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DESIGN AND MANUFACTURE SUBSOIL MANURE LAYING IMPLEMENT AND STUDYING ITS FIELD PERFORMANCE

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SUMMARY

A manure laying implement was designed to bury the manure under the soil surface. The main operations of the implement are digging the soil to make a shallow channel its depth is 30 cm to 60 cm, laying the manure in side the channel and bury the manure by retaining the dogged soil into the channel. The three operations are carried out simultaneously. The implement was designed to reduce the planting operations of the Tomato crop in the desert soil. The conventional operations of planting tomato crop in the desert soil is digging the soil manually by primitive tool to make a channel, the manure is laid in side the channel bottom and then buried. The purpose of burying the manure in the soil is to increase the soil ability in retention the water at the surface layers and to provide the tomato crop with nutrients.

The implement consists of a tine, two soil digging boards and two soil retaining boards. The tine consists of a shank and foot. The foot is provided with wings fixed on both sides of the foot. The implement is also provided with a tank of one tone capacity fixed on the implements frame. The manure is droped in side the channel mechanically.

After manufacturing the implement, it was tested in the field to evaluate its performance using different operating depths (20cm , 30cm, 40cm, 50cm, and 60cm). The evaluation was carried out using the implement draft force requirement, the cross-section width of the channel made by the implement, the specific resistance and the energy utilization efficiency of the implement.

The results showed that the increase in the operating depth increased the draft requirement of the implement considerably; increasing the operating depth from 20cm to 60cm increased the draft force from 12.63kN to 31.16kN (242%). The soil excavating boards required 4.35kN and 6.47kN at operating depths of 20cm and 60cm which consists of 35% and 21% from the total draft

depths of 20cm and 60cm which consists of 35% and 21% from the total draft force of the implement. While the soil retaining boards required draft force of 4.05kN and 6.47kN which consists of 32% to 21% from the total draft force for the same operating depths respectively. The total draft requirement of the implement and the draft force of the soil excavating and retaining boards for the other operating depths are within the draft force range of the operating depth of 20cm and 60cm. There is great improvement in the implement field performance when the operating depth was increased from 20 cm to 60 cm , the cross-section width of the channel which made by the implement's stem and soil excavating boards increased from $0.11m^2$ to $0.48m^2$ (436%) . The specific resistance deceased considerably from 116.67 to $64.92kN/m^2$ (41%) which means the draft requirement of the implement to dig out one meter square of the cross-section width decreased by 41% when the operating depth was increased from 20cm to 60cm and this reduction is regarded a great improvement in the field performance. The energy utilization efficiency of the implement improved appreciably when the operating depth increased, it increased from $8.57m^3/mJ$ to $15.40m^3/mJ$ (80%) which means the implement digs $15.40m^3$ soil out of the channel bottom for one mega Joule of energy when the operating depth increased from 20cm to 60cm.

1-Introduction

The deep operating implements required the highest draft force among other soil manipulated implements. The high draft force is related to the greater volume of soil disturbed by the implement as well as to the high moisture content at depth and greater soil compaction at deeper soil layers caused by the weight of upper layers of the soil. The high soil moisture content at depth increases the soil cohesion which play great roll in increasing the resistance to the implement during the soil manipulation operation and hence the draft force. However, despite of the high draft requirement of such implements but they are necessary to conduct certain fieldworks, such as laying manure under the soil surface or breaking the soil had pan.

Tomato crop is widely grown in the desert soil. However, the dessert soil can not hold the irrigation water for long time which would result in crop planting failure. To solve or reduce this problem manure should be buried under the soil surface at certain depth to absorb the irrigation water and to keep it available to the plants as well as provides the plants with nutrients. The hand manure laying method in the soil using the primitive tools is costly and time consuming operation. However, the mechanical subsoil laying method of manure by an implement is the suitable method because it can reduce was design for this purpose. The main implement performance is manipulating the soil and then digging it out to form a ditch which the manure is dropped in the bottom of it and then the manure is covered by returning the excavated soil to the ditch. The implement consists of a subsoiler which, consists of a shank and a foot fixed at the bottom end of the shank. The subsoiler is to manipulate the soil. Two movable boards were fixed behind the subsoiler. The angle between the boards can be changed to obtain different cross-section width of the ditch. They are used to excavate the soil out form the ditch (soil excavating boards). Another two movable boards with a diverge angle, they are a part at the front end and close at the rear end, fixed behind the first two boards. There purpose is to return the excavated soil to the ditch (soil returning boards).

This work was conducted to study the field performance of the designed implement which includes the draft force, cross-section area of the ditch, specific resistance and energy utilization efficiency. The implement was tested in silty clay soil at operation depths of 20,30,40,50 and 60cm with and without soil returning boards.

2-Materials and methods

2-1- the subsoil manure laying implements (figure 1-abc)

An implement was designed to lay the manure under the soil surface to increase the desert soil water retention ability. It consists of a single subsoiler. The subsoiler consists of a shank and foot. The shank forward angle (rake angle) is 60°. The foot is fixed at the lower end of the shank at angle of 150° from the shank front edge. The attack angle of the front of the foot is 30°. The attack angle is to facilitate the soil penetration by the subsoiler. The subsoiler was mounted on a frame provided with three hitching pints.

Two movable boards were fixed be behind the shank. The angle between them can be changed to obtained different ditches of cross-section area which can be done by a length-changeable bar fixed between them. These two boards are used to excavate the loosening soil by the subsoiler to form the ditch, thereupon called soil excavating boards. They are concave and there faces are opposite and diverge from the rear end to the front to increase its ability in retaining the soil into the ditch bottom. There purpose is to bury the manure in the ditch by returning the excavated to the ditch again, thereupon called soil returning boards. The angle between the soil returning boards can be changed by two length-changeable bars, one for each board and they are also used for supporting the boards from the side force created by the soil sliding into the ditch. The soil returning boards are fixed on the implement frame so that there lower edges are close to the soil surface to clean most of the excavated soil up and returning it to the ditch.

2-2- Procedures

After designing and manufacturing the implement, it was tested in the field to determined there performance. The experiments were carried in a silty clay soil using five operating depths 20cm,30cm,40cm,50cm and 60cm. The soil moisture content was 23.2%. The implement was attached to a tractor. The tractor-implement combination was towed by another tractor. A hydraulic dynamometer was used to measure the draft force of the tractor from one end to a flexible cable from the other end which was connected to the front of the towed tractor-implement combination. The hydraulic dynamometer was connected to the towing tractor from one end and to a flexible cable from the other end which was connected to the front of the towed tractor-implement combination. The experiments were conducted by predetermining the operating depth of the implement at one of previously mentioned operating depths. The speed of the engine of the towing tractor was set at 1500 rpm and the forward speed was

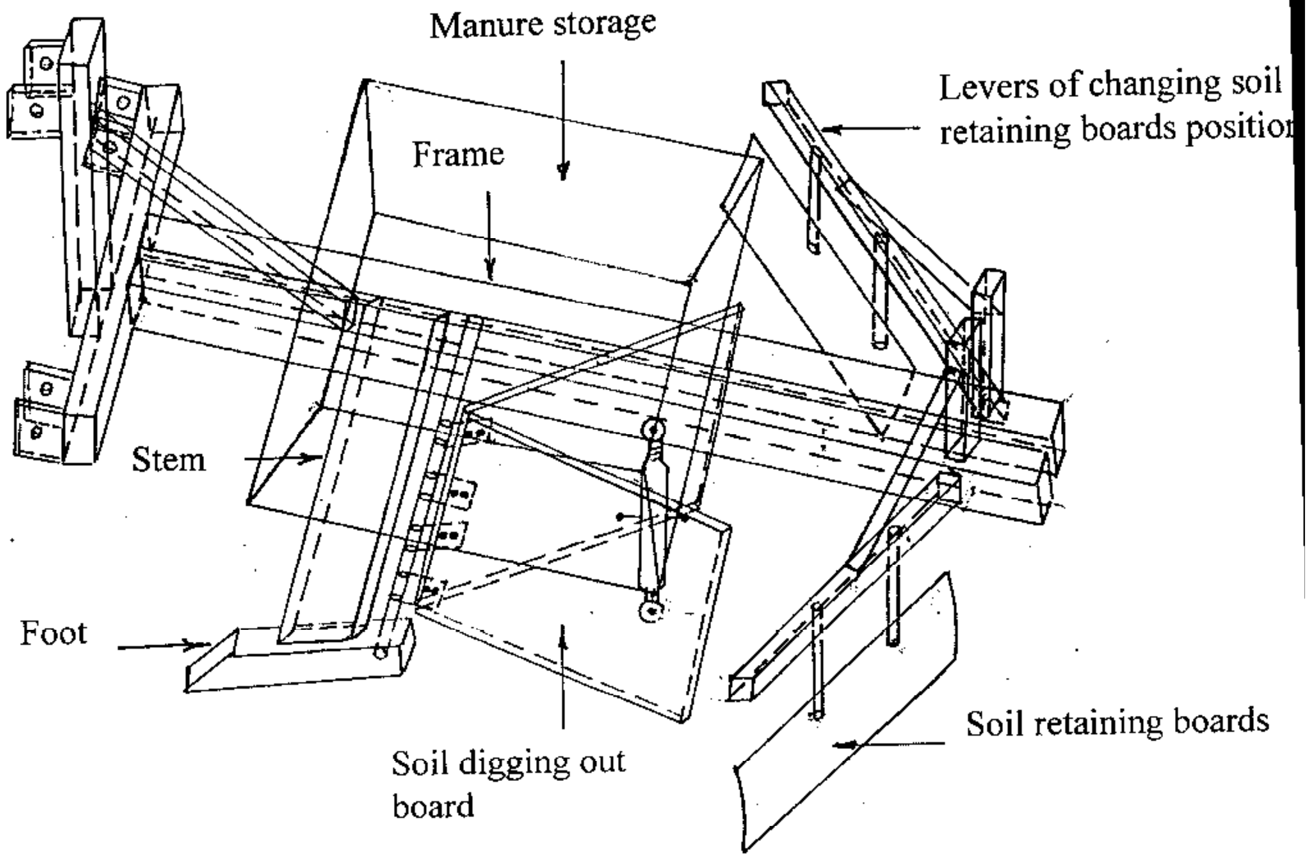

Figure (1-a) : Manure subsoil laying implement

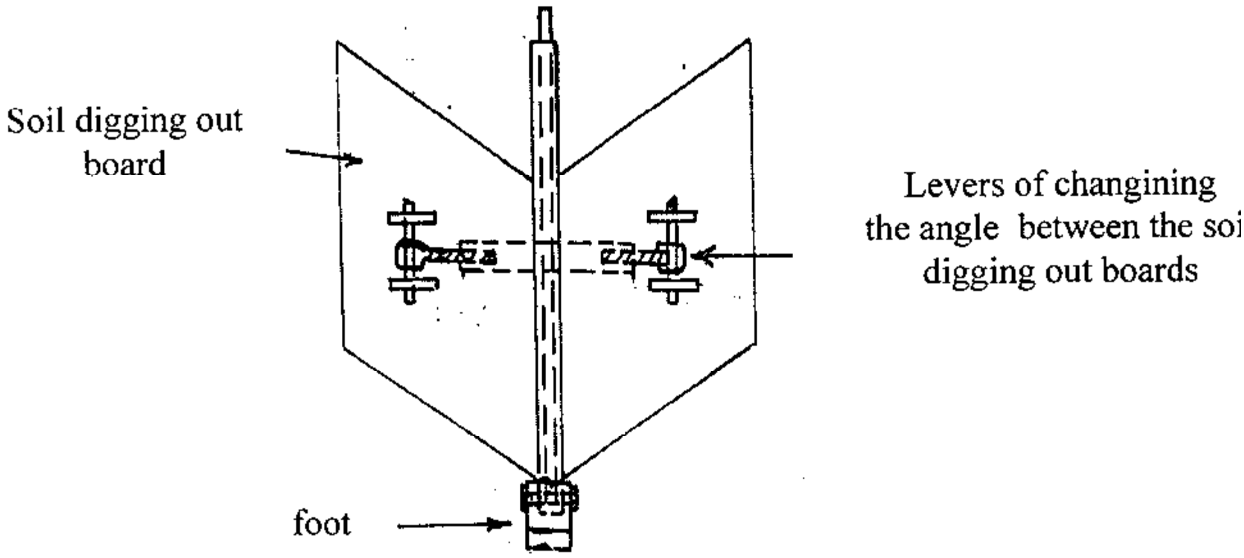

Figure (1-b): Stem and soil digging out boards

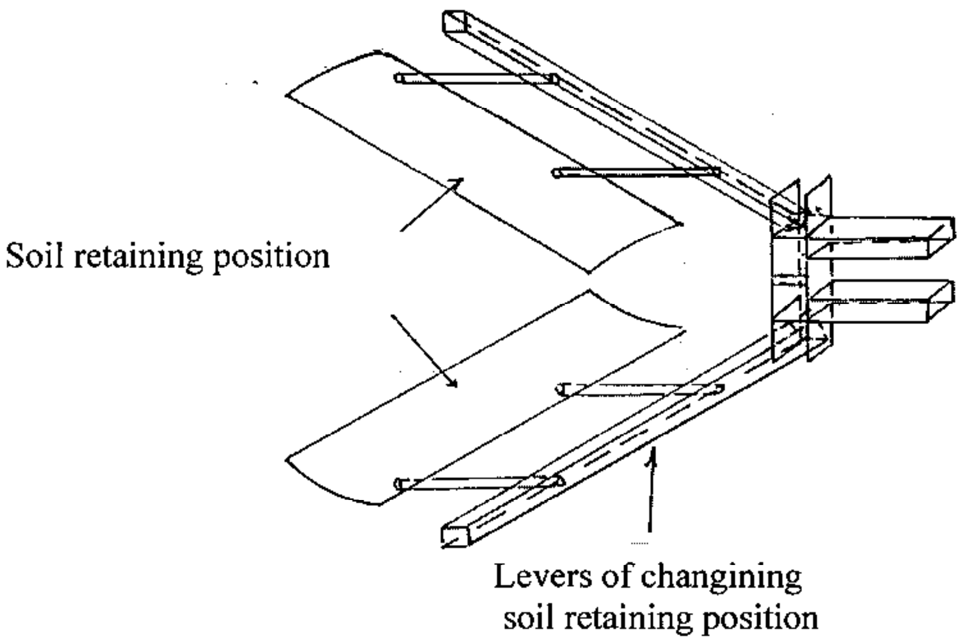

Figure (1-c): Mechanism of soil retaining boards

0.489m/sec. The towing tractor was left to 5m forward to approach the maximum forward speed and the depth of the implement stabilized the chosen operating depth. The towing tractor was left to move another 20m and the draft force was measured along the distance. The time taken to move this distance was also measured. The ditch depth, width at the soil surface and width of the base were measured at three positions along the ditch length 20m). Each run was repeated three times.

The cross-section area of the ditch is calculated by equation (1).

$$A=W*d + S*d \quad \ldots\ldots\ldots\ldots(1)$$

Where A= cross-section area (m^2)
W= ditch base width (m)
d= ditch depth (m)
b= ditch width at the soil surface (m)
S= side width of the ditch (m)

The specific resistance was calculated as follows:

$$SR=F/ A \quad \ldots\ldots\ldots\ldots(2)$$

Where SR= specific resistance (kN/m^2)
F= draft force (kN)
A= cross-section area (m^2)

The energy utilization efficiency of the implement which is defined as the number of the cubic meter disturbed by the implement when on mega Joule of the energy consumed by the implement can be calculated by equation (3).

$$\eta= 1/SR= (A/F)*(m/m) *1000 \quad \ldots\ldots\ldots(3)$$

Where η is energy utilization efficiency (m^3/mJ)

3-Results and Discussion

3-1-Draft force

The draft force of the implement increased as the plowing depth increased (Fig 2) and that was because the subsoiler of the implement manipulate greater volume of soil and the increase in moisture content of the soil with depth. The moisture content increased the cohesion and the adhesion of the soil which both increased the draft force. As well as the soil excavated by the soil excavating boards and the soil returned to the ditch by the returning boards required great deal of force. The results showed that the draft force increased from 12.63 to 31.16kN (242%) when the operating depth increased from 20cm to 60cm (300%). This means each centimeter of the operating depth required 0.52kN to be manipulated excavated and returned to the ditch.

However, when the soil returning boards were removed from the implement the draft force decreased appreciable. The reduction in draft force (the draft requirements of the soil returning boards) was between 4.35 to 6.47kN for operating depths 20cm and 60cm respectively. However, for other operating depth the draft requirements are within the previous draft range. This means that both soil returning boards required 39.5kN and 13.48kN to return one cubic meter of soil to the ditch which was dogged out by the soil excavating boards (39.5kN/m^3 and 13.48kN/m^3) for the operating depths of 20cm and 60cm respectively. The results of the other operating depths are in between also. The high reduction in draft requirement to return one cubic meter of soil as the operating depth increased (lower by 2.93 times) can be related to the easiness of soil sliding in the ditch bottom due to its grater height as the operating depth increases and its accumulation near the ditch edges. This means the draft force is more efficiently consumed as the operating depth increases.

The results showed that the soil returning boards required greater draft force than the operating depth. For example increasing the operating depth from 20cm to 30cm the draft force increased by 3.0kN while the soil returning boards draft force by 4.1kN for the same increase in operating depth. This is related to the high resistance of the excavated soil which lay on the soil surface to the forward movement created by the implement movement before returning to the ditch bottom and due to the soil sliding resistance on the soil returning boards faces. However, when the operating depth increased to 60cm the contrary occurred, the soil returning boards required lower draft force than the operating depth. For example, the draft force increased by 16.21kN when the operating depth increased from 20cm to 60cm while, the draft force requirement of the soil returning boards increased by only 6.47kN for the same increased in operating.

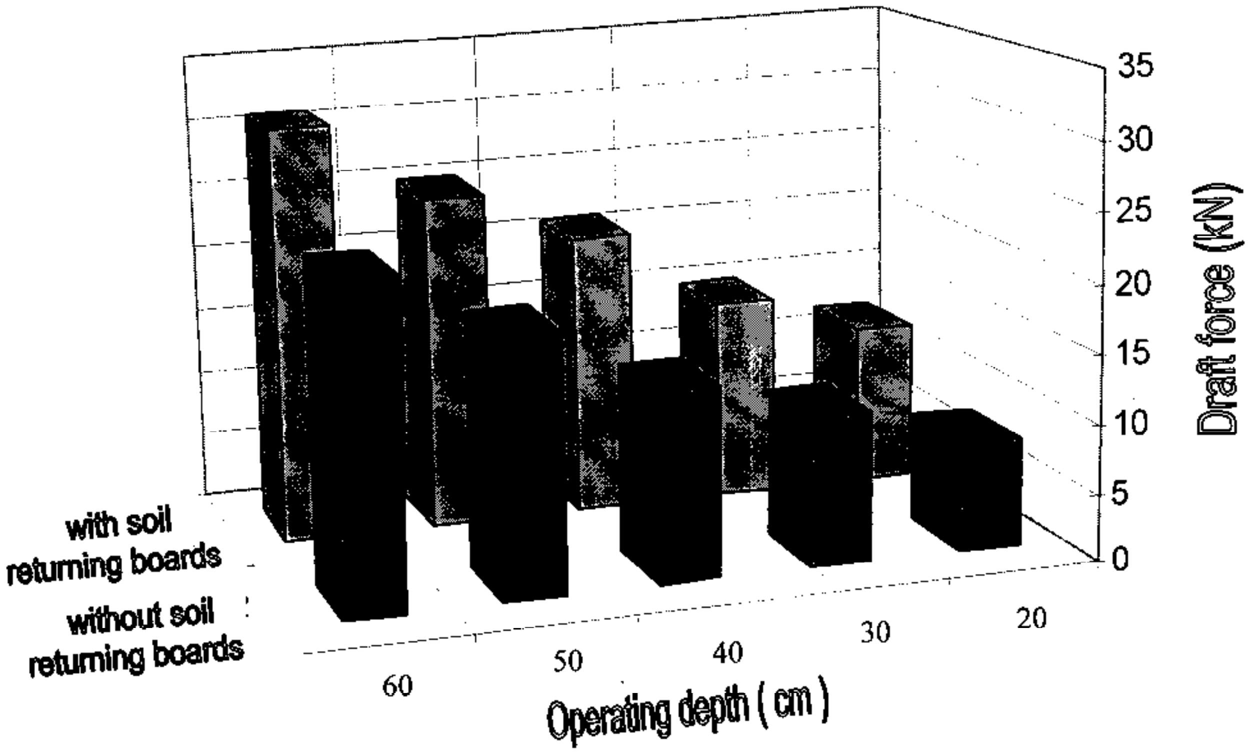

Figure (2). Draft force and versus the operating depth for the implement with and without the soil returning board .

The results of the cross-section area of the ditch formed by the soil excavating boards of the implement for different operating are shown in (3).

The cross-section area of the ditch increased as the operating depth increased and that was due to the increase in the operating depth and the effect of the angle between the soil excavating boards. The operating depth increased the ditch depth and the cross-section width. The increase in the operating depth accomplished with an increase in the disturbed area in the soil surface resulted in wider ditch at the soil surface and also an increase in the ditch base. So increasing the operating depth from 20cm to 60cm increased the ditch width at soil surface and at the base from 85cm to 130cm and 25cm to 30 cm respectively. However, the width of ditch is widening further by the edges of the soil excavating boards which cut the ditch sides during the operation. The effect of the excavating boards edges render the increase in the ditch width was greater than the increase in the operating depth of the implement. For example increasing the operating depth from 20cm to 60cm (300%), the cross-section area of the ditch increased from $0.11m^2$ to $0,48m^2$ (436%). The greater cross-section width area is to accommodate the manure which broadcast before returning the soil to the ditch.

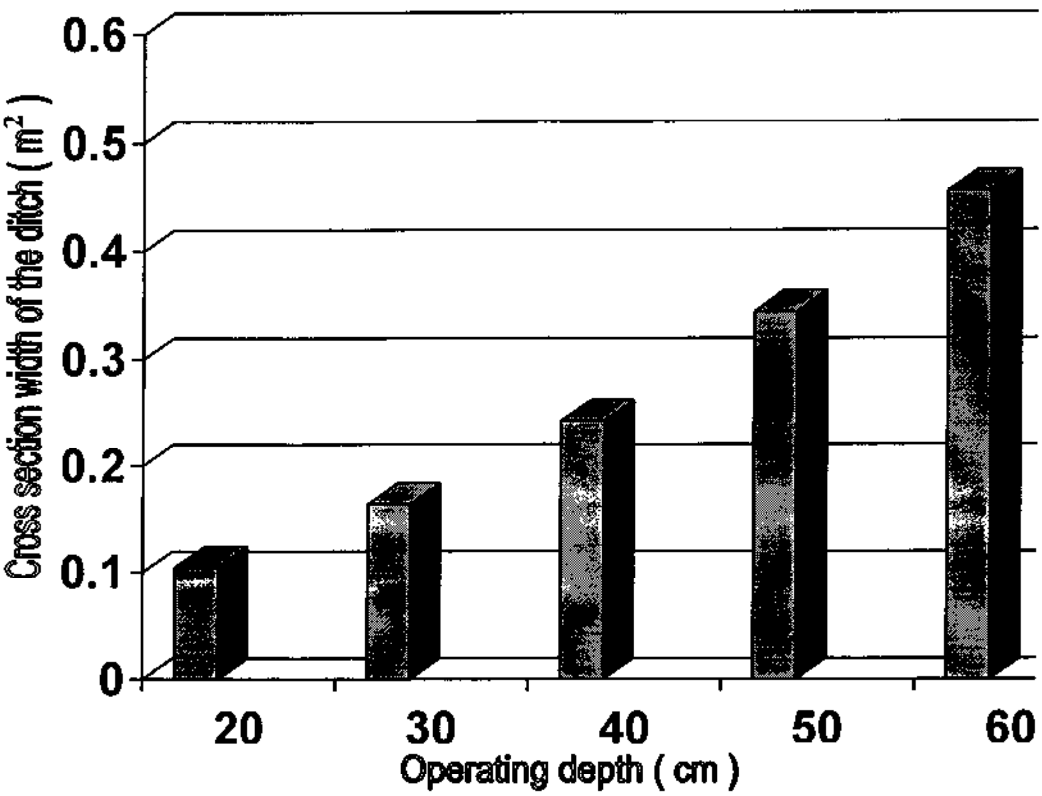

Figure (3).Cross – section width of the ditch versus the operating depth

3-3-Specific Resistance

The specific resistance is defined as the ratio of the draft force to the cross-section area of the ditch formed by the implement thereupon the values of the specific resistance depends on the rate increase in the draft force relative to that of the cross-section area.

The results showed that the specific resistance of the implement decreased considerable as the operating depth increased, figure (4). It decreased from $116.67kN/m^2$ to $64.92kN/m^2$ (41%) when the operating depth increased from

20cm to 60cm.This means the rate of increase in the soil disturbance and therefore the cross-section area of the ditch was greater than the increase in draft force which on the other hand the draft force is more efficiently used with deeper operating depth than the shallow depths and this regarded good improve in the implement field performance. However removing the soil returning boards reduced the specific resistance of the implement appreciably, it decreased from 116.67 kN/m^2 to 77.14 kN/m^2 (34%) and from 64.92kN/m^2 to 51.44kN/m^2 (21%) for operating depths of 20 and 60cm respectively. The reduction in the specific resistance due to the removal of the soil returning boards was because the draft force of the implement decreased while the cross-section area remained unchanged.

However, the operating depth of the implement surpassed the removing the returning boards in reducing the specific resistance, for example the specific resistance decreased by 51.71kN/m^2 when the operating depth increased from 20cm to 60cm but it decreased by 39.51 kN/m^2 and 13.48 kN/m^2 when the soil returning boards were removed for operating depth of 20 cm and 60cm.

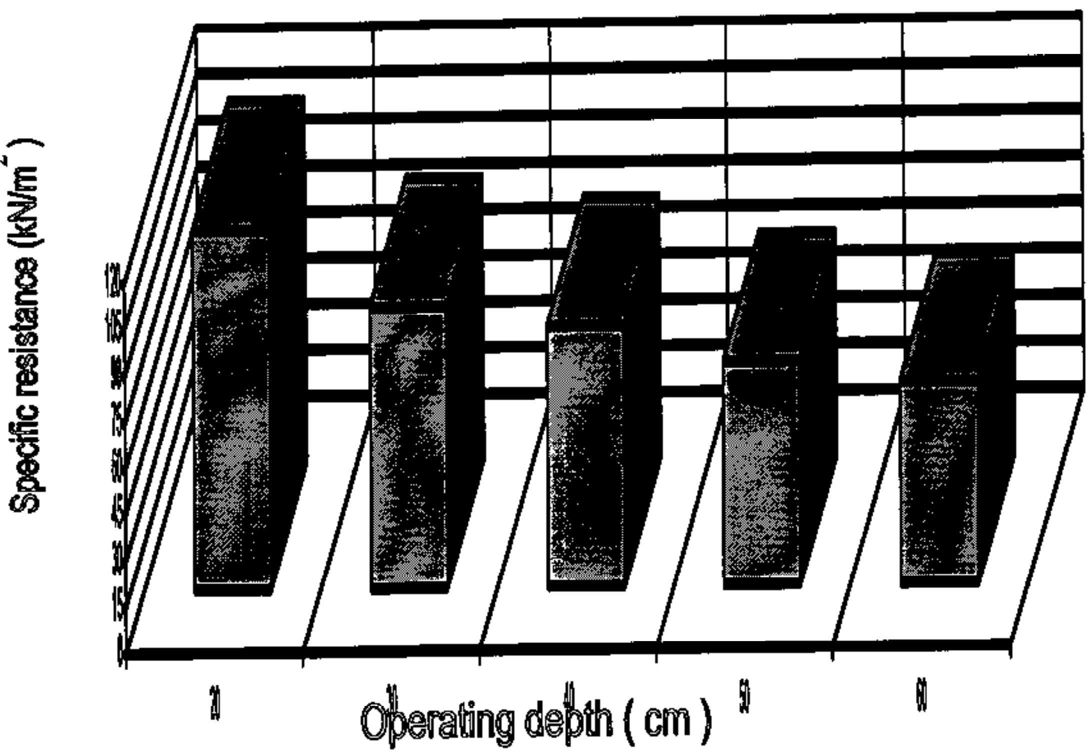

Figure (4) . Specific resistance versus the operating depth soil of the implement

3-4- Energy utilization efficiency

The energy utilization efficiency is the most important parameter to evaluate the field performance of the implement. It shows the ability of the implement to use the energy to do the useful work and the amount of the energy dissipated. The energy utilization efficiency is defined as the number of cubic meter of manipulated soil which includes cutting and disturbing the soil and the excavated soil to form a ditch for this implement when one mega Joules of energy is consumed. The energy utilization efficiency of the implement with soil returning boards improved considerably as the operating depth increased. It increased from 8.57 to 15.40m^3/mJ when the operating depth increased from 20 to 60cm respectively. At the shallow depths there was surplus energy which was not used by the implement (wasted) which resulted in lower energy utilization efficiency. However, at the deeper operating depths the surplus energy was used to manipulate and excavated future volume of soil reducing the energy losses causing higher energy utilization efficiency. The deep operating depth was also reduced the implement forward speed due to the greater volume of manipulated soil and this resulted in transferring the energy which was consumed to accelerate the soil particles for cutting and excavating the soil.

The subsoiler and the soil excavating boards are both manipulate and excavate the soil to form the ditch and this means they share the same volume of soil dogged out to create the ditch and hence they share same energy utilization efficiency. However, the soil returning boards return the excavated soil to the ditch to bury the manure and spent extra energy form this action. The field observation showed that about 5% of the excavated soil remained on the soil surface while 95% returned to the ditch bottom. The energy utilization efficiency of the returning boards is considerably higher than that for the implement without soil returning boards (subsoiler and soil excavated boards). It was greater by three times for the shallow operating depths to four times and half for 20 to 60cm respectively, the values of the remaining operating depth being medium. The high energy utilization efficiency for the soil returning boards was because the soil on the ditch sides was loose and very near to the ditch side edges and that greatly reduced the soil resistance to return to the ditch bottom. As well as the diverge angle of the soil returning boards facilitate the soil sliding into the ditch bottom which reduced the energy consumed in overcome the friction (wasted energy) between the soil and the boards.

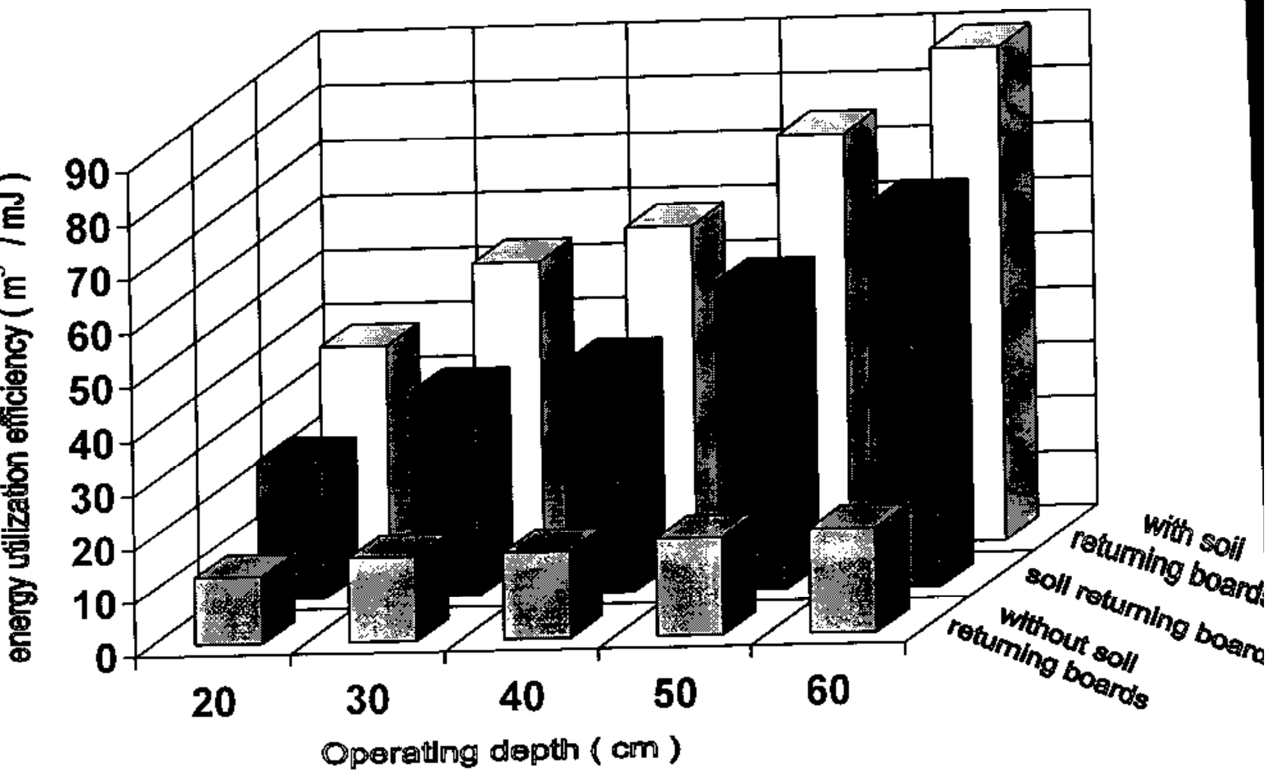

Figure (5). Energy utilization efficiency versus the operating depth of the implement with and without soil returning boards

4- conclusion

The following conclusions are drawn from the implement design and the experiments which were carried out on it :

1- The implement was durable and efficient in digging the soil out to form ditch and retaining the soil back to the ditch .
2- The draft force requirement increased by 2.4 when the operation depth increased 3 times.
3- The draft force of the excavating boards is only 35 % of total draft force the implement.
4- The cross-section area of the ditch made by the implement increased considerably when the operating depth increased while the specific resistance decreased appreciable.
5- The energy utilization efficiency increased by 80% when the operating depth increased from 20 cm to 60 cm .

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تصميم وتصنيع الة وضع السماد العضوي تحت سطح التربه ودراسة ادائها الحقلي

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الخلاصه

تم تصميم آلة تقوم بوضع السماد تحت سطح التربة . يتضمن عملها الاساسي حفر قناة على عمق 30cm – 60cm ووضع السماد العضوي في القناة وارجاع التربة المحفورة الى داخل القناة لدفن السماد . تم تصميم الآلة لغرض تقليل عمليات زراعة محصول الطماطة في الترب الصحراوية التي تتضمن حفر القناة ووضع السماد ثم دفنه والتي يتم اجرائها يدويا" والتي تأخذ فترة زمنية طويلة وأيدي عاملة كبيرة. ان اضافة السماد تحت سطح التربة هو لزيادة فعالية التربة على الأحتفاض بالماء بالأضافة الى تجهيز النباتات المزروعة بالمغذيات . تتكون الآلة من محراث تحت سطح التربة يتكون من ساق وقدم مزود بأجنحة ومن جناحين متحركين لأخراج التربة ووضعها على الجوانب لعمل القناة (أجنحة اخراج التربة) . زودت الآلة بخزان سعته 1 طن لينزل السماد منها الى داخل القناة ميكانيكيا" . قيم أداء الآلة حقليا" بأستخدامها على أعماق حفر مختلفة (20 ، 30 ، 40 ، 50 ، 60) cm وبأستخدام قوة السحب والمساحة العرضية للقناة والمقاومة النوعية وكفاءة الآلة على استخدام الطاقة . أظهرت النتائج زيادة قوة السحب مع زيادة عمق الآلة ، حيث زادت من 12.63kN الى 31.16 kN (242 %) عند زيادة العمق من 20cm الى 60 cm بينما كانت متطلبات أجنحة حفر التربة من قوة السحب 4.36 kN و 6.74 kN للعمقين السابقين والذي يشكلان 35% و 21% من قوة السحب الكلي للآلة على التوالي . أما أجنحة ارجاع التربة فكانت متطلباتها من قوة السحب 4.05 kN و 6.47 kN والذي يشكلان 32% و21% من قوة السحب الكلية للآلة وللعمقين السابقين على التوالي . أما نتائج الأعماق الأخرى هي وسط بين نتائج العمقين 20 و 60 cm . كما أدى زيادة عمق الآلة الى زيادة مساحة مقطع القناة بصورة كبيرة حيث زاد من 0.11 m^2 عند العمق 20 cm الى 0.48 m^2 عند العمق 60 cm ، اذ كانت الزيادة (436 %) أما المقاومة النوعية فقد انخفضت من 116.67 kN/ m^2 الى 64.92 kN/ m^2 (41 %) عند زيادة العمق من 20 cm الى 60 cm . أما كفاءة الآلة على استخدام الطاقة زادت من 8.57 m^3/mj الى 15.40 m^3/mj (80 %) عند زيادة العمق من 20cm الى 60cm وهذا يعني

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ان الآلة تستطيع حفر 15.40 متر مربع لكل ميكاجول من الطاقة المستهلكة عند زيادة العمق مـــن 20cm الى 60cm .