USING DIFFERENT TYPES OF SUBSOILER SHARES TO IMPROVE THE PRODUCTIVITY OF COMPACTED SOILS

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ABSTRACT

Soil compaction is an environmental problem and has been recognized as the main form of soil degradation in some Mediterranean areas. Soil compaction may increase soil strength and compacted soil layers can affect root growth and crop productivity. The aim of the present work was to investigate the effect of using different types of sub-soilers shanks and shares on physical soil properties, seed germination and crop productivity of faba bean (vicia faba). The experiment was carried out at El- Hamam district area- Matrouh in sandy loam soil. The soil was characterizes by hard pan compaction down to 40 cm. Parameters such as changes in soil penetration resistance, bulk density, hydraulic conductivity and soil moisture content were measured. The results revealed that the highest increase of soil penetration resistance and lowest hydraulic conductivity due to the soil compaction occurred in non treated soil with sub-soilers. The seed germination and yield of faba bean increased with decreasing soil penetration resistance. A positive action was detected between using fit equipped mole behind different shanks and shares of the sub-soilers used on both soil penetration resistance, and hydraulic conductivity. The ability to eliminate soil compaction could be useful on agricultural field in the South district of El Hamam canal area by using sub-soiler with mole fit equipped behind shank as well as decreased the effect of the hard pans and improve soil properties such as soil penetration resistance and hydraulic conductivity. The deep tillage gained that the lowest energy requirements were recorded either without using the fit mole equipped or with using single point share with straight shank. However using the curved shank - winged share with mole achieved the highest seed germination values and crop yield as compared with other treatments.

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INTRODUCTION

In the South district of El Hamam canal, soil compaction commonly occurs in some agricultural fields. Compacted layers commonly referred to as "hard pans" which impede root growth causing adverse effects on crop yields. In addition, plant roots may reinforce field soils. However, the vegetation component will not be further considered here (**Yavuzcan et al., 2002**). Moreover, agricultural soils are subjected to loosening processes by tillage and load bearing processes by agricultural machinery traffic during the seasonal production cycle. The farmer's aim during tillage operations is to ameliorate the compacted soil by plowing to the full depth of the arable layer (20–40 cm). This practice has resulted in a special soil compaction problem (**Jones et al., 2003**). It is recognized that many arable soils have a severely compacted layer below the plough depth created by the standard practice of plowing with sub-soilers. Farmers try to remove these layers by periodic deep loosening. Tillage improves the poor macro-soil structure but seldom improves the micro-soil structure. Soil water content is the most important factor influencing soil compaction processes because cone resistance is highly dependent on soil water content at the time of measurements **(Abu-Hamdeh, 2003)**. Compacted soil layers which are highly resistant to penetration are one of the most common problems that affect root systems **(Rosolem *et al.*, 2002)**, decreasing length and rooting depth, and concentrating roots in the top layer. Soil compaction caused a rapid decrease in spring barley root weight on sandy loam soils **(Trükmann *et al.*, 2008)**. **(Reintam *et al.*, 2006)** also pointed out that there was only a slight decrease in root and shoot mass on yellow lupine growing on the most compacted area, as compared with control in sandy loam soil. **(Gan-Mor and Clark 2001)** indicated that controlled traffic can lessen and in some cases eliminate the need for deep tillage operations. **(Raper and Bergtold 2007)** reported a 6% fuel savings and 9% draft force reduction could be achieved with controlled traffic subsoiling. They also recommended that, subsoiling when soil has adequate moisture so that surface soil disruption and energy requirement can be minimized. They reported a 19% fuel savings and a 28% draft reduction by avoiding tillage in dry conditions.

(Corey 2008) clarified that deep tillage, sometimes called subsoiling, provides a method to alleviate poor physical properties caused by soil compaction. He added that, the presence of hardpans and other restrictive layers requires deep tillage to break up these layers and permit roots to reach the B-horizon early in the growing season to access valuable nutrients and moisture. Knowing where the hardpan is located throughout the field and performing tillage site-specifically can decrease energy requirements and optimize crop yields **(Raper et al., 2005)**. However, portions of the field exceeded the cone index threshold of 2.0 MPa. Fuel consumption estimations yielded a 50% reduction in fuel usage could be achieved with subsoiling the portions of field exceeding the 2.0 MPa cone index value compared to uniform deep subsoiling the entire field. **(Gary 2008)** reported that, winged shares cost more than conventional one. Typical winged shares were 6 to 16 inches wide with 1 to 4 inches of lift, and a 40- to 60-degree.sweep angle. Winged tips should be designed to fracture the soil uniformly without lifting or furrowing the surface excessively. About 25 to 55 % more horsepower was needed to pull shanks with winged tips, but often the shanks can be farther apart. considering the volume of soil loosened per horsepower, shanks with winged shares may be more efficient than shanks with conventional one. Parabolic shanks require the least amount of horsepower to pull. In some applications, parabolic shanks may lift too many stumps and rocks, disturb surface materials. Straight or "L" shaped shanks have characteristics that fall somewhere between those of the parabolic and swept shanks. The same trend was found **(Raper and Sharma 2004)** tested two different shanks, a straight shank and a "minimum tillage" shank, they were tested in sandy loam soil. The "minimum tillage" shank required more energy and disrupted less surface soil than the straight shank. **(Karoonboonyanan *et al* 2007)** investigated the performance of a single-shank subsoiler on sandy loam for cultivating sugarcane. the vibrating mode of the single-shank subsoiler significantly reduced the draft force but increased the total power requirement. The soil failure areas in vibrating and non-vibrating modes were not statistically different. The average vertical force during the vibrating mode increased due to lifting up of soil clods during the forward movement of the shank and the tine. The difference in the draft force per unit soil failure area was found insignificant for the vibrating mode compared to that for the non-vibrating mode. **(Kasisira and du Plessis 2006)** experimented both horizontal and vertical forces acting on two sequenced subsoilers in a fine sandy clay loam soil till depth of 60 cm, they have straight shanks with 80 mm blades, but without wings. The results showed that the cross-sectional area failed per unit draft force linearly increased with spacing between the subsoilers. The efficiency of the subsoilers in this configuration was maximized when the longitudinal spacing was such that the soil failed by the front subsoiler was allowed to stabilize before the rear subsoiler reached it. The maximum cross-sectional area failed per unit draft force was recorded when the depth of the front subsoiler was equal to about 80% of the operating depth of the rear subsoiler.

Therefore, the present research aimed to:
(1) Evaluate and compare the changes in some soil properties during faba bean cultivation season on a sandy loam soil by using different types of sub-soilers.
(2) Compare the impacts of sub-soiling tillage parameters due to variable factors namely; four different sub-soiler shares and two different types of mole fitted.
(3) Find out the best sub-soiler type for maximizing the productivity of faba bean production in the compacted soils.

MATERIALS AND METHODS

Field experiments were carried out in South of El Hamam district area, Marsa Matrouh; Matrouh Governorate, Egypt. The experimental site was located at 30° 48' 20" N and 29° 24' ,12" E. The soil of the experimental farm was textured as sandy loam (61.82 % sand, 27.08 % silt and 11.10 % clay). Particle size distribution of soil was determined according to **(Kulte 1986)**. In such soil four different subsoiler practices and two mole fitted equipped were examined under operation depth of 60 cm to identify their effect on soil penetration resistance, soil bulj density, soil hydraulic conductivity, soil moisture content and seeds germination as well as yield of faba bean (*vicia faba*) which was planted through the 1st week of November 2014.

Field operations:

Two wheel drive FIAT Agri. Tractor, model 100-90 DT, with 100 hp (73.6 kW) and Diesel fuel type was used for field operations including tillage and sub-soiling. The sub-soiler used was locally manufactured with one shank lengthen of 92 cm.

The experimental unit area was 500 m^2 (100 x 5 m) and the total projected area was 4500 m^2. The experiments consisted of 4 sub-soiling shanks combined with two mole with and without fit equipped moles as mentioned below comparing with a treatment without sub-soiling as illustrated in table (1):

A- Control treatment without sub-soiling

B- Straight shank- single point share

C -Curved shank- single point share

D -Straight shank- winged share

E -Curved shank- winged share

F- Straight shank- single point share with mole

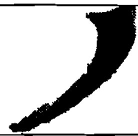
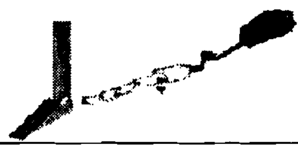
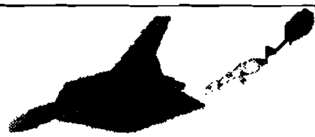
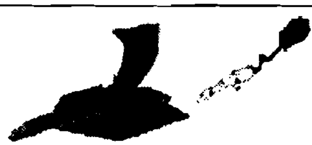
G- Curved shank- single point share with mole

H- Straight shank- winged share with mole

I- Curved shank- winged share with mole

Field experiments were conducted and treatments were arranged in a complete randomized plot design with three replicates. The field was under conventional tillage of chiseling twice as a control treatment through the growing season of faba bean. All field operations were done on forward speed of 3.2 km/h. After applying the previous treatments, two chiseling passes were performed to prepare the soil for faba bean cultivation.

Table (1): Applied treatments of the field experiments.

Treatments	Shank type	Type of sub-soiling shank	Description of sub-soiling shank
A (Control)	without	---	without
B	Without mole fit equipped		straight shank-single point share
C			curved shank-single point share
D			straight shank-winged share
E			curved shank-winged share
F	With mole fit equipped		straight shank-single point share + mole
G			curved shank-single point share + mole
H			straight shank-winged share + mole
I			curved shank-winged share + mole

Field measurements:

Soil penetration resistance and soil moisture content were measured periodically on each plot before and after each sub-soiling operation. Measurement of controlled traffic rows took place at the centre of wheel tracks. All measurements related to these properties were performed with regard to row position rather than randomly within each plot in order to reduce sampling error. After harvesting the samplings were performed at each differently sub-soiled plot. The seed germination was measured in the beginning of the season and productivity was measured at the end of the growing season.

The soil penetration resistance (kPa).

Soil penetration resistance was measured with a hand operated recording type electronic penetrometer (penetrologger) having a 308 steel cone of 1 cm^2 base area, and values were recorded at each 0.05 m interval down to 0.6 m (Model P1.52, Eijkelkamp Agrisearch Equipment, The Netherlands). Three insertions were made in each plot according to **(Kulte 1986).**

The soil bulk density (gm/cm^3).

Soil bulk density, g/cm^3, at soil depths of (0–30cm) and (30-60 cm) were determined at 3 days after the planting date (1^{st}) and before harvesting (2^{nd}) for each treatment using core method, **(Klute 1986)**

The hydraulic conductivity (cm/h).

The hydraulic conductivity, of the sub-soiling area was measured at surface soil depth (0–60cm) after 3 days of planting as a (1^{st}) record and before harvesting as (2^{nd}) record date for each treatment, using the columns method according to **(Kulte 1986).**

The soil moisture content, (%)

The soil moisture content, % of the projected sub-soiling area was measured at soil depths of (0–30cm) and (30-60 cm), then determined after 3 days of planting as a (1^{st}) record and before harvesting (2^{nd}) record, using the oven dry method. **(Kulte 1986).**

Seed germination and yield.

Seed germination, and yield of faba bean after 3 months of planting for each treatment were determined. Least significant difference (LSD) test was used for the comparison among treatments means, **(Steel and Torrie 1980).**

Effective field capacity:

Effective field capacity represented the actual average rate of field coverage and can be determined as described by (**Hanna *et al.* 1985**).

Fca = 60/ (Tu + Ti) fed/h.

Where: Fca = The actual field capacity of machine, fed/h

Tu = The utilized time per fed in minutes

Ti = The summation of the lost time/fed in minutes which was calculated from turning time, refuel, repair and adjusting.

Power required.

Estimation of the required power as well as the required energy requirements were calculated according to the formula of (**Hunt 1983**)::-

$$Power = \left[F.C\left(1/3600\right)PE.LCV.427.\xi_{thb}.\xi_{m}.1/75.1/36\right] \text{ (kW)}$$

where: F.C= Fuel consumption, (lit/h)

P.E= Fuel density (for solar 0.85 kg/m^3)

LCV= Calorific value of fuel (11000 k.cal/kg)

ξ_{thb}.= Thermal efficiency of engine (35% for diesel engine)

ξ_{m} = Mechanical efficiency of the tractor engine (85%)

therefore the energy can be determined as follows:

Energy requirements (kW. h/fed) = Required power (kW)/ Effective field capacity (fed/h).

RESULTS AND DISCUSSION

Soil penetration resistance and bulk density as affected by the experimental treatments.

Cone penetrometer readings were performed after sub-soiling as (1st) record and before harvesting as (2nd) record were shown in Table (1). There were no field operations between those operations. As seen from the table, the penetrometer data are inherently very variable, due to the shanks type, mole fit equipped and period readings. Thus, the 2nd readings were significantly higher than 1st readings at all depths and sub-soiling methods concerned. Another important note is that, the penetration resistance of non-mole fit equipped tracks in sub-soiling plots remarkably increased as compared with mole fit equipped treatments.

Table (2): Effect of sub-soilers shanks on soil penetration resistance and bulk density under different sub-soiling treatments of the projected area.

Treatments	Soil physical properties under studied plots							
	Soil penetration resistance (kPa)				Soil bulk density (gm/cm³)			
	0- 30 cm depth		30- 60 cm depth		0- 30 cm depth		30- 60 cm depth	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A	1820	2040	2040	2055	1.56	1.63	1.63	1.66
B	1155	1520	1755	2015	1.55	1.58	1.60	1.64
C	1150	1510	1750	1960	1.53	1.54	1.54	1.64
D	1135	1505	1745	1935	1.53	1.53	1.59	1.62
E	1120	1504	1740	1920	1.50	1.53	1.56	1.60
F	1120	1500	1720	1910	1.50	1.53	1.56	1.59
G	925	1500	1720	1840	1.43	1.50	1.52	1.55
H	900	1470	1700	1775	1.42	1.44	1.47	1.49
I	890	1380	1610	1770	1.42	1.43	1.44	1.48

1st: The physical properties determined after 3 days of sub-soiling.
2nd: The physical properties determined before harvesting.

From the shank type point of view readings, it can be clearly seen that, both curved and straight winged shanks showed considerable difference about both straight and curved sub-soilers shanks plots. Generally, there were more compaction for the single point shares as compared with winged shares, probably due to the relatively high soil disturbance and more soil loosening in the hard pans. The highest penetration resistances for sub-soiled treatments were obtained in treatment (B) of straight shank with single point share, however treatment (A) is the highest penetration resistances for all experimented plots as a control treatment. Apart from this, penetrometer readings before harvesting were higher than those of after sub-soiling. Obviously, there were no differences between the curved shanks and straight shanks, under experimented plots. However, in case of using fit equipped mole, sub-soiling plots exhibited clear changes. The impacts of shank, whatever straight or curved were not visible. In contrast, considerable differences can be seen in between both straight and curved winged shares. Impacts of mole fit equipped was also visible in these conditions both at single point shares and winged shares treatments.

The comparative effect of sub-soilers on the soil penetration resistance values of soil depths during growth season revealed that deeper soil had the highest soil penetration resistance values and could be arranged as follows, 2nd (30-60 cm) > 2nd (0-30 cm) > 1st (30-60 cm) > 1st (0-30 cm), this may be due to the soil stability for the 2nd (30-60 cm) depth as compared to the others.

Concerning the bulk density, results in Table (2) showed that soil bulk density values after 3 days of the planting date were lower than that obtained before harvesting under studied treatments. On the other hand, the cultivated soil depth at first and second records, were obviously lower than the control treatment. These lower values could be attributed to disturbing soil aggregates and decreasing of soil compaction, consequently decreased soil bulk density. The soil bulk density values for both two records under studied treatments ranged from 1.42 to 1.63 and 1.44 to 1.66 g/cm^3, for depths of (0-30) and (30-60) cm, respectively. The comparative effect of sub-soiling appeared that the straight shank- single point share had the highest soil bulk density values, while other values in this study were ranked as straight shank- single point share > curved shank- single point share > straight shank- winged share > curved shank- winged share. The comparative effect of the fit mole equipped on the soil bulk density appeared that straight shank- single point share + mole had the highest soil bulk density values and ranked as straight shank- single point share + mole > curved shank- single point share + mole > straight shank- winged share + mole > curved shank- winged share + mole. On the other hand, These higher values could be due to the reorientation of soil particles and increased soil compaction resulted from the wetting and drying cycles during growing season, consequently increased soil bulk density. Such results were in agreement with the finding of (**Raper *et al.*, 2005**).

Soil hydraulic conductivity and soil moisture content as affected by the experimental treatments.

Soil hydraulic conductivity was remarkably affected under different studied treatments as shown in Table (3). Sub-soiling treatments have an obvious effect on hydraulic conductivity at soil depth. Hydraulic conductivity in the control treatment plots were considerably lower than other treatments, confirming the measurements of the soil penetration resistance. Nevertheless, after sub-soiling, no remarkable evidence was achieved between straight and curved shanks treatments. Moreover the hydraulic conductivity of fit mole equipped plots were increased or even being higher for the non fit mole equipped plots. These increments were attributed to the improvement of the soil profile aeration which facilitate water movement through the soil profile. In this respect (**Lipiec and Hatano 2003**) found that, the hydraulic conductivity in any of the sub-soiling treatments was higher than the control treatment. Thus, sub-soiling induced considerable effects changes occurred through the growing season. However, differences within each reading were clear for both the 1st one after sub-soiling and the 2nd reading before harvesting.

Due to the deep loosening of the soil which resulted a higher air permeability except the control treatment. Under studied treatments, the highest value of hydraulic conductivity in the first record after planting by 3 days was 2.94 cm/h for the control treatment, while the lowest value of hydraulic conductivity was 1.59 cm/h for the curved winged share with fit mole equipped, while the respective values were 2.31 and 3.92 cm/h for the controlled treatments, and the curved winged share with fit mole equipped respectively before harvesting.

The comparative effect of sub-soiling on soil moisture content values elucidated that the straight shank- single point share had the highest soil moisture content values during growth season of two recorded time values. The soil moisture content values were ranked as: straight shank-single point share > curved shank- single point share > straight shank-winged share > curved shank- winged share. This trend might be attributed to that the winged shares decreased soil bulk density, thus the soil porosity increased.

Table (3): Effect of sub-soilers shanks on hydraulic conductivity and soil moisture content under different sub-soiling treatments of the projected area.

Treatments	Soil physical properties under studied plots							
	Hydraulic conductivity (cm/h)				Soil moisture content (%)			
	0- 30 cm depth		30- 60 cm depth		0-30 cm depth		30- 60 cm depth	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A	0.82	0.75	0.61	0.56	19.15	22.98	27.57	31.88
B	2.14	1.66	1.59	1.25	18.14	21.76	26.11	31.47
C	2.52	1.96	1.88	1.48	17.95	21.54	25.84	31.00
D	2.57	2.01	1.93	1.52	15.59	18.70	22.44	30.53
E	2.89	2.26	2.17	1.71	15.04	18.05	21.66	26.23
F	3.23	2.51	2.43	1.91	13.45	16.13	19.35	22.10
G	3.36	2.60	2.52	1.98	11.94	14.33	17.19	21.65
H	3.85	3.01	2.90	2.28	11.64	13.97	16.76	21.28
I	3.92	3.05	2.94	2.31	9.82	11.78	14.13	21.16

1st: The physical properties determined after 3 days of sub-soiling.

2nd: The physical properties determined before harvesting.

Also, this trend is similar to that obtained for hydraulic conductivity under the same treatments. The comparative effect of the mole fit equipped on the soil moisture content values revealed that the non using of the mole fit equipped keeps more water retention through the soil profile. Also, the obtained results indicated that soil moisture content values before harvesting were higher than that obtained at the first irrigation after 3 days under studied treatments. This higher value of soil moisture content could be due to the reorientation of soil particles resulting from the wetting and drying cycles during growing season.

Effect of sub-soilers shanks on field capacity and energy requirements:

Concerning the field capacity, Table (4) shows that the lowest value was observed for curved shank- winged share with mole as compared with the other different treatments. It was remarkable that, using fit mole equipped led to more time consumed as compared with non using the mole due to more soil- friction with soil pattern and increased surface area of the shanks, the blades and the mole. Also, the winged blades shares required more time than single point shares under the same conditions.

Energy consumed was calculated for all treatments and the obtained results were presented in Table(4). Higher energy consumption value was observed for curved shank- winged share with mole as compared with the other different treatments. Using the fit mole equipped led to increase energy consumption as compared with non using the mole.

Table (4): Effect of sub-soilers shanks on field capacity and energy consumed under different sub-soiling treatments of the projected area.

Treatments	Field Capacity (fed/h)	Energy consumed (kW.h/fed)
A	-	-
B	0.69	52.66
C	0.85	36.25
D	0.42	102.54
E	0.57	71.94
F	0.28	148.53
G	0.42	86.04
H	0.22	211.40
I	0.28	156.00

A- Control treatment without sub-soiling, B- Straight shank- single point share, C-Curved shank- single point share, D -Straight shank- winged share, E -Curved shank- winged share, F- Straight shank- single point share with mole, G- Curved shank- single point share with mole, H- Straight shank- winged share with mole, I- Curved shank- winged share with mole, This could be attributed to more soil-metal friction that exerted higher force with soil pattern, the horizontal component of the force exerted by surface area of the shanks, the blades and the mole. The winged blades shares required higher power values as compared to single point share under the same conditions. The obtained data revealed that the factor namely, shares (blade type) used had an effect on fuel consumed. The single point share penetrate partly the soil slice along through the full depth of the blade, while the winged shares penetrate widely the soil slice along horizontally with more soil resistance. These results were in agreement with the finding of **(Raper and Bergtold 2007)**.

The effect of sub-soilers shanks on seed germination percentage and yield.

The effect of sub-soilers shanks on seed germination values revealed that the curved shank- winged share with mole had the highest values as shown in table (5). The seed germination percentages of faba bean showed that the fit mole equipped treatments had the highest values as compared with non mole equipped. As the seed germination percentages were significantly increased, such percentages ranged between 83.3 to 87.4 %,for non fit mole equipped treatments and 87.4 to 90.5% for fit mole equipped treatments, respectively.

Table (5): The effect of sub-soilers shanks on seed germination percentage and yield.

Treatments	Seed Germination (%)	Yield (Mg/fed)
A	81.0	220
B	83.3	432
C	84.8	433
D	85.4	476
E	87.4	480
F	87.4	480
G	88.0	487
H	90.2	538
I	90.5	546
LSD 0.05	2.93	188

The yield of faba bean was given in table (5). Obviously the yield of faba bean was significantly increased by the experimented treatments. The highest faba bean yield (546 Mg/fed) was obtained by using fit mole equipped. Such values varied between 432 to 433 Mg/fed, 476 to 480 Mg/fed, 480 to 487 Mg/fed and 538 to 546 Mg/fed for single point shares without mole fit equipped, winged shares without mole fit equipped, single point shares with mole fit equipped and winged shares with mole fit equipped, respectively. By using the curved shank- winged share with mole. This factly affect on decreasing soil compactions and improving soil profile to be more suitable for root growth as compared to control treatment, consequently seedling emergence, vegetation growth and crop yield were relatively high. The lowest yield value was 220 Mg/fed that was found in the control treatment.

CONCLUSION

The results clearly demonstrate that for conditions of El- Hamam district area, where hard pans may cause compaction down to 20–40 cm depth on field conditions. The risk for compaction is apparently higher in ranged to low root spreading through the soil profile and low crop productivity. The soil penetration resistance seemed to be decreased and the impact on hydraulic conductivity increased and induced by sub-soiling. The compactive forces were positively decreased with encouraging seed emergencies and crop productivity due to the better structure and resistance conditions provided.

From the above mentioned results it can be concluded that.

1) Using sub-soiler with mole fit equipped was more effective for ameliorating the soil compaction, decreasing the effect of the hard pans and improving soil properties such as soil penetration resistance and hydraulic conductivity.

2) The deep tillage showed that the lowest energy requirements can be found without using the fit mole equipped and with using single point share with straight shank. But no differences in between all sub-soiling experiments for all implements applied.

3) Using the curved shank - winged share with mole achieved the highest seed germination values and crop yield as compared with other sub-soiling treatments.

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<u>الملخص العربي</u>

استخدام انماط مختلفة من اسلحة المحراث تحت التربة لتحسين انتاجية الاراضى المندمجة

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تعد مشكلة انضغاط التربة مشكلة بيئية تؤدى الى تدهور الاراضى وتشكل عائقا يمنع نمو وانتشار الجذور خلال طبقات التربة المختلفة مما يؤثر سلبا على نمو المحصول وانتاجيته. وتهدف هذة الدراسة الى استخدام عدة اشكال مختلفة من اسلحة المحراث تحت التربة لتحسين خواص التربة ولاسيما الانضغاط وتعظيم إنتاجية محصول الفول البلدى الى وحدة المساحة.

وقد تم اجراء هذة الدراسة جنوب زمام ترعة الحمام على تربة رملية لومية تتواجد بها ظاهرة انضغاط التربة على عمق فى حدود ٤٠ سم. وقد تم اخذ بعض القياسات مثل مقاومة التربة للاختراق والكثافة الظاهرية للتربة – والتوصيل الهيدروليكى والمحتوى الرطوبى للتربة كبيان لبعض خواص التربة الطبيعية. وقد ادى استخدام السلاح المجنح مع القصبة المائلة متبوعة بالطوربيد الى الحصول على افضل النتائج لتحسين خواص التربة الطبيعية مما انعكس بالايجاب على نسبة انبات البذور وبالتالى انتاجية محصول الفول تحت هذة المعاملة فى حين ادى استخدام هذا السلاح الى استهلاك نسبى للطاقة مقارنة بباقى المعاملات التجريبية. وقد ادى استخدام الطوربيد خلف الاسلحة بشكل عام الى تحسين الاداء مقارنة بالمعاملات التى لم تستخدم الطوربيد من حيث تحسين خواص التربة الا ان استخدام الطوربيد بشكل عام ادى الى زيادة فى استهلاك الطاقة. وقد ادى استخدام السلاح –لسان العصفور الى اقل استهلاك للطاقة بوجة عام .

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