Iran Agricultural Research (2022) 40(2)51-60

Research Article

Shiraz University

Field evaluation of a bent leg tillage implement

A. Solhjou *, M. Shaker

Agricultural Engineering Research Department, Fars Agricultural and Natural Resources and Education Centre, Agricultural Research, Education and Extension Organization, Shiraz I. R. Iran.

* Corresponding Author: a.solhjou@areeo.ac.ir

DOI: 10.22099/IAR.2022.40632.1440

ARTICLE INFO

***Article history*:**

Received: **11 May 2021**

Accepted: **22 January 2022**

Available online: **5 March 2022**

***Keywords*:**

Bent leg

Blade geometry

Draft force

Forward speed

ABSTRACT - This study was aimed to determine the effect of the geometry of a bent leg tillage implement on draft force and specific draft. This research designed as a split-split plot experiment with three replications. Treatments were three soil moisture content levels of 7-10, 10-13 and 13-16 % as main plots, three forward speeds of 5, 7.5 and 10 km h^{-1} as sub-plots and three lateral blade spacing of 12, 16 and 20 cm as sub-sub-plots. Results indicated that forward speed, lateral blade spacing and soil moisture content affected draft force and specific draft. Reducing soil moisture content from 13-16% to 7-10% increased draft force by 12% and reduced specific draft by 9%. Increasing forward speed from 5 to 10 km h^{-1} increased draft force and specific draft by 71.8% and 70.7%, respectively. The lateral blade spacing of 16 and 20 cm was recognized to be proper for tilling by the bent leg tillage implement. Other findings showed that the geometry and characteristics of the bent leg tillage have the potential to have reduced draft force at higher levels of the forward speed.

INTRODUCTION

The factors that have previously been identified in the literature which influence draft force and soil disturbance include soil conditions such as texture, moisture and structure, tool setting like working depth, forward speed and tool geometry (Fielke, 1996; Godwin and O’Dogherty, 2007; Godwin, 2007; Sharifat, 1999; Solhjou et al., 2012; Salar and Karparwerfard, 2017). One of the important factors which affect draft force is the geometry of the tool such as rake angle. It has been reported that the rake angle affects draft force, soil failure and soil layer mixing (Godwin and Spoor, 1977; Solhjou et al., 2012). It has been also shown that increasing rake angle increases draft force and reduces the cross-sectional area of furrow (Payne and Tanner, 1959; Godwin, 2007; Solhjou et al., 2012). Adding a chamfer to the face of vertical narrow tool declined draft force and lateral soil throw (Rosa and Wulfsohn, 2008). Sharifat (1999) showed that the 45° triangular and elliptical face geometry had the lowest lateral soil movement and energy when compared to a blunt and a 90° triangular narrow tool. Also, Solhjou et al. (2013) showed that adding a chamfer to the face of a vertical narrow point opener decreased lateral and forward soil movement, but increased the size of the furrow cross-sectional area and the opener critical depth.

Another factor that affects the draft force is forward speed. Increasing forward speed increased the draft force of three primary tillage implements including mouldboard plough, chisel plough and disc plough, the maximum exhibited by mouldboard plough (Naderloo et al., 2009). The draft force of subsoiler increased by increasing forward speed (Askari et al., 2017). Also, increasing forward speed raised the draft force of chisel plough (Al-Neama and Herlitzius, 2017; Moeenifar et al., 2014; Hoseini and Karparfard, 2012). Raising forward speed increased the draft force of implements because of creating high acceleration to the soil particle during their translocation. Thus, tool geometry and forward speed are two important factors that highly affect the draft force of implement. The ability to conduct tillage operations at more forward speeds is desirable to farmers for higher work rates and timelines; which result in, reducing labour and machinery costs. However, it has been reported that tillage operation at high speed (more than 8 km h^{-1}) often results in significantly higher demand for draft force (Godwin and O’Dogherty, 2007).

Solhjou et al. (2014) quantified the soil disturbance and soil translocation of a bent leg opener design in soil bin. As shown in Figs. 1 and 2, the bent leg opener includes a footed bent leg opener (bent leg opener with a foot component) and a footless bent leg opener (bent leg opener without a foot component). The design was based on the RT blade (Fig. 1, left) developed by a South African farmer (Solhjou et al., 2014; Barr et al., 2020), who scaled down the concept of bent leg subsoilers aiming to reduce draft force and surface soil disturbance (Harrison, 1990; Raoufat and Mashadi Mighani, 1999; Esehaghbeygi et al., 2005). The RT blade included the bent leg opener with foot component and shank offset of 95 mm (Fig. 1, left and Fig. 2). However, Solhjou et al. (2014) found that the bent leg opener without a foot and shank offset of 45 mm has the potential to increase soil loosened furrow cross-sectional area with less soil translocation and soil mixing (Fig. 1, right). This footless bent leg opener can be proper for no-till seeding. Barr et al. (2016) found that the footed bent leg opener can work at the forward speed of 16 km h^{-1} with less draft force and lateral soil throw compared to the straight shank openers of 53° and 90° rake angles. The field evaluation of a footed bent leg opener in the seeding system showed increasing forward speed from 8 to 12 km h^{-1} had no penalty to wheat emergence. However, increasing the forward speed of seeders using a straight opener reduced 31% wheat emergence (Barr et al., 2019).

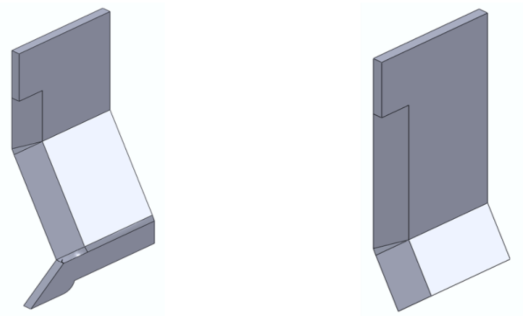

Fig. 1. Bent leg openers (left) with a foot component and without a foot component (Right) (retrieved from Solhjou et al., 2014)

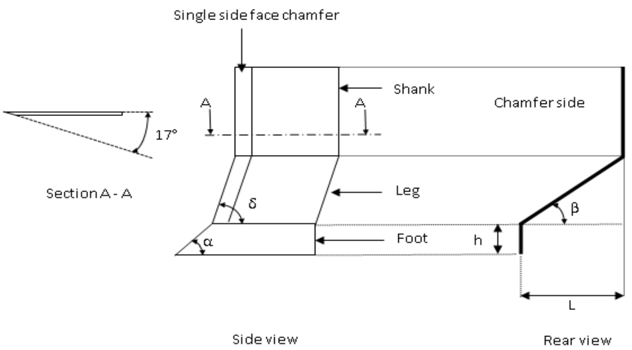

Fig. 2. The geometry of a bent leg opener. L= shank lateral offset, h= foot height, β= side bend angle, α= foot rake angle and δ= leg forward angle (retrieved from Solhjou et al., 2014)

The aforementioned results have been only obtained based on a footed bent leg opener and various levels of the forward speeds. However, less information is available on a footless bent leg opener and the effects of soil moisture, forward speed and lateral blade spacing on its draft force. Therefore, the objectives of this study were to evaluate the effects of soil moisture, forward speed and lateral blade spacing on the draft force of a footless bent leg tillage implement in field conditions. The findings of this study would highlight some implications for improving the performance of tillage practices and determine the suitable lateral blade spacing for a bent leg tillage implement.

MATERIALS AND METHODS

To determine the draft force of the newly designed bent leg plough, experiments were undertaken in a field near Zarghan region in Fars province, Iran. The soil texture of the field was silty clay loam containing 16.4% sand, 43.6% silt and 40% clay. A split-split plot design with three replications was designed to conduct this study. Treatments were three levels of soil moisture contents including 7-10 (M1), 10-13 (M2) and 13-16 % (M3) as main plots, three forward speeds of 5 (V1), 7.5 (V2) and 10 km h^{-1} (V3) as sub-plots and three lateral blade spacing of 12 (d1), 16 (d2) and 20 cm (d3) as sub-sub-plots.

To determine soil moisture contents in the field, the field was irrigated and when the gravimetric soil moisture contents of the field declined to moisture content levels of 13-16, 10-13 and 7-10 percent dry basis (db), the treatments were applied in the field. The size of each plot was 3 × 50 m and the wheat residue retained on the soil surface before tillage was 2512 kg ha^{-1}. The bent leg blade with a chamfered face, was manufactured from 15 mm thick steel. The details of the bent leg blade are shown in Fig. 3 and Table 1. The bent leg tillage implement was made of seven bent leg blades and an average working depth of 10-12 cm (Fig. 4).

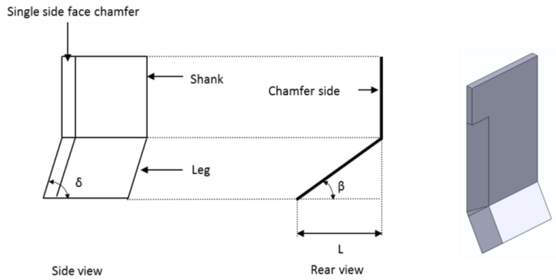

Fig. 3. The geometry of the bent leg blade (left) and its isometric view (right). L= shank lateral offset, β= side bend angle and δ= leg forward angle

Table 1. Geometry parameters of experimental bent leg blade

Blade	Shank offset, L (mm)	Side bend angle, β (°)	Leg forward angle, δ (°)	Leg face condition
Bent leg	45	45	70	Chamfered*

* Single side face chamfer of 17°

Fig. 4. The bent leg tillage implement

Soil moisture was measured by taking samples at the soil depth of 0-15 cm before tillage. Also, forward speed was obtained by dividing the distance of 20 m by the time of operating tillage for this distance. The draft force of bent leg tillage implement was measured by RNAM standard method using a drawbar dynamometer and two tractors (Fig. 5). A 75 hp ITM-285 tractor was used to pull another 75 hp MF-285 one (Iran Tractor Manufacturing Co., Tabriz, Iran) carrying the bent leg tillage implement. The draft was measured and recorded by a recording drawbar dynamometer (DBBP-3t, Korea) placed between the two tractors and the procedure recommended by RNAM standard method for draft measurement was adopted (Fig. 5). In both cases, the tractor forward speed was 5, 7.5 and 10 km h^{-1} such as treatments of the forward speed. The net difference between the two measurements was the draft force needed to pull the bent leg tillage implement in soil (Raoufat and Firuzi, 1998; Majidi and Raoufat, 1997). The measurements were taken in two stages, first when the bent leg tillage implement was engaged in soil and the second, when the implement was raised by the hydraulic lift of the tractor. To determine the soil disturbance area in each treatment, the loosened cross-sectional areas were measured. To measure the cross-sectional area of each treatment was used a wooden ruler. The first and the end of the ruler were placed on the unloosened soil surface and then it was levelled by a leveller. Then, the depth of soil was measured at 2 cm intervals. (Esehaghbeygi et al., 2005). The soil disturbance area of each treatment was calculated by using Equation (1), the soil disturbance area of each trapezoidal area of the element was calculated using $(d_1 + d_2)\,h/2$, where h was constant at 2 cm intervals (Salar et al., 2017).

$$A = \left(h \sum_{i=1}^{n} d_i \right) - (d_1 + d_n) \qquad (1)$$

where, A is soil disturbance area; i is the profile meter readings; and 1 and n are the first and the last profile meter reading in every section profile, respectively. Also, the specific draft of each treatment was calculated by dividing draft force to the soil disturbance area as a measure of tool performance. All the statistical analysis was performed using SAS software and Duncan's multiple range test ($P=0.05$) were used to compare the treatments means

Fig. 5. Measuring draft force with a drawbar dynamometer and two tractors method

RESULTS AND DISCUSSION

Draft Force

Increasing soil moisture in the field decreased draft force (Fig. 6). The highest draft force was obtained at the soil moisture content of 7-10 % db with 2.38 Kilo Newton (kN) and the lowest of it was obtained at the soil moisture content of 13-16% db with 2.09 kN. The draft force of the bent leg tillage implement at soil moisture of 13-16% db reduced 12% compared to the draft force at the soil moisture of 7-10% db. Previous studies showed stated that draft force increased with decreasing soil moisture (Sharifat, 1999; Dehghani and Karparvarfard, 2017; Manuwa and Ademosun, 2007). With increasing soil moisture, molecules of water absorb on the surfaces of the particles and create a moist film around soil particles. This moist film reduces cohesion force (Kepner et al., 1978); and as a result, draft force reduces.

As shown in Fig. 7, increasing forward speed strongly increased draft force. Increasing forward speed from 5 to 10 km h^{-1} increased draft force by 71%. Other studies have shown that draft force increased with increasing forward speed (Godwin, 2007; Sharifat, 1999; Abbaspour-Fard et al., 2014; Barr et al., 2016; Dehghani and Karparvarfard, 2017). Also, in this study, increasing forward speed increased the draft force of the bent leg tillage that was supposed to be due to creating high acceleration to the soil particles during their translocation.

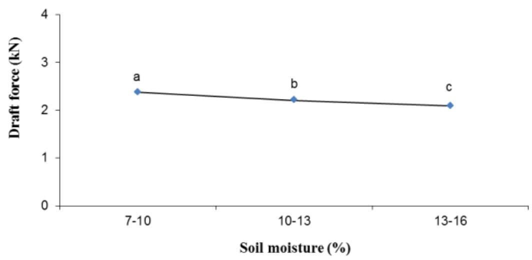

Fig. 6. Effect of soil moisture on draft force
Values with different letters have significant differences in the probability level of 0.05 ($P=0.05$) based on Duncan's Multiple Range Test.

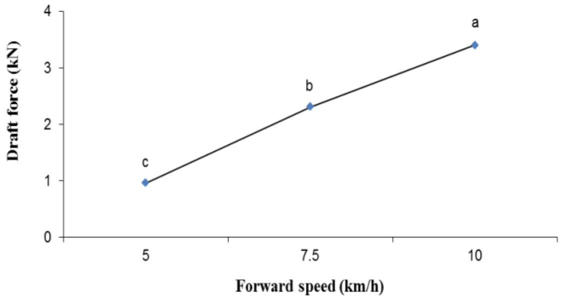

Fig. 7. Effect of forward speed on draft force
Values with different letters have significant differences in the probability level of 0.05 ($P=0.05$) based on Duncan's Multiple Range Test.

As detailed in Fig. 8, the bent leg draft force was affected by the lateral blade spacing of the tillage implement. The highest draft force of 2.26 kN was obtained for the lateral blade spacing of 16 cm and the lowest of 2.20 kN was obtained for the blade spacing of 12 and 20 cm. Increasing lateral blade spacing of bent leg from 12 to 16 cm raised draft force by 2.5%. Decreasing draft force at lateral blade spacing of 20 cm compared to the lateral blade spacing of 16 cm, was due to easier moving of soil particles and mulch around the blades at lateral blade spacing of 20 cm.

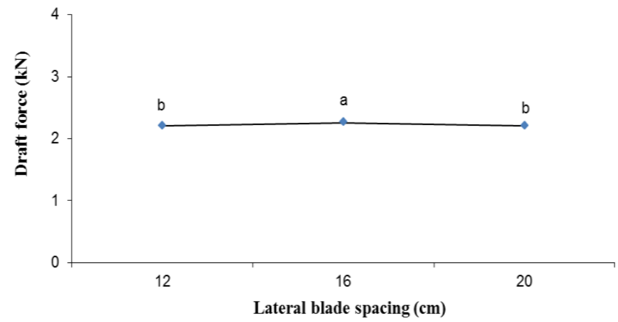

Fig. 8. Effect of lateral blade spacing on draft force
Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

The interactions between soil moisture content and forward speed on the draft force of the bent leg tillage implement are shown in Fig. 9. The lowest draft force of 0.87 kN was measured at soil moisture of 13-16% and forward speed of 5 km h^{-1} (M3V1). The highest draft force with 3.59 kN was obtained at soil moisture of 7-10% and forward speed of 10 km h^{-1} (M1V3). Therefore, increasing soil moisture and decreasing forward speed declined the draft force of the bent leg tillage implement. This shows that soil moisture and forward speed strongly affect draft force. However, the effect of the forward speed was more compared to the effect of soil moisture on the draft force.

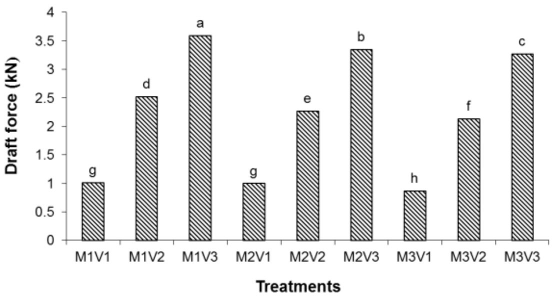

Fig. 9. The interactions between soil moisture and the forward speed on draft force
M1= Soil moisture of 7-10%, M2= Soil moisture of 10-13%, M3= Soil moisture of 13-16%
V1= Forward speed of 5 km h^{-1}, V2= Forward speed of 7.5 km h^{-1}, V3= Forward speed of 10 km h^{-1}
Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

As shown in Fig. 10, the maximum draft force of 2.42 kN was measured at soil moisture of 7-10% and lateral blade spacing of 16 cm (M1d2). However, this treatment (M1d2) was not significantly different (*P=0.05*) from the M1d3 treatment. The minimum draft force of 2.02 kN was measured at soil moisture of 13-16% and lateral blade spaces of 12 cm (M3d1). With increasing soil moisture, molecules of water absorb on surface of soil particles and create a moist film around particles. This moist film reduces cohesion force (Kepner et al., 1978); and as a result, draft force reduces. Also, decreasing draft force at lateral blade spacing of 20 cm compare to the lateral blade spacing of 16 cm, was due to move easier soil particles and mulch around the blades at lateral blade spacing of 20 cm. Results indicate that the effect of soil moisture on draft force was greater than lateral blade spacing of the bent leg tillage.

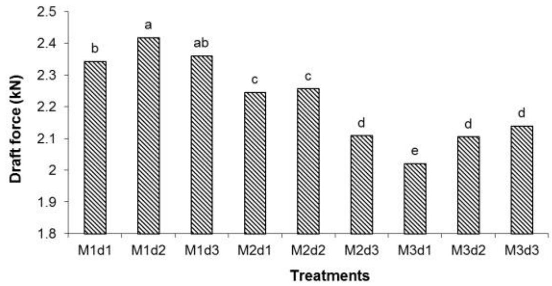

Fig. 10. The interactions between soil moisture and the forward speed on the draft force
M1= Soil moisture of 7-10%, M2= Soil moisture of 10-13%, M3= Soil moisture of 13-16%
d1= Lateral blade spacing of 12 cm, d2= Lateral blade spacing of 16 cm, d3= Lateral blade spacing of 20 cm
Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

The interactions between the forward speed and lateral blade spaces on the draft force of bent leg tillage implement are shown in Fig. 11. The lowest draft force with an amount of 0.87 kN was obtained at the forward speed of 5 km h^{-1} and lateral blade spacing of 12 cm (V1d1). The highest draft force of 3.47 kN was obtained at the forward speed of 10 km h^{-1} and lateral blade spacing of 16 cm (V3d2). However, this treatment (V3d2) was not significantly different (*P=0.05*) from the V3d1 treatment. These results indicated that the effect of the forward speed on the draft force was more compared to the effect of lateral blade spacing of bent leg tillage.

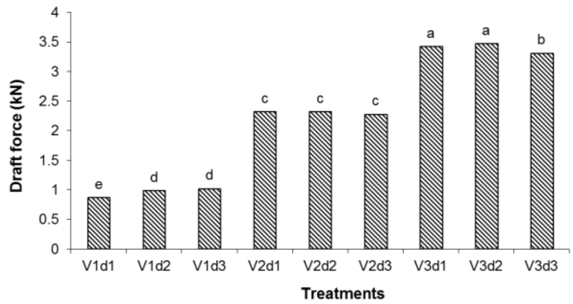

Fig. 11. The interactions between the forward speed and lateral blade spaces on the draft force
V1= Forward speed of 5 km h^{-1}, V2= Forward speed of 7.5 km h^{-1}, V3= Forward speed of 10 km h^{-1}

d1= Lateral blade spacing of 12 cm, d2= Lateral blade spacing of 16 cm, d3= Lateral blade spacing of 20 cm
Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

Soil Disturbance Area

As shown in Fig. 12, the soil disturbance area is influenced by soil moisture. The highest soil disturbance area was measured at the soil moisture content of 7-10% with 0.105 m^2 and the lowest one at the soil moisture content of 10-13% with 0.098 m^2 (Fig. 12). Soil disturbance area of the bent leg tillage implement at soil moisture of 7-10% increased by 7.1% relative to soil moisture of 10-13%. Differences in soil disturbance area were due to the difference in soil failure type. According to similar studies soil disturbance area was affected by soil moisture content (Sharifat, 1999; Rahmatian et al., 2018).

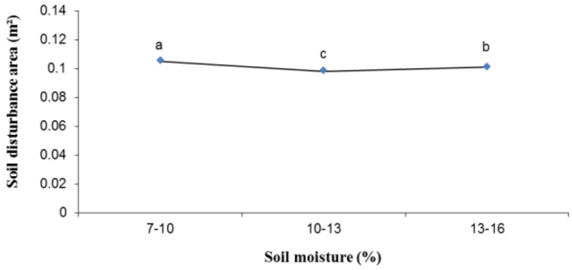

Fig. 12. Effect of soil moisture on soil disturbance area
Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

The effect of the forward speed on the soil disturbance area was not significant (Fig. 13). This is due to the geometry of the bent leg blade. It is in line with the results reported by others (Barr et al., 2016 and 2020).

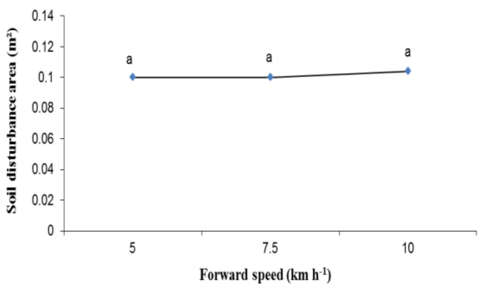

Fig. 13. Effect of forward speed on soil disturbance area
Values with the same letter have no significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

Increasing lateral blade spacing increased soil disturbance area (Fig. 14). Increasing lateral blade spacing from 12 to 20 cm raised soil disturbance area by 25.2% due to the overlap between blades. According to similar studies, increasing lateral blade spacing increased soil disturbance area (Godwin et al., 1984; Godwin, 2007).

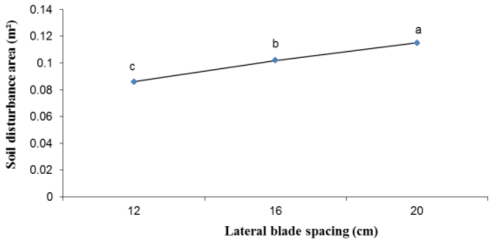

Fig. 14. Effect of lateral blade spacing on soil disturbance area
Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

The interactions between soil moisture content and forward speed on soil disturbance area are shown in Table 2. The highest soil disturbance area of 0.109 m^2 was obtained at the forward speed of 10 km h^{-1} and at soil moisture of 7-10% (M1V3). However, the value of this treatment was not significantly different with the values of the M1V1, M1V2, M3V2, M3V1 and M2V3 treatments. The lowest soil disturbance area of 0.096 m^2 was measured at soil moisture of 10-13% and forward speed of 5 and 7.5 km h^{-1} (M2V1 and M2V2). However, the value of these treatments were not significantly different with the values of the M1V1, M1V2, M3V2, M3V1 and M2V3. Thus, reducing soil moisture and increasing forward speed increased soil disturbance area. However, the effect of soil moisture was more than the forward speed on the size of the soil disturbance area.

As shown in Table 3, the highest soil disturbance area of 0.118 m^2 was obtained at lateral blade spacing of 20 cm and soil moisture of 7-10% (M1d3) which was not significantly different with values of lateral blade spacing of 20 cm and soil moisture of 10-13% and 13-16% treatments (M2d3 and M3d3) and also with the value of lateral blade spacing of 16 cm and soil moisture of 7-10% treatment (M1d2). The minimum soil disturbance area of 0.083 m^2 was measured at lateral blade spacing of 12 cm and soil moisture of 10-13% (M2d1) which was not significantly different from the values of M1d1 and M3d1 treatments. This shows that using the lateral blade spacing of 20 cm at soil moisture of 7-16% can raise the soil disturbance area of a bent leg tillage implement. Thus, it seems that the effect of lateral blade spacing was more than soil moisture on the size of the soil disturbance area.

The maximum soil disturbance area of 0.117 m2 was found at lateral blade spacing of 20 cm and forward speed of 10 km h-1 (Table 4). However, the value of this treatment (V3d3) was not significantly different with the value of V1d3 and V2d3 treatments. The minimum soil disturbance area was obtained at lateral blade spacing of 12 cm and the forward speed of 5 km h-1 (0.084 m2) which was not significant at lateral blade spacing of 12 cm at forward speeds of 7.5 and 10 km h-1. Therefore, increasing forward speed and lateral blade spacing increase soil disturbance area. However, it seems that the effect of lateral blade spaces was more on the soil disturbance area as compared to the effect of the forward speed.

Specific Draft

The lowest specific draft value (20.86 kN m^{-2}) was obtained at the soil moisture content of 13-16% and the highest one (22.92 kN m^{-2}) was obtained at soil moisture of 7-10%. The latter value was not significantly different from the value of soil moisture of 10-13% (Fig. 15). Reducing soil moisture from 13-16% to 7-10% reduced the specific draft of the bent leg tillage implement by 9.0%. Reducing specific draft at soil moisture of 13-16% was due to decreasing in draft force at this soil moisture content. Similar studies have also shown that soil moisture affected specific draft (Salar et al., 2017; Dehghani and Karparvarfard, 2017).

Table 2. Mean comparison of soil disturbance area by different soil moisture contents and forward speeds

Treatments	M1V1	M1V2	M1V3	M2V1	M2V2	M2V3	M3V1	M3V2	M3V3
Soil disturbance area (m^2)	0.103^{ab}	0.103^{ab}	0.109^{a}	0.096^{b}	0.096^{b}	0.101^{ab}	0.099^{ab}	0.100^{ab}	0.103^{ab}

Means followed by the same letter in the row are not significantly different at the 5% level by Duncan's Multiple Range Test.
M1= Soil moisture of 7-10%, M2= Soil moisture of 10-13%, M3= Soil moisture of 13-16%
V1= Forward speed of 5 km h^{-1}, V2= Forward speed of 7.5 km h^{-1}, V3= Forward speed of 10 km h^{-1}

Table 3. Mean comparison of soil disturbance area by different soil moisture contents and lateral blade spacing

Treatments	M1d1	M1d2	M1d3	M2d1	M2d2	M2d3	M3d1	M3d2	M3d3
Soil disturbance area *(m^2)*	0.085^{d}	0.112^{a}	0.118^{a}	0.083^{d}	0.096^{bc}	0.114^{a}	0.090^{cd}	0.099^{b}	0.114^{a}

Means followed by the same letter in the row are not significantly different at the 5% level by the Duncan's Multiple Range Test.
M1= Soil moisture of 7-10%, M2= Soil moisture of 10-13%, M3= Soil moisture of 13-16%
d1= Lateral blade spacing of 12 cm, d2= Lateral blade spacing of 16 cm, d3= Lateral blade spacing of 20 cm

Table 4. Mean comparison of soil disturbance area by different forward speeds and lateral blade spacing

Treatments	V1d1	V1d2	V1d3	V2d1	V2d2	V2d3	V3d1	V3d2	V3d3
Soil disturbance area *(m^2)*	0.084^{d}	0.099^{c}	0.116^{ab}	0.086^{d}	0.100^{c}	0.113^{ab}	0.088^{d}	0.107^{bc}	0.117^{a}

Means followed by the same letter in the row are not significantly different at the 5% level by the Duncan's Multiple Range Test.
V1= Forward speed of 5 km h^{-1}, V2= Forward speed of 7.5 km h^{-1}, V3= Forward speed of 10 km h^{-1}
d1= Lateral blade spacing of 12 cm, d2= Lateral blade spacing of 16 cm, d3= Lateral blade spacing of 20 cm

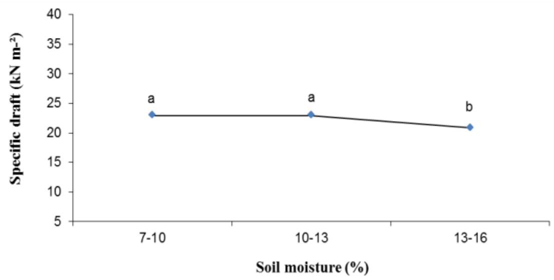

Fig. 15. Effect of soil moisture content on specific draft
Values with the same letter have no significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

Increasing the forward speed raised specific draft (Fig. 16). Increasing the forward speed from 5 to 10 km h^{-1} increased the specific draft of the bent leg tillage implement by 70.7%. The reason could be that the soil disturbance area was not influenced by the forward speed (Fig. 13) but, the draft force significantly increased with raising forward speed (Fig. 7), this would result in increasing in the specific draft. Thus, raising draft force increased specific draft. These results are in line with the results reported by others (Dehghani and Karparvarfard, 2017; Godwin, 2007).

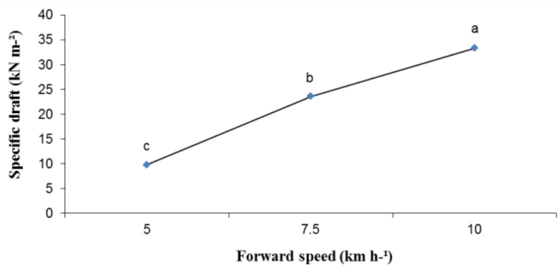

Fig. 16. Effect of the forward speed on specific draft
Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

As detailed in Fig. 17, increasing lateral blade spacing decreased the specific draft of the bent leg tillage implement. Raising lateral blade spacing from 12 to 20 cm decreased the specific draft of the bent leg tillage implement by 24.8%. Because increasing lateral blade spacing strongly increased soil disturbance area

(Fig. 14). Also, raising lateral blade spacing reduced draft force. Other researchers also reported that the lateral blade spacing affected specific draft (Godwin et al., 1984; Godwin, 2007).

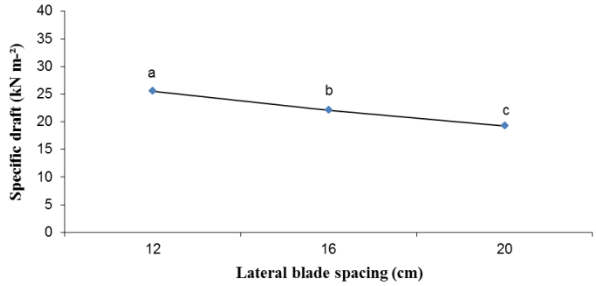

Fig. 17. Effect of lateral blade spacing on specific draft

Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

The interactions between soil moisture and forward speed on the specific draft of the bent leg tillage implement are shown in Fig. 18. The highest specific draft of 34.1 kN m^{-2} was obtained at the highest forward speed of 10 km h^{-1} and soil moisture of 10-13% (M2V3) that was not significantly different from those of the forward speed of 10 km h^{-1} and soil moisture of 7-10% and 13-16% (M1V3 and M3V3). The lowest specific draft of 8.8 kN m^{-2} was calculated at the lowest forward speed of 5 km h^{-1} and soil moisture of 13-16% (M2V1) which was not significantly different from those of the forward speed of 5 km h^{-1} and soil moisture of 7-10% and 10-13% (M1V1 and M3V1). Thus, decreasing forward speed at soil moisture of 7-16% declined specific draft of the bent leg tillage implement. This shows that the effect of the forward speed is more effective than the effect of soil moisture on the specific draft of the bent leg tillage implement.

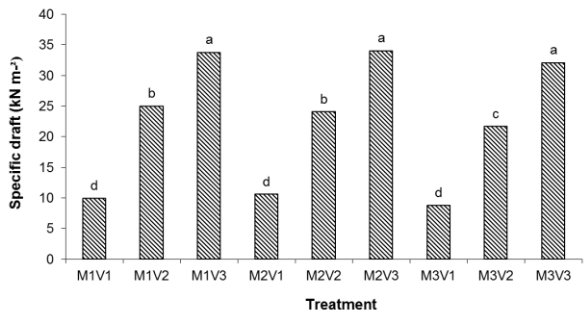

Fig. 18. The interactions between soil moisture and forward speed on specific draft

M1= Soil moisture of 7-10%, M2= Soil moisture of 10-13%, M3= Soil moisture of 13-16%

V1= Forward speed of 5 km h-1, V2= Forward speed of 7.5 km h-1, V3= Forward speed of 10 km h-1

Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

As shown in Fig. 19, the highest values of the specific draft of the bent leg tillage implement were obtained at the lateral blade spacing of 12 cm and soil moisture of 7-10% and 10-13% (M1d1 and M2d1), respectively. The lowest values of the specific draft were obtained at lateral blade spacing of 20 cm and soil moisture of 13-16, 10-13 and 7-10% (M3d3, M2d3 and M1d3), respectively. This showed that both the lateral blade spacing and soil moisture influenced specific draft. However, the effect of lateral blade spacing was more than the effect of soil moisture on the specific draft of the bent leg tillage implement.

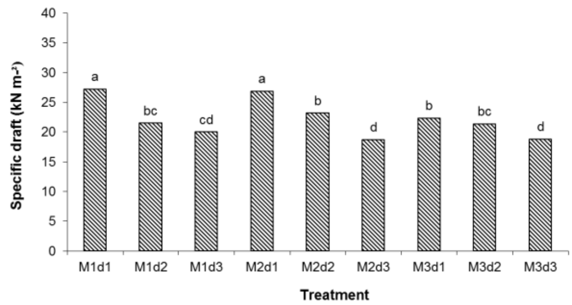

Fig. 19. The interactions between soil moisture and forward speed on specific draft

M1= Soil moisture of 7-10%, M2= Soil moisture of 10-13%, M3= Soil moisture of 13-16%

d1= Lateral blade spacing of 12 cm, d2= Lateral blade spacing of 16 cm, d3= Lateral blade spacing of 20 cm

Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

The maximum specific draft value of the bent leg tillage tool was measured at the highest forward speed of 10 km h^{-1} and the lowest lateral blade spacing of 12 cm (Fig. 20). The minimum specific draft values were measured at the lowest forward speed of 5 km h^{-1} and lateral blade spacing of 20, 16 and 12 cm (V1d3, V1d2 and V1d1), respectively. These results indicated that forward speed and the lateral blade spacing significantly affected specific draft. However, the effect of the forward speed was more than the effect of the lateral blade spacing on the specific draft of the bent leg tillage implement.

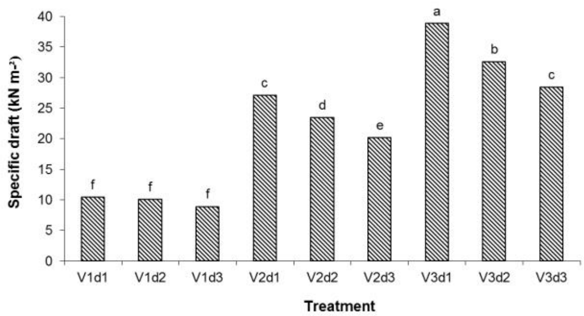

Fig. 20. The interactions between forward speed and lateral blade spacing on specific draft

V1= Forward speed of 5 km h^{-1}, V2= Forward speed of 7.5 km h^{-1}, V3= Forward speed of 10 km h^{-1}

d1= Lateral blade spacing of 12 cm, d2= Lateral blade spacing of 16 cm, d3= Lateral blade spacing of 20 cm

Values with different letters have significant differences in the probability level of 0.05 (*P=0.05*) based on Duncan's Multiple Range Test.

CONCLUSIONS

The results of this study indicated that

1. Increasing soil moisture content significantly reduced the draft force and the specific draft of the bent leg tillage implement (BTI). However, increasing forward speed strongly increased draft force and specific draft. The suitable lateral blade spacing for the bent leg implement studied was recognized to be 16 and 20 cm.

2. Other results showed that the bent leg tillage implement was able to work in dry soil conditions at high speed as 10 km h^{-1}. As a result, increasing forward speed increases the field capacity of the implement which in turn can reduce the cost of tillage operations.

3. The highest draft force for the bent leg implement was determined to be around 3.6 kN at a high forward speed of 10 km h^{-1} in dry soil conditions (7-10% soil moisture). This showed that, due to the geometry of the bent leg blade, the bent leg tillage implement could reduce draft force. Therefore, the bent leg tillage implement can reduce the draft force of tractor and fuel consumption which can decline the environmental hazards due to less CO_2 emission from fuel consumption.

4. The findings of this study showed the potential for the bent leg tillage technology to increase forward speed and lateral blade spaces at tillage operation by reducing draft force; therefore, it can improve field capacity and also decrease the cost of tilling. Moreover, results indicated that the bent leg tillage implement (BTI) was suitable for tilling in dry soil conditions with less soil mixing layer and draft force. The bent leg tillage implement can decline soil disturbance with retaining residue on the soil surface; thus, it can proper for conservation tillage.

5. Further work is recommended to examine the performance of the BTI under conservation farming practices and also to investigate the effects of BTI on crop yield and irrigation efficiency.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Organization of Fars Agriculture-Jahad and Agricultural Research, Education and Extension Organization (AREEO) in co-funding for this research (Research code: 24-50-14-031-950768).

REFRENCES

Abbaspour-Fard, M. H., Hoseini, S. A., Aghkhani, M. H., & Sharifi, A. (2014). The behavior of tillage tools with acute and obtuse lift angles. *Spanish Journal of Agricultural Research*, 12(1), 44-51.

Al-Neama, A. K. & Herlitzius, T. (2017). Draft forces prediction model for standard single tines by using principles of soil mechanics and soil profile evaluation. *Landtechnik*, 72(3), 157-164.

Askari, M., Shahgholi, G., & Abaspour-Gilandeh, Y. (2017). The effect of tine, wing, operating depth and speed on the draft requirement of subsoil tillage tines. *Research Agricultural Engineering*, 63(4), 160-167.

Barr, J. B., Desbiolles, J., & Fielke, J. (2016). Minimising soil disturbance and reaction force for high speed sowing using bentleg furrow openers. *Biosystems Engineering*, 151, 53-64.

Barr, J. B., Desbiolles, J., Fielke, J., & Ucgul, M. (2019). Development and field evaluation of a high-speed no-till seeding system. *Soil and Tillage Research*, 194, 104337.

Barr, J. B., Desbiolles, J., Ucgul, M., & Fielke, J. (2020). Bent leg furrow opener performance analysis using the discrete element method. *Biosystems Engineering*, 189, 99-115.

Dehghani, M., & Karparvarfars, S. H. (2017). Optimizing of chisel tine operation used in combined tillage machine. *Iranian Journal of Biosystems Engineering*, 47(4), 651-658.

Esehaghbeygi, A., Tabatabaeefar, A., Keyhani, A. R., & Raoufat, M. H. (2005). Depth and rake angle's influence on the draft force of an oblique blade subsoiler. *Iran Agricultural Science*, 36(4), 1045-1052.

Fielke, J. M. (1996). Interactions of the cutting edge of tillage implements with soil. *Journal of Agricultural Engineering Research*, 63(1), 61-72.

Godwin, R. J. (2007). A review of the effect of implement geometry on soil failure and implement forces. *Soil and Tillage Research*, 97(2), 331-340.

Godwin, R. J., & Spoor, G. (1977). Soil failure with narrow tine. *Journal of Agricultural Engineering Research*, 22(3), 213-228.

Godwin, R. J., Spoor, G., & Soomro, M. S. (1984). The effect of tine arrangement on soil forces and disturbance. *Journal of Agricultural Engineering Research*, 30, 47-56.

Godwin, R. J., & O'Dogherty, M. J. (2007). Integrated soil tillage force prediction models. *Journal of Terramechanics*, 44 (1), 3-14.

Harrison, H. P. (1990). Soil reacting force for two, tapered bentleg plows. *Transactions of the ASAE*, 33(5), 1473-1476.

Hoseini, S., & Karparfard, S. H. (2012). A prediction of force acting on chisel plow tine through dimensional analysis method (dimensional analysis approach). *Iranian Journal of Biosystems Engineering*, 43(1), 93-103.

Kepner, R. A., Bainer, R., & Barger, E. L. (1978). *Principles of farm machinery*, chapter 5. New York: The AVI Publishing Company

Majidi, H., & Raoufat, M. H. (1997). Power requirement of a bentleg plow and its effects on soil physical conditions. *Iran Agricultural Research*, 16, 1-16.

Manuwa, S. I., & Ademosun, O. C. (2007). Draught and soil disturbance of model tillage tines under varying soil parameters. *Agricultural Engineering International: CIGR Journal*, 6(16), 1-18.

Moeenifar, A., Mousavi-Seyedi, S. R., & Kalantari, D. (2014). Influence of tillage depth, penetration angle and forward speed on the soil/tine-blade interaction force. *Agricultural Engineering International: CIGR Journal*, 16 (1), 69-74.

Naderloo, L., Alimardani, R., Akram, A., Javadikia, P., & Zeinali Khanghah, H. (2009). Tillage depth and forward speed effects on draft of three primary tillage implements in clay loam soil. *Journal of Food, Agriculture and Environment*, 7(3 & 4), 382-385.

Payne, P. C. J., & Tanner, D. W. (1959). The relationship between rake angle and the performance of simple cultivation implements. *Journal of Agricultural Engineering Research*, 4(4), 312-325.

Rahmatian, M., Karparvarfard, S. H., & Nematollahi, M. A. (2018). Prediction for optimizing performance of chisel blade used in combined tillage to obtain suitable effectiveness. *Iran Journal of Biosystems Engineering*, 49(1), 73-82.

Raoufat, M. H., & Mashadi Mighani, H. (1999). Appropriate tine spacing of a double bentleg plow for better tillage and efficient performance. *Iranian Journal of Agricultural Science*, 30(2), 319-330.

Raoufat, M. H. & Firozi, S. (1998). Field evaluation of a dual bentleg plow. *Iran Agricultural Research*, 17, 67-82.

Regional Network for Agricultural Machinery. (1983). RNAM test codes and procedures for farm machinery. Technical series No. 12, Bangkok, Thailand. 129 pp.

Rosa, U. A., & Wulfsohn, D. (2008). Soil bin monorail for high-speed testing of narrow tillage tools. *Biosystems Engineering*, 99(3), 444-454.

Salar, M. R., & Karparverfard, S. H. (2017). Modeling and optimization of wing geometry effect on draft and vertical force of winged chisel plow. *Journal of Agricultural Machinery*, 7, 468-479.

Sharifat, K. (1999). *Soil translocation with tillage tools*. (Doctoral dissertation, University of Saskatchewan, Canada).

Solhjou, A., & Alavimanesh, S. M. (2019). Effect of soil moisture, forward speed and bent leg blade spaces on soil pulverization. *Journal of Engineering Research in Agricultural Mechanization and Systems*, 73(20), 83-92.

Solhjou, A., Desbiolles, J., & Fielke, J. (2013). Soil translocation by narrow openers with various blade face geometries. *Biosystems Engineering*, 114(3), 259-266.

Solhjou, A., Fielke, J., & Desbiolles, J. (2012). Soil translocation by narrow openers with various rake angles. *Biosystems Engineering*, 112(1), 65-73.

Solhjou, A., Fielke, J., Desbiolles, J., & Saunders, C. (2014). Soil translocation by narrow openers with various bent leg geometries. *Biosystems Engineering*, 127, 41-49.

تحقیقات کشاورزی ایران (۱۴۰۰) ۴۰(۲)۶۰-۵۱

مقاله علمی- پژوهشی

دانشگاه شیراز

ارزیابی مزرعه‌ای یک دستگاه خاک‌ورز کج‌ساق

علی اکبر صلح‌جو[*]، محمد شاکر

بخش تحقیقات فنی و مهندسی کشاورزی، مرکز تحقیقات و آموزش کشاورزی و منابع طبیعی فارس، سازمان تحقیقات، آموزش و ترویج کشاورزی، شیراز ج.ا. ایران

*نویسنده مسئول

اطلاعات مقاله

تاریخچه مقاله:

تاریخ دریافت: ۱۴۰۰/۰۲/۲۱

تاریخ پذیرش: ۱۴۰۰/۱۱/۲

تاریخ دسترسی: ۱۴۰۰/۱۲/۱۴

واژه‌های کلیدی:

سرعت پیشروی

شکل‌هندسی تیغه

کج‌ساق

نیروی کشش

چکیده - هدف از انجام تحقیق حاضر، تعیین اثر شکل هندسی خاک‌ورز کج‌ساق بر نیروی کشش مصرفی و مقاومت ویژه بود. این مطالعه در قالب طرح آماری کرت‌های دوبار خرد شده با سه تکرار اجرا شد. کرت اصلی، رطوبت خاک شامل ۱۰-۷، ۱۳-۱۰ و ۱۶-۱۳ درصد، کرت فرعی، سرعت پیشروی شامل ۵، ۷/۵ و ۱۰ کیلومتر بر ساعت و کرت فرعی- فرعی، فاصله بین تیغه‌های کج‌ساق شامل ۱۲، ۱۶ و ۲۰ سانتی‌متر بود. نتایج نشان داد که اثر سرعت پیشروی تراکتور، فاصله بین تیغه‌های کج‌ساق و درصد رطوبت خاک در زمان خاک‌ورزی بر نیروی کشش مصرفی و مقاومت ویژه موثر هستند. کاهش رطوبت خاک از ۱۶-۱۳ به ۱۰-۷ درصد، نیروی کشش مصرفی را ۱۲ درصد افزایش و مقاومت ویژه را ۹ درصد کاهش داد. افزایش سرعت پیشروی از ۵ به ۱۰ کیلومتر بر ساعت به ترتیب نیروی کشش مصرفی و مقاومت ویژه را ۷۱/۸ و ۷۰/۷ درصد افزایش داد. فاصله عرضی مناسب بین تیغه‌های خاک‌ورز کج‌ساق ۱۶ و ۲۰ سانتی‌متر تشخیص داده شد. دیگر یافته‌ها نشان داد که شکل هندسی و خصوصیات خاک‌ورز کج‌ساق، پتانسیل کاهش نیروی کشش مصرفی در سرعت پیشروی زیاد را دارد.