



Comparison between the performance of a movable boards ditch opener and conventional ditch opener in cultivated and uncultivated soils Part 1: The draft force

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Abstract: The draft force of the movable boards ditch opener (MB) was compared with that of the conventional ditch opener (CD). The parameters of the experiments were three operating depths (30, 40 and 50 cm), three angles between the boards of MB (45, 60 and 75°), the angle of the boards of CD was constant (65°), three wings widths of the foot of MB whereas, one share width (35cm) for CD and two soil types (cultivated and uncultivated soils). The texture of soils was silty clay. The results showed that MB can penetrate the soil to the required depth easily and its draft force requirements were lower than that for CD for all operating depths, angle between the boards and in the cultivated and in uncultivated soils. Whereas, CD could not penetrate the soil more than 25cm in the uncultivated soil that its draft force higher than that for MB for operating depth of 30 and 40 cm and for all angles between the boards but the contrary occurred with operating depth of 50cm. The draft force requirement of MB increased slightly with the angle between the boards but it MB increased considerably with increasing wings width of the foot. However, the wings of MB required less draft force than the share of CD which its width was 35 cm (constant width). MB surpassed CD in the field performance, it required less draft force and it could penetrate the soils easily.

Keywords: Draft force, Operating depth, Ditch opener, Soil.

Introduction

The conventional ditch opener suffers from many drawbacks among of them the difficulty in penetrating the soil especially the uncultivated soil, high draft force requirements, high specific resistance and low energy utilization efficiency. Because of these drawbacks a new ditch opener was designed to eliminate some or all of these drawbacks. The conventional ditch opener has a fixed

boards as well as wide share. The new implement has many advantages among them it penetrates the soil easily whether it was friable or hard to the required depth and that related to the design feature of its parts. It consists of subsoiler which was provided with foot. The penetration angle of the foot was 25° which facilitated the implement soil penetration. The implement was provided

with two movable boards which make it easy to penetrate the soil as well as producing ditches of different cross section areas.

The draft force requirement of the deep operating machines is high. The draft force requirement increased as the operating depth increased and it is higher in the uncultivated soil compared with cultivated (Mielke *at el.*, 1994; Aday *et al.*, 2016). The implement types affect the draft force requirement. The subsoiler which was provided with wings required higher draft force compared with that of without wings (Owen 1988; Aday *et al.*, 2008; Aday and Ramadan 2018).

MB and CD were tested in the field to evaluate the draft force requirement of both machines. The experiments parameters were three operating depths, 30, 40 and 50 cm for MB in the cultivated and uncultivated soils, while for CD these operating depths were in the cultivated soil only. Whereas, in the uncultivated soil, CD penetrated the soil to 25 cm only. Three angles between the movable boards of MB, 45, 60 and 75°, while for CD, it was one angle. The experiments were conducted in cultivated and uncultivated soils.

Materials and Methods:

A conventional ditch opener (CD) consists of a frame, two fixed boards and wide share. The boards edges were sharp to cut through the sides of the ditches made by the machine (Fig. 1). Movable boards ditch opener (MB) consists of a frame made of steel to withstand the stress created by the soil and subsoiler which consists of Leg (shank) and foot which was fixed at the lower end of the leg (Fig. 2). The forward inclination angle (rake angle) of the leg is 60°. The foot was provided with wings of 35cm wide. The inclination angle of the wings relative to the horizontal line was 30°. The attack angle of the foot front is 25°. The subsoiler was fixed tightly the implement frame. MB was provided with two boards. The length and width of each board are 1.0 and 75cm respectively. MB was provided with steel shaft of 25mm diameter which was fixed behind the leg of the subsoiler.

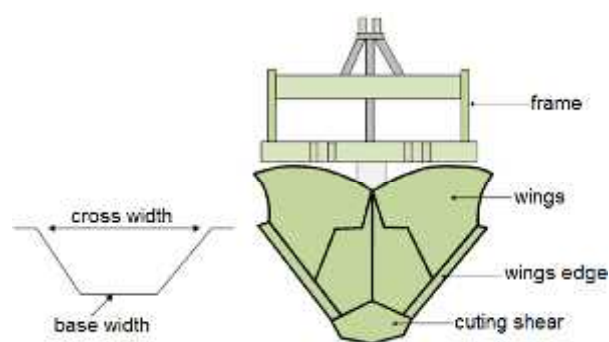


Fig. (1): The conventional ditch opener.

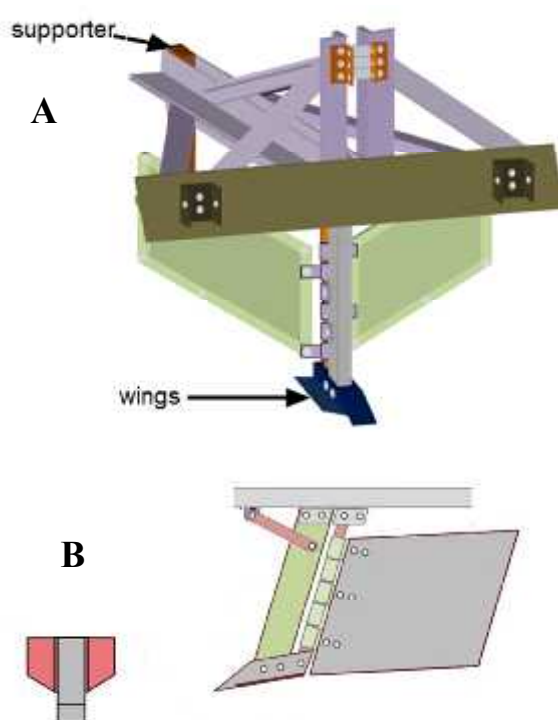


Fig. (2): the movable boards ditch opener (A): Geometrical view, (B): Side view.

The two boards were attached to the shaft of the subsoiler by wide hinged. The hinges enabled the two boards to move freely in and out of the center line of the implement. Different angles between the two boards can be obtained by this method of attachment. The two boards were provided with telescopic bar fixed between them from inside to obtain the required angle. The lower edges of the two boards are inclined with soil surface, they made with soil surface angle of 45° to prevent skidding on the soil surface. To prevent the sideways movement of both boards when they suffered from unequal side force, top edge of one board was provided with support bar which attached to MB frame. The top edge of

the board was provided with many holes to attach the bar in any one of them when the angle between the two boards was changed.

The soil properties measurement

The soil bulk density and the soil moisture content were measured by methods described in Black *et al.* (1965). The soil strength parameters, cohesion, internal friction angle and the soil penetration index were measured by the Annual ring and the penetrometer tool using the methods described by Gill & Vanderberg (1968). These parameters were measured for the uncultivated and cultivated soils. The results are shown in tables 1 & 2.

The draft force measurement

The draft force of the implement was measured using hydraulic dynamometer. The implement was attached to a tractor. The tractor- implement combination was towed by another tractor using flexible cable. The hydraulic dynamometer was attached to the towing tractor from one end and to the flexible cable from the other end. The

operating depth was determined in advance and the towing tractor put in gear while the gear box of the towed tractor left in neutral. The towing tractor was left to move at least three meters to approach the maximum speed then the readings from the dynamometer were recorded. The tractor–implement combination was left to move a distance of 15m. The run was repeated three times in different position within the field of the experiments. The same runs were repeated for the other operating depths, angle between the movable boards and in both soil types.

The draft force was calculated using the following equation.

$$F=0.8+ A.X$$

Where:

F= draft force (kN)

X= the dynamometer readings (kN m⁻²)

A= Cross-section area of the hydraulic cylinder (0.44165m²)

Table (1): Soil physical properties for cultivated and uncultivated soils.

Soil depth (cm)	Cultivated soil			Uncultivated soil		
	Bulk density (kg m ⁻³)	Cone index (kN m ⁻²)	M.C (%)	Bulk density (kg m ⁻³)	Cone index (kN m ⁻²)	M.C (%)
0-10	1266	1713.20	23.8	1458	3115.00	9.25
10-20	1150	1495.20	26.65	1449	3893.80	13.20
20-30	1367	2803.50	24.70	1417	3166.70	16.61
30-40	1240	2118.20	30.61	1272	2219.40	24.77
40-50	1141	1869.00	33.30	1161	1619.80	30.33

Table (2): Soil mechanical properties.

Soil types	Cohesion C (kN m ⁻²)	Angle of internal friction Ø (Degrees)	Soil texture		Consistency		
			Sand	Silt	Clay	P.L.	L.L.
Cultivated	9.48	40.09	4.20	44.20	51.60	28.00	46.00
Uncultivated	6.83	34.37					

Results and discussion

3.1 The effect of the operating depth and the soil types on the draft force requirement of CD and MB.

The draft force requirement of MB and CD are shown in Fig. (3). The draft force increased significantly ($P < 0.01$) with operating depth in both soil types. The values of the draft force were doubled when the operating depth increased from 30 to 50 cm in both soil types. It increased from 21.30 to 42.71 kN (100%) in the uncultivated soil while it increased from 16.58 to 33.99 kN (105%) in cultivated soil. For CD the draft force requirement in the uncultivated soil despite of its shallow operating depth (25cm), surpassed that of MB for operating depth of 30 and 40cm. While, for operating depth of 50 cm the contrary occurred and that was because MB disturbed greater volume of soil and the soil strength increased with operating depth. In the cultivated soil where both machines had the same operating depth, the draft force for both machines increased,

however, the draft force requirement of CD surpassed that of MB considerably. The difference between their draft force requirements were decreased as the operating depth increased and they are between 70.4% to 38.8%. The considerable increase in the draft force is related to the great increase in the volume of the disturbed soil with operating depth as well as the dig volume of soil which was dogged out from the ditch which required great force to be thrown the soil out of the ditch stream (Spoor & Godwin, 1978; Godwin *et al.*, 1984; Mckyes, 1984; Reeder *et al.*, 1993; Mckyes & Maswaure, 1997). In additional to that great friction occurred between the disturbed soil and the implement boards. Comparing the draft force of CD and MB, the draft force requirement of CD was higher than that for MB and that was because the greater resistance on CD share as well as the edges of its boards cut through the ditch sides which added great resistance on the implement.

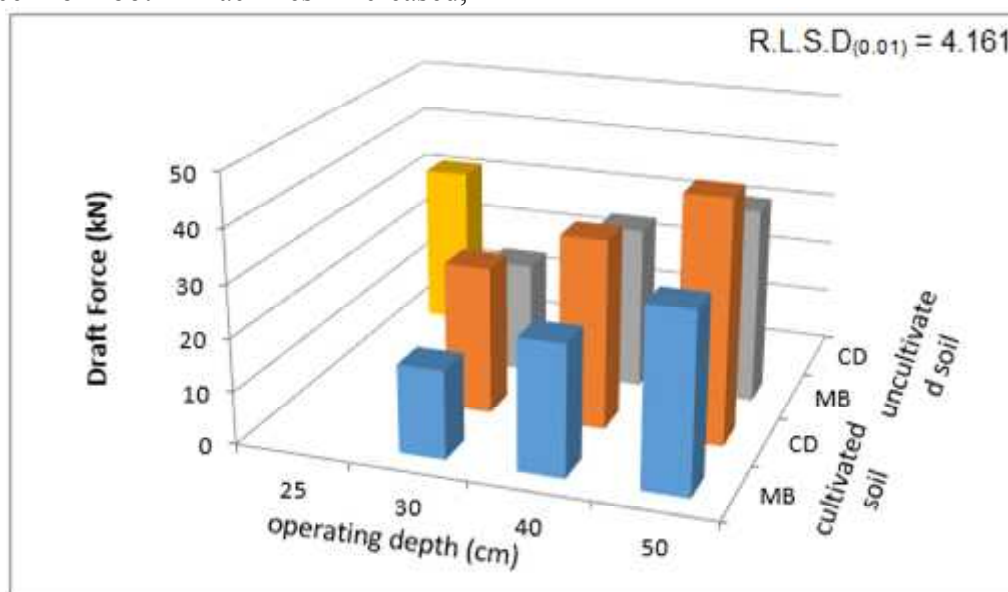


Fig. (3): The relationship between the draft force of MB and CD and the operating depth in cultivated and uncultivated soils.

Comparing the draft force requirement of MB in the cultivated soil with that in the uncultivated soil, the draft force was higher in the uncultivated. The difference between the draft force requirements in both soils increased as the operating depth of the implement increased, for operating depth of

30 cm the difference between the draft force requirement is 4.72 kN (28.5%) whereas, for the operating depth of 50 cm is 8.72 kN (25.6%). This can be related to the soil strength of uncultivated soil which was higher than that for cultivated soil especially at greater depths.

The results showed that the effect of the operating depth on the draft force requirement for MB and CD was greater than that of the soil types.

3.2 The effect of the operating depth and the angle between the movable boards of the implement on draft force requirement.

The effect of the operating depth and the angle between the movable boards of MB on the draft force requirement is shown in Fig. (4). The trend of increase of the draft force requirement with operating depth remained unchanged for the different angle between the boards. However, for the same operating depth the draft force requirement increased slightly with the angle between the boards, but at decreasing rate. For example, for depth of 30 cm the draft force requirement increased from 17.39 to 18.40 kN (1.01 kN) when the angle between the boards increased from 45 to 60°, while, it increased to 21.01 kN (3.62 kN) when the angle increased to 75°. Whereas, for operating depth of 50 cm the draft force increased from 36.98 to 38.43 kN (1.45 kN) and increased to 39.64 kN (2.66 kN) for the same increases in the angle between the boards. The reason was that at the shallow operating depth (30 cm) the width

of the ditch was small but the ends of the two boards cut through the ditch sides which widen the ditch width further this operation required more draft to overcome the soil resistance. When the operating depth increased to 50cm the ditch width increased appreciable and that reduced the soil volume cut by the ends of the boards which reduced the draft requirements. Comparing the draft force requirement of CD with that of MB, the draft force of CD is higher than that for MB for all the angle between the boards of MB. Even though, the draft force of CD is greater than that for MB for the same operating depth. For example, for angle of 75° the draft force of MB is 39.64 kN while for CD is 47.20 kN which (the angle between its boards 65°) is higher by 7.56 kN (19%).

3.3 The effect of the soil types and the angles between the boards on the draft force requirement of MB and CD.

The effect of the soil types and the angle between the boards on the draft force requirement of MB and CD is shown in Fig. (5).

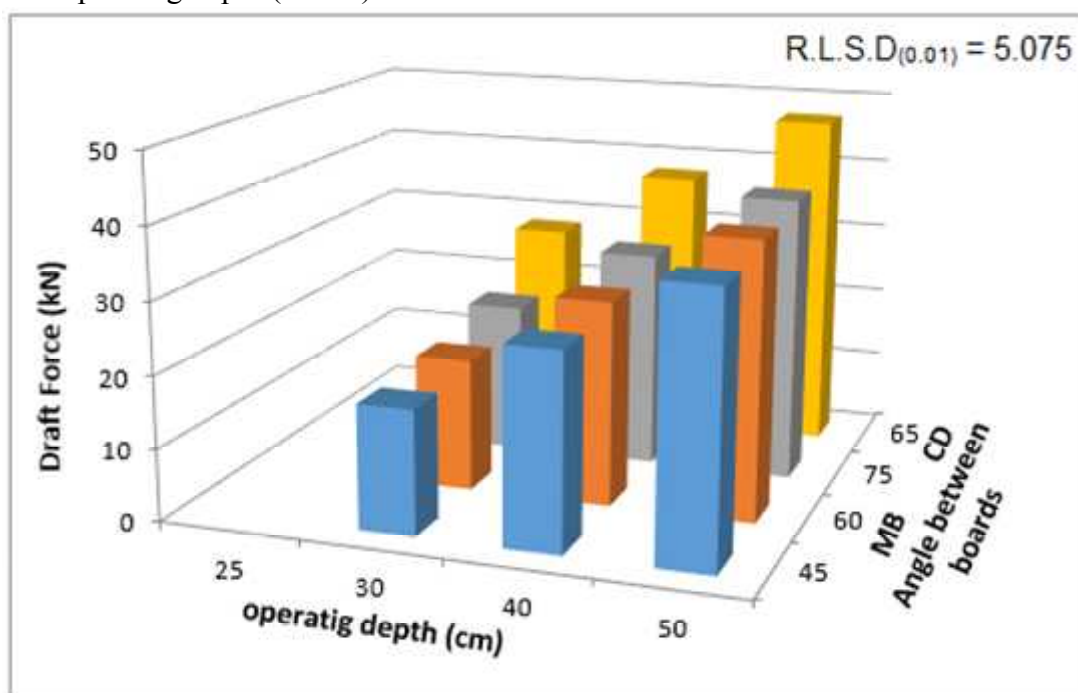


Fig. (4): The relationship between the draft force of MB and CD and the operating depths for different angles between the boards.

The results showed that the angle between the boards of MB is slightly affected the difference between the draft force requirement of MB in the cultivated and uncultivated soils. For example for angle of 45°, the difference between the draft force requirement in both soil types is 6.5 kN. Increasing the angle to 60° the difference is 6.6 kN while, for angle 75° the difference is 7.0 kN.

The results also showed that increasing the angle between the boards of MB increased the draft force in both soils but it was marginally

higher in the uncultivated soil compared with the cultivated soil.

Comparing the draft force requirement of CD with that of MB. The draft force requirement of CD in the cultivated and uncultivated soils were higher than that for MB for all angles between the boards except that for MB at angle of 75° in the uncultivated soil. The reason for that is the operating depth of CD was 25 cm in the uncultivated soil whereas, for MB the operating depths were greater which they are 30, 40 and 50 cm.

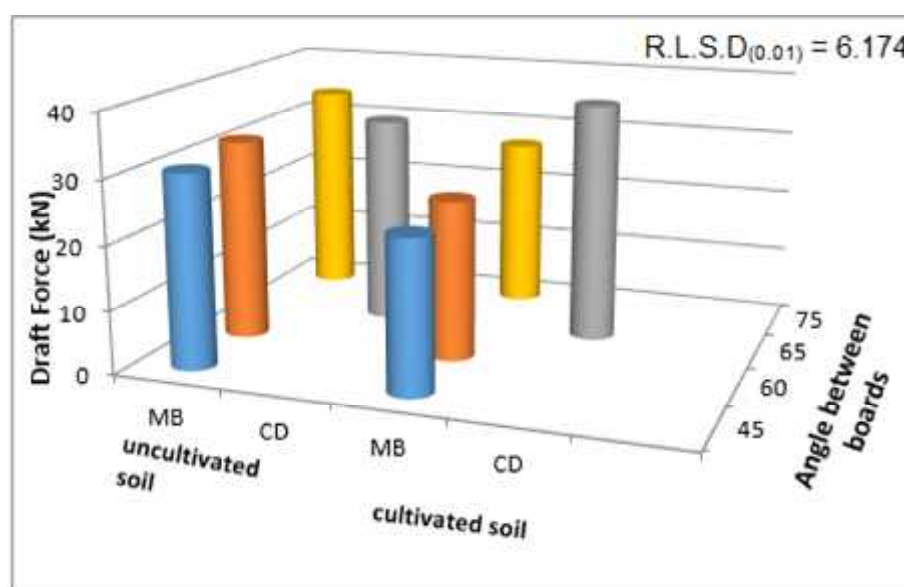


Fig. (5): The relationship between the draft force and the angles between the boards in uncultivated and uncultivated soils.

3.4 The effect of the operating depth and the width of the wings on the implement draft force requirement.

The draft force requirement of MB was significantly ($P < 0.01$) lower than that for CD for all wings widths used on MB, (Fig. 6). At operating depth of 30 cm and for wing width of 35 cm, the draft force of CD was 29.6 kN while for MB was 20.4 kN (lower by 31%). When the width of the wings of MB was increased to 45 cm the draft force of MB remained lower than that for CD by 7.8 kN. This difference can be related to the front of the foot of MB which was cut at angle of 30° (penetration angle). This angle enabled MB to penetrate the soil easily and made cracks in the soil at depth which reduced the soil

resistance on the wings when they started penetrating the soil. However, for CD the share was wide which the soil imposed great soil resistance on it when penetrating the soil and this problem becomes worse at greater depths. In general, the draft force for MB and CD increased with operating depth and the wings created many cracks which increased the disturbed volume of soil (Ahmed & Godwin, 1983; Aday & Hmood, 1995; Aday & Hilal, 2001a, b).

The results showed that the operating depth of MB increased the draft force more than the wings width of the foot. For example, at operating depth of 30 cm the draft force increased by 26% when the wings width was increased from 25 to 45 cm but when the

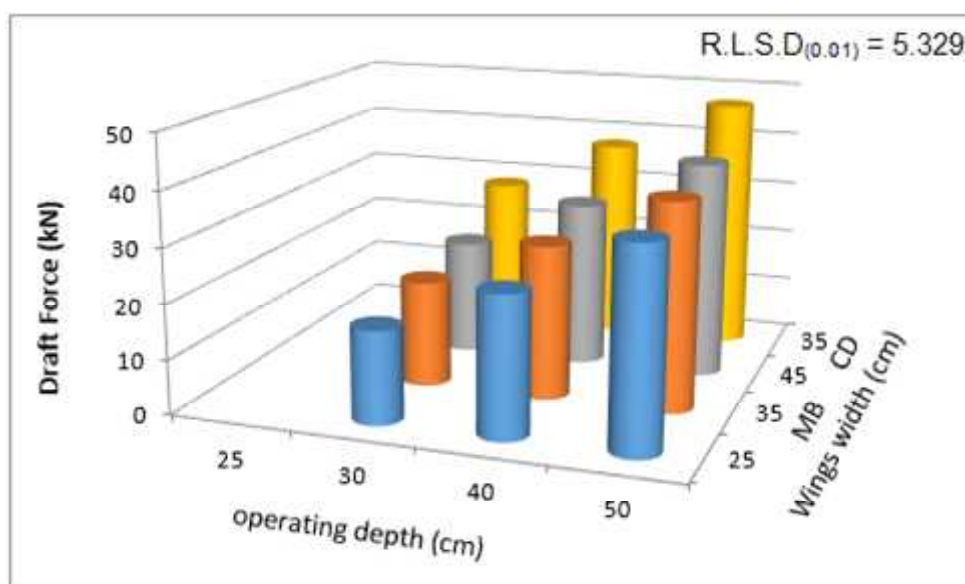


Fig. (6): The relationship between the draft force of MB and CD and the operating depths for different wings widths.

operating depth was increased from 30 to 50 cm for wing width of 25 cm the draft force increased by 118%. This can be related to that the operating depth increased the volume of the disturbed soil more than the wings. In addition to that the soil strength and the moisture content at depths are greater imposed high resistance on MB (Aday *et al.*, 2004; Aday *et al.*, 2011).

Conclusions

The following conclusions can be drawn from the results:

- 1-MB can penetrate the soil to the required depth without difficulty.
- 2-The draft force requirements were lower for MB for all operating depths, angle between the boards and in the cultivated and in cultivated soils.
- 3-CD did not penetrate the soil more than 25 cm in the uncultivated soil and despite that its draft force higher than that for MB for operating depth of 30 and 40 cm and for all angles between the boards.
- 4-The draft force requirement of MB increased slightly with the angle between the boards.
- 5-The draft force of MB increased with increasing wings width but the wings of MB

required lower draft force than the share which CD was provided with.

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