cm.

The chain length, in pitches, was calculated by using the following formula according to **(Chaild, 2004):**

$$L = \frac{N_1 + N_2}{2} + \frac{2C}{P} + \left(\frac{N_2 - N_1}{2\pi}\right)^2 \frac{P}{C} \qquad (2)$$

Where:

L = number of pitches, m.

N1 = number of teeth, in the driving sprocket

N2 = number of teeth in the driven sprocket

C= center distance, m.

P = chain pitch, m.

2- Crank shaft :

Crank shaft is one of the most important moving parts in first prototype aerator, which gives the reciprocating motion to tine holder.

3- Connection rod:

Connecting rod is used to transmit motion from crankshaft to core tine holder, its function is to transmit the movement of push and pull from the crankpin to the tine holder pin.

The pin diameter of connection rod with tine holder was calculated by following formula according to **(Khurmi and Gupta, 2005)**:

$$F_t = d_c * l_c * P_{bp} \qquad (3)$$

Where:

d_c = diameter of the pin of connection rod, mm,

l_c = length of the pin of connection rod, mm.

P_{bp} = Bearing pressure, 20 N/mm^2.

4- Bearing :

The term 'bearing' typically refers to contacting surfaces through which a load is transmitted. Bearings may roll or slide or do both simultaneously, the term 'sliding bearing' refers to bearings where two surfaces move relative to each other without the benefit of rolling contact.

5- Tine Holder:

The channel beam was used as the tine holder (fig.2), Beams are generally horizontal members which transfer loads horizontally along their length to the supports where the loads are usually resolved into vertical forces.

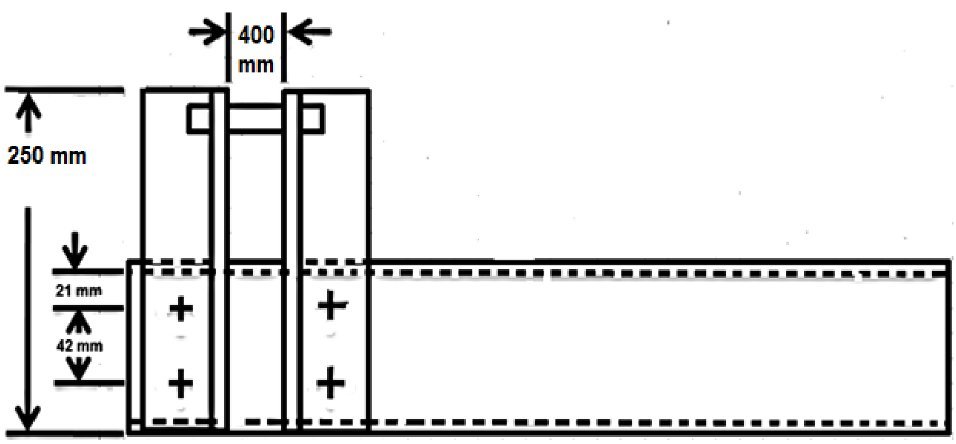


Fig. 2. Tine holder and linkage plats.

6- Core Tine:

Core tine (fig.3) was fabricated from steel 1042 with three diameters 1.27, 1.9 and 2.54 cm.

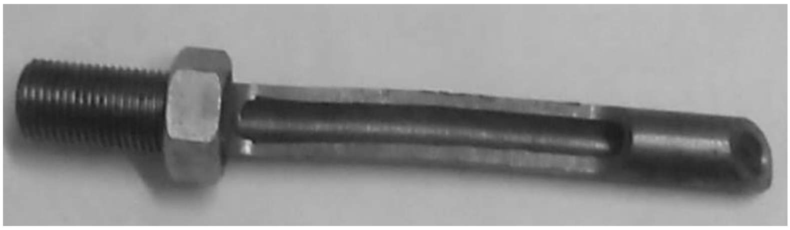


Fig.3. The core tine.

7- Flexible linkage:

The main aim of this linkage is to produce neat holes in the ground surface, when the tine engaged to soil with tractor motion it is allow for tine to scrape or damage the turf, this problem of engagement the ground is particularly acute in aeration having resilient restraining mechanisms that allow some shifting of tine when the tine is lifted out of the ground during operation.

a- Body of linkage:

The body of linkage (fig.4) Consists of the horizontal beam (A) connected to frame of machine with two bolts and connected to vertical beam (B) with one point by axle to allow limited motion with extension helical spring (C) with two fixed point axle in body of device, and connected plate between vertical beam and tine holder with dimensions 36*5*1 cm and fixed with the tine holder beam by angle plate with dimensions 7*7*1 cm.

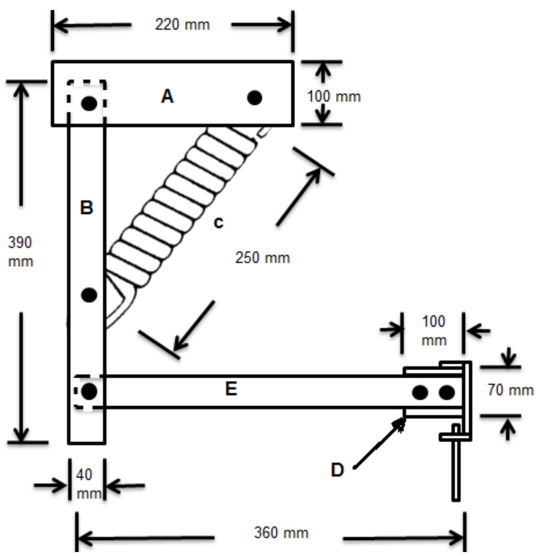


Fig.4. Content of flexible linkage.

3-1- Methods:

The field study was initiated 2014 on turfgrass growing on a loamy sand soil and maintained under greens conditions. The studies were located at faculty of agriculture, Cairo University. A 3x2x3 factorial arranged randomized complete block design with 4 replications. Treatments utilized were three tine diameter (T) (1.27, 1.9 and 2.54 cm) with at two depths (d) (5 and 8 cm) with three operation speed (s) (1.5, 2 and 2.7 cm).

a- Laboratory tests :

The soil physical properties such as soil moisture content, soil mechanical analysis and soil bulk density were measured before and after aeration operations as follows:

1- Soil moisture content:

The moisture content of the soil was determined using an electric oven adjusted to (105co) for 24 hours. Soil samples were taken at field through executing the different operation of turfgrass aeration (three replicates for each sample).and moisture was determine based on oven dry weight

The soil moisture was calculated by using the following formula:

$$S_m = \frac{W - W_1}{W} * 100\% \qquad (4)$$

Where:

W = mass of soil sample before dried, g.

W1 = mass of the same soil sample after dried, g.

2- Soil bulk density:

Soil samples were taken using cylindrical core sampler (100 cm^3 volume) Soil samples were taken at field through executing the different operation of turfgrass aeration (three replicates for each sample, to determine soil bulk density of soil samples which dried at ($105c^o$) for 24 hours.

The bulk density was calculated by using the following formula:

$$\rho_b = \frac{m_b}{v_b} \qquad (5)$$

Where:

ρ_b = Soil bulk density, gm. /cm^3.

mb = Dry weight of the soil in the container, gm.
vb = Volume container, cm^3.

3- Mechanical analysis:

The soil mechanical analysis was carried out using the international method with NH_4OH as dispersing agent piper.

4- Soil porosity:

Soil porosity (E) was calculated using the following formula:

$$E = \frac{\rho_s - \rho_b}{\rho_s} = 1 - \frac{\rho_b}{\rho_s} \qquad (6)$$

E= soil porosity, %.
ρ_s = real soil density, gm. /cm^3.

5- Void ratio:

Void ratio (e) was calculated using the following formula:

$$e = \frac{\rho_s - \rho_b}{\rho_b} = \frac{\rho_b}{\rho_{s-1}} \qquad (7)$$

b- Calculation of field capacity:

The theoretical field capacity was calculated by using the following formula:

$$TFC = \frac{W * s * 1000}{4200} \quad fed/h \qquad (8)$$

Where:
W= working width of machine, m.
S= average working forward speed, Km/h.
The actual field capacity (AFC) was calculated as follows:

$$AFC = \frac{1}{\text{Actual totl time in hours required per feddan}} \quad fed/h \qquad (9)$$

The field efficiency (η_f) wad calculated by using the following equation:

$$\eta_f = \frac{AFC}{TFC} * 100\% \qquad (10)$$

c- Fuel consumption:

The average fuel consumption in L/h for different treatment of turfgrass aeration were estimated by measuring the decrease in fuel level in the tractor fuel tank after executing each operation , taking into consideration the actual consumed time.

d- Energy consumption:

To estimate the engine power during turfgrass aeration process, the decrease in fuel level accurately measuring immediately after each treatment. The following formula was used to estimate the engine power, **(Embaby, 1985):**

$$EP = \left[f.c \left(\frac{1}{3600}\right) \rho_f * L.C.V * 427 * \eta_{th} * \eta_m * \frac{1}{75} \right] KW \qquad (11)$$

EP= Engine power, kW.
f. c = Fuel consumption, L/h.
ρ_f = Density of fuel, 0.85 kg/L.
L. C. V = Lower calorific value of fuel, 10.000 k.cal/kg.
427= thermo- mechanical equivalent. Kg.m/ k.cal.
η_{th} = Thermal efficiency of the engine (35 for diesel).
η_m = Mechanical efficiency of the engine (83 % for diesel).

Hence, the specific energy consumption can be calculated by following formula:

$$\text{Energy consumption} = \frac{\text{Engine power kW}}{\text{Field capacity fed/h}} \quad \frac{\text{kW. h}}{\text{fed}} \qquad (12)$$

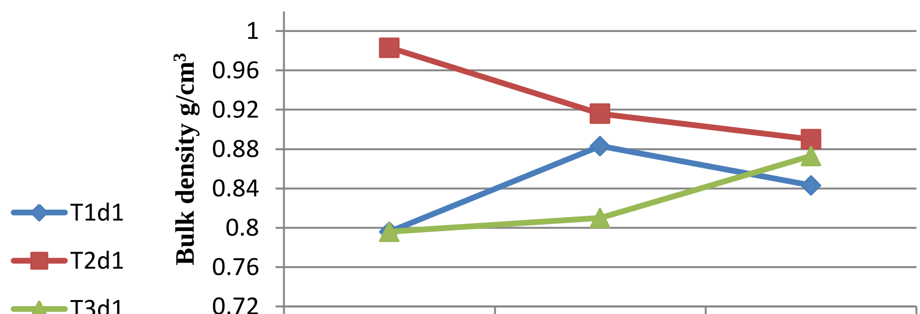
RESULTS AND DISCUSSION

a- The effect of different turfgrass aeration treatments on bulk density of the soil:

From data in (figs 5, 6) it's shown treatments of turfgrass aeration decreased the values of bulk density than the value at no aeration treatment (1.086 gm/cm3), the percentage of mean relative decrease of bulk density as a results of applying turfgrass aeration this may be due to the effect of depth of thatch layer, tine diameter and forward speed.

Considering the working speed and depth for each treatment, It is noticed that bulk density at 5cm depth (fig 5) is influenced by aeration speed up and down, treatments with first diameter (1.27) cm was lower value of the bulk density with the first speed 1.5 km/h (0.796 g/cm3). The second treatment with the second diameter (1.9 cm) was decreased bulk density with increasing forward speed 1.5, 2 and 2.7 km/h respectively and the third diameter (2.54 cm) was increasing bulk density with increasing forward speed.

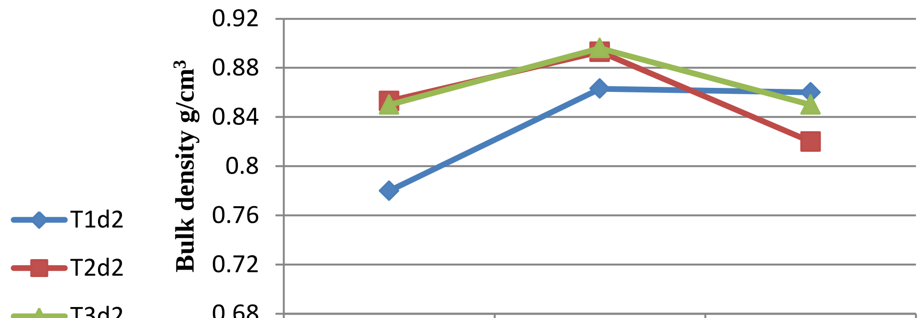
It is noticed that bulk density at 8cm depth (fig. 6) was influenced by aeration speed up and down, where the treatments with first diameter (1.27 cm) was increasing soil bulk density with the second speed 2 km/h while decreasing with the first 1.5 km/h and third speed 2.7 km/h and the lower value of the bulk density was with the first speed 1.5 km/h (0.780 g/cm3), Similarly the second treatment with the second diameter (1.9 cm) and the third diameter (2.54 cm).



	1.5	2	2.7
T1d1	0.796	0.883	0.843
T2d1	0.983	0.916	0.89
T3d1	0.796	0.81	0.873

Forward speed km/h

Fig 5. Mean bulk density of the soil for different turfgrass aeration treatments at 5 cm depth.



	1.5	2	2.7
T1d2	0.78	0.863	0.86
T2d2	0.853	0.893	0.82
T3d2	0.85	0.896	0.85

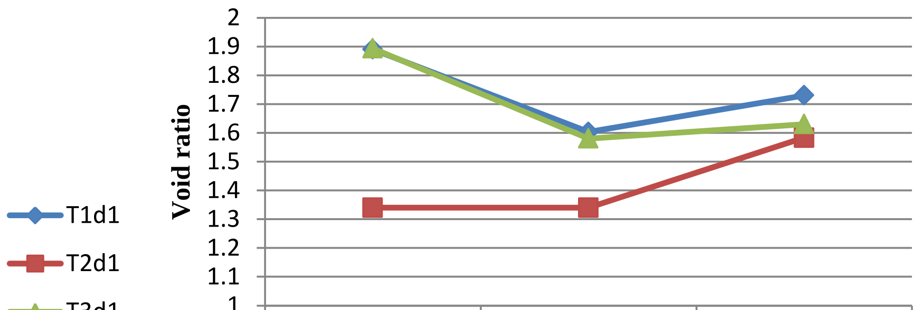
Fig 6. Mean bulk density of the soil for different turfgrass aeration treatments at 8 cm depth.

According to statistical analysis the effective treatment was 0.780 g/cm3 with first diameter 1.27cm at second depth 8cm with first speed 1.5 km/h. the effective speed for the first diameter (1.27 cm) and third diameter (2.54 cm) was 1.5 km/h and for the second diameter was 2.7 km/h. The effective depth was 8cm for first diameter (1.27 cm) and second diameter (1.9 cm) and the effective depth was 5cm for third diameter (2.54 cm) and the effective diameter for the second depth was 1.27 cm.

b- The effect of different turfgrass aeration treatments on Void ratio:

From (fig. 7, 8). It is noticed the change in void ratio a result of turfgrass aeration with 5 m depth is equal to 1.890, 1.603 and 1.730 for first diameter (1.27 cm) with three forward speed 1.5, 2 and 2.7 km / h. respectively, the value of void ratio with the second diameter (1.9 cm) was 1.340 , 1.510 and 1.583 with forward speed 1.5, 2 and 2.7 km/h. respectively and third diameter (2.54 cm) has decreasing void ratio 1.893, 1.583 and 1.630 with forward speed 1.5, 2 and 2.7 km/h respectively.

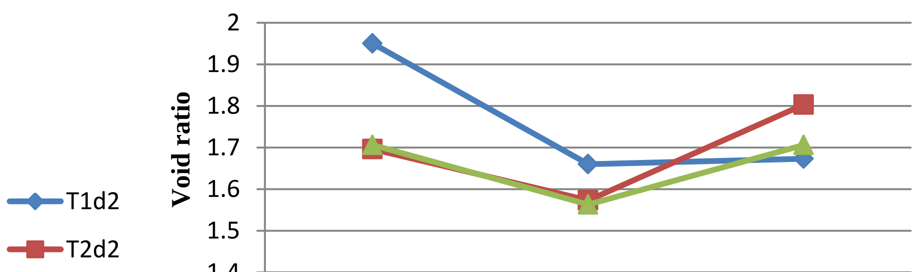
It is clear that (Fig.8) the change in void ratio as a result of turfgrass aeration at 8 cm depth is equal to 1.950, 1.660 and 1.673 for first diameter (1.27 cm) with three forward speed 1.5, 2 and 2.7 km / h respectively, the second diameter (1.9 cm) was 1.696, 1.573 and 1.803 with forward speed 1.5, 2 and 2.7 km/h respectively and third diameter (2.54 cm) was 1.706, 1.563 and 1.706 with forward speed 1.5, 2 and 2.7 km/h respectively.



	1.5	2	2.7
T1d1	1.89	1.603	1.73
T2d1	1.34	1.34	1.583
T3d1	1.893	1.58	1.63

Forward speed km/h

Fig 7. Mean void ratio of the soil for different turfgrass aeration treatments at 5 cm depth



	1.5	2	2.7
T1d2	1.95	1.66	1.673
T2d2	1.696	1.573	1.803
T3d2	1.706	1.563	1.706

Forward speed km/h.

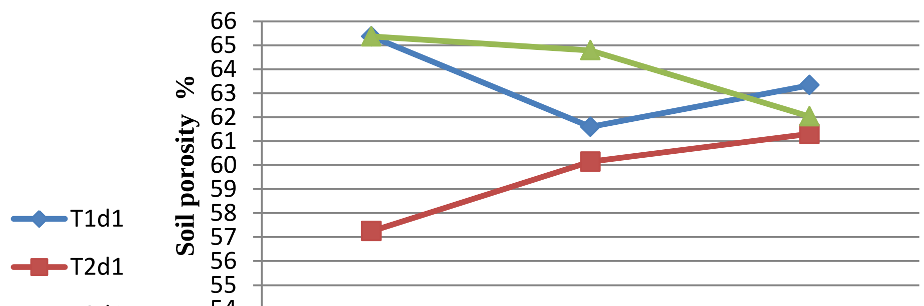
Fig 8. Mean void ratio of the soil for different turfgrass aeration treatments at 8 cm depth.

c- The effect of different turfgrass aeration treatments on soil porosity:

Soil porosity is a function of bulk density and it change with change of bulk densities, the higher bulk densities value will meet the lower value of the soil porosity.

The change in soil porosity at 5 cm (fig.9) was equal to 65.363, 61.593 and 63.333% for first diameter (1.27 cm) with forward speed 1.5, 2 and 2.7 km/h respectively, the second diameter (1.9 cm) had change in soil porosity 57.247, 60.147 and 61.303% with forward speed 1.5, 2 and 2.7 km/h respectively and the third diameter (2.54 cm) had change in soil porosity 65.363, 64.783 and 62.027% with forward speed 1.5, 2 and 2.7 km/h respectively .

It is clear that the change in total porosity as a result of turfgrass aeration at depth 8 cm (fig.10) was equal to 66.090, 62.4630 and 62.610% for first diameter (1.27 cm) with forward speed 1.5 , 2 and 2.7 km/h respectively , the second diameter (1.9 cm) has change in soil porosity 62.897, 61.157 and 64.347% with forward speed 1.5,2and 2.7 km/h respectively and the third diameter (2.54 cm) has change in soil porosity 63.043 , 61.010 and 63.043% with forward speed 1.5 , 2 and 2.7 km/h respectively.



	1.5	2	2.7
T1d1	65.363	61.593	63.333
T2d1	57.247	60.147	61.303
T3d1	65.363	64.783	62.027

Forward speed km/h

Fig 9. Mean soil porosity of the soil for different turfgrass aeration treatments at 5 cm depth.

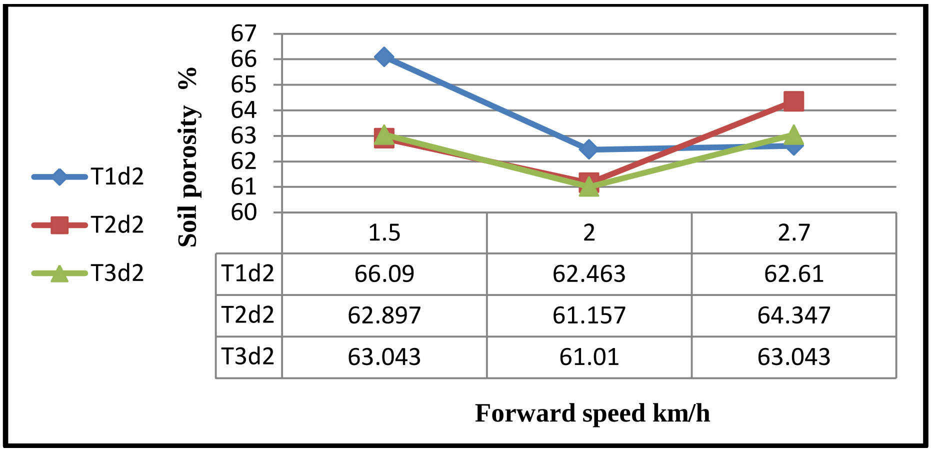


Fig 10. Mean soil porosity of the soil for turfgrass aeration treatments at 8 cm depth

d- The performance of different treatments for aeration turfgrass:

1- Field capacity of turfgrass aeration treatment :

From the data presented in (fig.11) it is noticed that: the field capacity at first depth 5 cm and with the first forward speed 1.5 km / h. was equal 0.377, 0.373 and 0.375 fed / h with the first (1.27 cm), second (1.9 cm) and third (2.54 cm) diameter respectively, the value of field capacity with the second forward speed 2 km / h was 0.503, 0.497 and 0.497 fed./h. for the first (1.27 cm), second (1.9 cm) and third (2.54 cm) diameter respectively and the third forward speed 2.7 km/h. has actual field capacity equal 0.683 , 0.670 and 0.687 fed/h for the first (1.27 cm) , second (1.9 cm) and third (2.54 cm) diameter respectively.

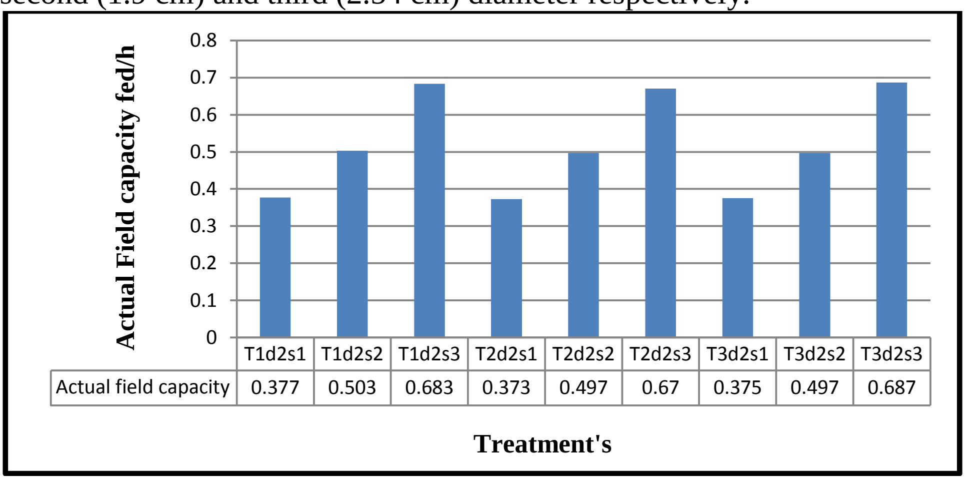
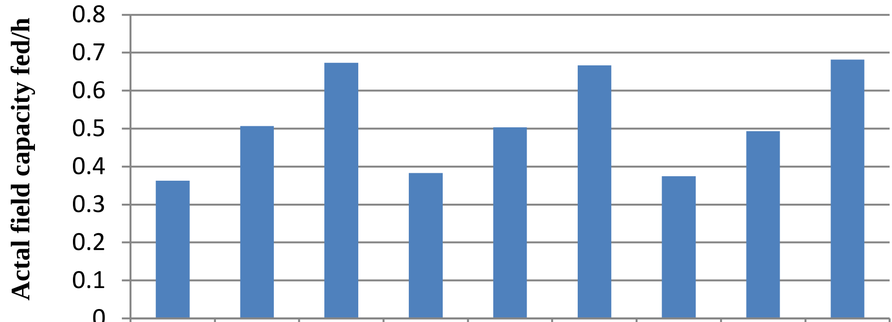


Fig 11. Mean field capacity of different treatments for aeration turfgrass at 5 cm depth.



	T1d1s1	T1d1s2	T1d1s3	T2d1s1	T2d1s2	T2d1s3	T3d1s1	T3d1s2	T3d1s3
Actual field capacity	0.363	0.507	0.673	0.383	0.503	0.667	0.375	0.493	0.682

Fig 12. Mean field capacity of different treatments for aeration turfgrass at 8 cm depth.

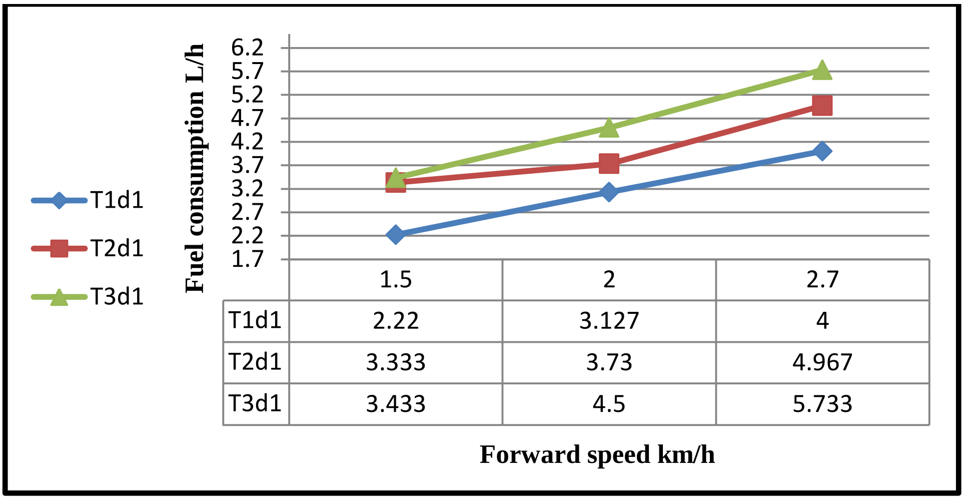
From the data presented in (fig.12) it is clear that: the field capacity at depth 8 cm and with the first forward speed 1.5 km/h was equal 0.363, 0.383 and 0.375 fed/h with the first (1.27 cm), second (1.9 cm) and third (2.54 cm) diameter respectively , the value of field capacity with the second forward speed 2 km/h was 0.507, 0.503 and 0.493 fed/h for the first (1.27 cm) , second (1.9 cm) and third (2.54 cm) diameter respectively and the third forward speed 2.7 km/h had actual field capacity equal 0.673 , 0.667 and 0.682 fed/h for the first (1.27 cm) , second (1.9 cm) and third (2.54 cm) diameter respectively.

2- The effect of turfgrass aeration treatments on fuel consumption :

The fuel consumption was measured after executing all treatments of turfgrass aeration from the results shown in (fig. 13, 14):

It is noticed that the fuel consumption was increased with increasing diameter of tine, depth and forward speed and the higher treatment in consumed fuel was 5.78 L/h with the third diameter (2.54 cm) at 8 cm depth and 2.7 km/h forward speed.

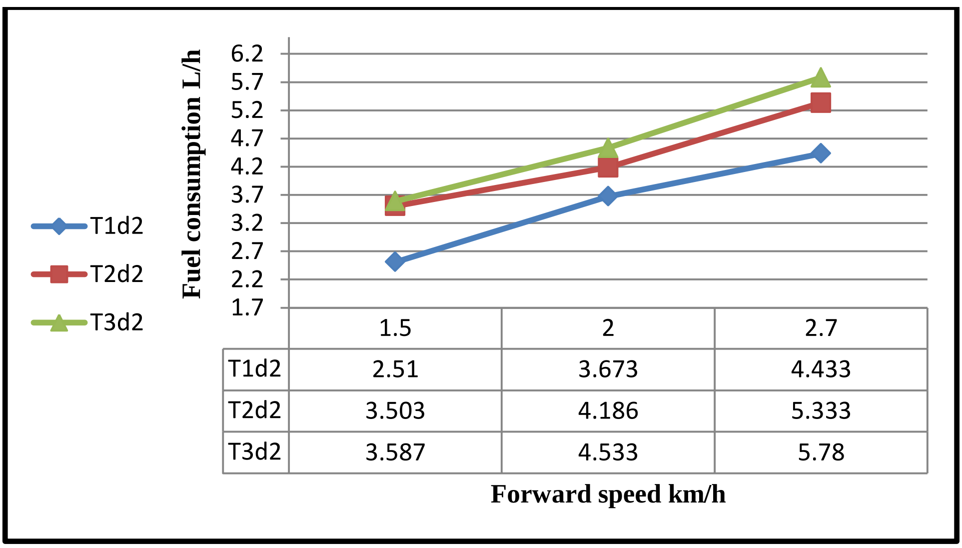
From (fig. 13) it is noticed that the first tine diameter (1.27 cm) had the lowest fuel consumption at 5 cm depth and for all treatments.



	1.5	2	2.7
T1d1	2.22	3.127	4
T2d1	3.333	3.73	4.967
T3d1	3.433	4.5	5.733

Fig 13. Mean fuel consumption of different treatments for aeration turfgrass at 5 cm depth.

From (fig.14) it is noticed that the first tine diameter (1.27 cm) had the lower fuel consumption at 8 cm depth and the fuel consumption for second tine diameter (1.9cm) is medium, while the third diameter (2.54cm) had the higher value of fuel consumption 5.78 L/h.



	1.5	2	2.7
T1d2	2.51	3.673	4.433
T2d2	3.503	4.186	5.333
T3d2	3.587	4.533	5.78

Fig 14. Mean fuel consumption of different treatments for aeration turfgrass at 8 cm depth.

3- The effect of turfgrass aeration treatments on energy consumption:

The energy consumption was calculated for all treatments of aeration turfgrass and shown in (fig. 15, 16):

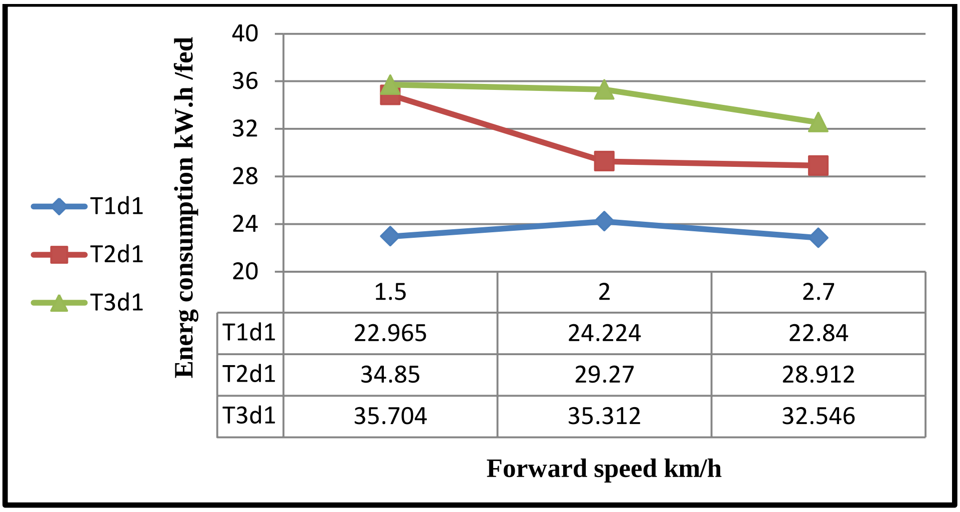


Fig 15. Mean energy consumption for different turfgrass aeration treatments at 5 cm depth.

from (fig. 15) shown the behavior of energy consumption for different treatments at 5cm depth and it is noticed the higher value was 35.704 kW.h/fed with the third diameter (2.54 cm) with first speed 1.5 km /h. and the lowest value was 22.84 kW.h/fed for the first tine diameter (1.27 cm) with third forward seed 2.7 km/h.

From (fig.16) The energy consumption with the first diameter (1.27 cm) had the lower value at 8 cm depth and the value of energy consumption was 26.967, 28.254 and 25.689 kW.h/fed with three forward speed 1.5, 2 and 2.7 km /h. this trend for actual field capacity and it is clear that the energy consumed value for the second tine diameter (1.9 cm) and third tine diameter (2.54 cm) decreased with increasing the forward speed. The third tine diameter had the higher value for energy consumption 37.305, 35.860 and 33.053 kW.h/fed with forward speed 1.5, 2 and 2.7 km/h.

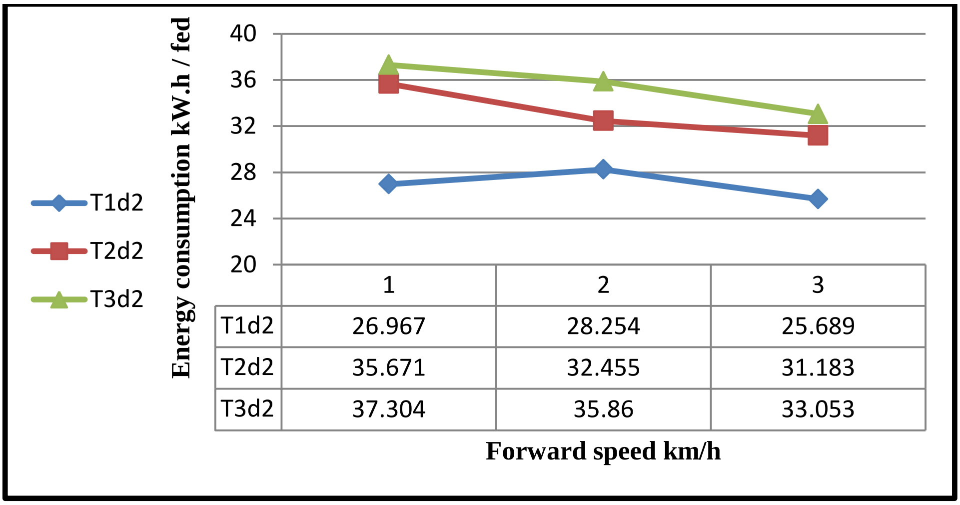


Fig 16. Mean energy consumption for different treatments for aeration turfgrass at 8 cm depth.

CONCLUSION

The following conclusions were made from the study:

- Bulk density decreased for all treatments, while the effective treatment was 0.780 g/cm^3 at with 8 cm depth, tine diameter 1.27 cm and forward speed 1.5 km/h compared to control value (1.086 g/cm^3).
- The void ratio increased for all treatments, while the high increasing value was 1.950 at 8 cm depth, tine diameter 1.27 cm and forward speed 1.5 km/h.
- The soil porosity increased for all treatments, and the effective treatment from variance analysis was $T_1d_2s_1$ at 8 cm depth, tine diameter 1.27 cm and forward speed 1.5 km/h. and it was value 66.09 %.
- The highest value of field capacity was 0.687 fed/h with third diameter 2.54 cm at 5 cm depth with 2.7 km/h.
- It is noticed that the fuel consumption was increased with increasing diameter of tine, depth and forward speed and the higher treatment in consumed fuel was 5.78 L/h with the third diameter 2.54 cm at 8 cm depth and 2.7 km/h.
- It was found that $T_1d_1s_3$tine diameter 1.27 cm at depth 8 cm and forward speed 2.7 km /h was the lowest energy consumption for turfgrass aeration (22.840 kW.h/fed.)

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الملخص العربى

تطوير و تقييم آلة لتهوية المسطح الأخضر

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تعتبر عملية تضاغط التربة للمسطح الأخضر من أهم العوامل المؤثرة علي جودة المسطح الاخضر لذلك كان من الضروري إجراء عملية التهوية للمسطح الأخضر, وتعرف عملية تهوية المسطح الأخضر بالأسلوب الميكانيكي المستخدم للتقليل من تضاغط تربة المسطح الأخضر . وتتم عملية تهوية المسطح الأخضر بطرق عديدة منها أستخدام الأسنان الصلبة و الأسنان المفرغة التي تقوم بنزع عمود من التربة بنفس القطر الداخلي للأسنان ثم يتم إجراء عملية التسفيف بعد إجراء عملية التهوية و ذلك لملئ الفراغات بمخلوط الرمل و الكمبوست لتحسين الخواص الفيزيائية للتربة و زيادة جودة المسطح الأخضر لذلك كان الهدف الرئيسي للبحث هو تطوير وتقييم و تصنيع آلة لتهوية المسطح الأخضر.

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ولتحقيق ذلك الهدف تم تطوير وتصنيع آلة تتكون من الاطار و نظام الشبك و مجموعة نقل الحركة من عمود الأدارة الخلفي الي عمود الكرنك و تتكون منظومة نقل الحركة من الوصلة المرنة و مجموعة فرقية و ترسين و يتم نقل الحركة بينهما عن طريق جنزير,ويتم دخول الاسنان في التربة راسيا عن طريق حركة ترددية , و هذه الحركة تنقل إلي ماسك الأسنان و الأسنان و الجزء الاخير هو الو صلة المرنة التي تم تصميمها للسماح للحفاظ علي قطر و شكل الثقوب في التربة أثناء حركة الجرار مع ظروف التشغيل المختلفة.

تم اختبار الآلة بأستخدام ثلاث أقطار للأسنان (١,٢٧-١,٩ – ٢,٥٤ سم) و عمقين لعملية التهوية (٥ سم - ٨ سم) و ثلاث سرعات أمامية للجرار (١,٥ – ٢ – ٢,٧ كم / ساعة) وتم تقيم تأثير عملية التهوية علي الكثافة الظاهرية للتربة , نسبة الفراغات , و مسامية التربة و الطاقة المستهلكة لأجراء عملية التهوية .

و كانت أهم النتائج المتحصل عليها كما يلي:

- أعلي قيم لانخفاض الكثافة الظاهرية مقارنة بالكنترول (١,٠٨ جرام / سم^{٣}) تحققت مع القطر الأول (١,٢٧ سم) و العمق الثاني (٨ سم) عند السرعة الأولي (١,٥كم /ساعة) وكانت الكثافة عند هذه المعاملة ٠,٧٨٠ جرام / سم^{٣} .
- أرتفعت قيمة نسبة الفراغات لجميع المعاملات و كانت أعلي قيمة لزيادة نسبة الفرغات البينية ١,٩٥٠ وذلك عند أستخدام القطر الأول (١,٢٧ سم) و العمق الثاني (٨ سم) عند السرعة الأولي (١,٥كم / ساعة).
- أرتفعت أيضا قيمة المسامية لجميع المعاملات و كانت أعلي قيمة للزيادة هي ٦٦,٠٩ % وذلك عند أستخدام القطر الأول (١,٢٧ سم) و العمق الثاني (٨ سم) عند السرعة الأولي (١,٥كم / ساعة).
- كانت أعلي قيمة للسعة الحقلية للآلة هي 0.687 عند أستخدام القطر الثالث (٢,٥٤ سم) و العمق الأول (٥سم) و السرعة الثالثة (٢,٧ كم / ساعة).
- أظهرت النتائج زيادة أستهلاك الوقود مع زيادة السرعة الأمامية للجرار و عمق التهوية وكانت أعلي قيمة لأستهلاك الوقود هي ٥,٧٨ لتر/ساعة عند أستخدام القطر الثالث (٢,٥٤ سم) و العمق الثاني (٨سم) و السرعة الثالثة (٢,٧ كم / ساعة).
- اظهرت النتائج أن أقل المعاملات أستهلاكا للطاقة ٢٢,٨١ كيلووات ساعة / فدان وذلك مع القطر الأول (١,٢٧ سم) و العمق الأول (٥ سم) عند السرعة الثالثة (٢,٧ كم / ساعة).

ومن خلال النتائج تم التوصل إلي:

- يوصي البحث بأستخدام الآلة المطورة لتهوية المسطح الأخضر بأستخدام مؤشرات تشغيلية عند القطر الأول (١,٢٧ سم) و العمق الثاني (٨سم) و السرعة الأولي (١,٥ كم/ساعة) لتحقيقها أعلي قيمة لأنخفاض الكثافة الظاهرية و أعلي قيمة لنسبة التهوية و المسامية.