Effect of tillage methods and seeding by a bent leg grain drill on wheat yield and water productivity

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Abstract: The factors influencing on seed germination and wheat yield are such as the optimum use of tillage and seeding methods. This study was a randomized complete block experimental design with four treatments and four replications to determine the suitable tillage method for a grain drill with bent leg furrow opener (bent leg grain drill) and also determine the effect of these implements on wheat yield and water productivity in dry soil conditions. Treatments were seeding wheat by a bent leg grain drill in three tillage application of no-tillage (NT), reduced tillage (RT), conventional tillage (CT) and also control (conventional tillage + seeding wheat by conventional grain drill). Results indicated that tillage methods and seeding wheat by the bent leg grain drill affected residue remained on the soil surface, soil bulk density, seedling emergence percent, wheat yield and water productivity. Reduce tillage by the bent leg tillage implement and seeding by the bent leg grain drill (RT) increased residue remained on the soil surface (45%), seedling emergence (13%), wheat yield (11%) and water productivity (11%) compared to the control. The bent leg tillage provides a proper seedbed for seeding wheat with less passes of tractor in dry soil conditions. The results show that the technology of bent leg tillage and bent leg grain drill has the potential to increase wheat yield and water productivity.

Keywords: no tillage, reduced tillage, conventional tillage

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1 Introduction

The factors previously identified in the literature influencing soil disturbance include: soil conditions such as texture, moisture and structure, tool settings like working depth, forward speed and tool geometry (Godwin and O'Dogherty, 2007; Godwin, 2007; Sharifat, 1999; Solhjou et al., 2012). One of the important factors which affect soil disturbance is the geometry of opener. One important factor of opener geometry is rake angle. The rake angle of tool affects draft force, soil failure and soil layer mixing (Godwin and Spoor, 1977; Solhjou et al., 2012). Increasing rake angle increases draft force and reduces the cross-section area of furrow (Payne and Tanner, 1959; Godwin, 2007; Solhjou et al., 2012). Adding a chamfer to the face of vertical narrow opener 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 cross-section area of furrow and the opener critical depth.

Bent leg subsoiler made reducing soil compaction in deep layers (about 30-50 cm) and breaks hard pan (Harrison, 1990; Raoufat and Mighani, 1999;

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Esehaghbeygi et al., 2005). However, bent leg tillage implement made working in shallow depth (10-15 cm) that reduces clod mean weight diameter (MWD) in the field (Solhjou and Alavimanesh, 2019) and declines draft force.

Different tillage and seeding methods affect seed germination due to changing in soil physical conditions of seedbed, soil temperature, soil moisture and soil resistance (Godwin, 1990). Uniform seed germination and fast germination of wheat seeds can increase crop yield (Hemmat, 1996). No-till reduces wheat yield compare to reduced tillage (RT) or conventional tillage (CT) under irrigated conditions (Sarikhani et al., 2018; Afzalinia et al., 2019; Pittelkow et al., 2015). However, some researchers indicated that there was no significant difference between tillage methods from the irrigated wheat yield point of view (Hedayatipour and Alamouti, 2018; Afzalinia et al., 2012). Different methods of tillage can use for seedbed preparation, residue management, erosion control and weed control. However, tillage method selection is affected by the local consideration such as technical, pedo-climic and socio-economical constraints (Guerif et al., 2001). The objective of this study was to evaluate the effect of tillage methods and seeding by a grain drill with bent leg furrow opener on wheat yield and water productivity in dry soil conditions.

2 Material and methods

The experiments were undertaken in the field conditions (clay loam, 34.0% sand, 39.6% silt and 26.4% clay) in Zarghan region of Fars province of Iran. This study was a randomized complete block experimental design with four treatments and four replications to determine the suitable tillage method for a grain drill with bent leg furrow opener (bent leg grain drill) and also determine the effect of these implements on wheat yield and water productivity in dry soil conditions (7.7%, based on dry basis). Treatments were seeding winter wheat by a grain drill with bent leg furrow opener (Figure 1) in three tillage practices of no-tillage (NT), RT, and CT. Seeding wheat by conventional grain drill in the conventionally tilled plots was also used as control treatment (C). The size of each plot was 3 m × 20 m.

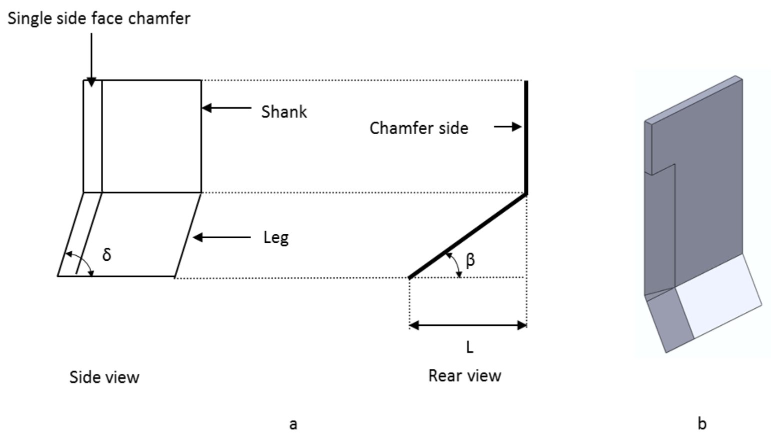
The RT plots were prepared with one pass of the bent leg tillage implement and seeding wheat by a grain drill with the bent leg furrow opener. The bent leg tillage implement made of nine blades with lateral blade spaces of 17 cm and working at depth of 13-15 cm (Figure 2). The bent leg blade with a chamfered faced, was constructed from 15 mm thick steel. The geometry parameters of experimental bent leg blade were the shank offset of 45 mm (L), side bend angle of 45° (β), leg forward angle of 70° (δ) and single side face chamfer of 17°. The details of the bent leg blade are shown in Figure 3. In NT, wheat planted directly by a grain drill with the bent leg opener that had 11 bent leg openers with lateral opener spaces of 17 cm (Figure 1). Seed bed preparation was performed for treatments of CT and control (C) with operating one pass of combined tillage implement (including seven sweep blade, three discs and one roller, together) which made in Overum of Austria and two times of disc harrow to reduce clods in dry soil conditions. For seeding wheat in the control treatment (C) was used a Sazehkesht grain drill that made in Iran and had 15 inverted T openers with 17 cm lateral spaces (Figure 4). The bent leg grain drill was the conventional grain drill which the furrow openers of it has been changed with the bent leg furrow openers. Also, 180 kg ha^{-1} wheat seeds (Parsi cultivar) were planted in all treatments. The parameters which measured in this study were residue remained on the soil surface, soil bulk density, seedling emergence, 1000 seeds weight, wheat yield, water consumption and water productivity.

Residue remained on the soil surface was determined for the samples taken from area of 0.5 by 0.5 m with four replications in each plot. Soil bulk density was measured with taking samples at the soil depth of 0 cm -10 cm and 10 cm -20 cm using core samplers and drying samples at 105°C for 24 hours in oven. To determine seedling emergence percent, the length of one meter with three replications was randomly selected in each plot. Emerged seeds were counted and the seedling emergence percent was calculated. Irrigation operations was performed by tape in drip irrigation system with a dripper distance of 20 cm and a strip distance of 60 cm. Water requirement of wheat was corrected by Cropwat 7 software and

Penman Monteith equation and calculated considering the crop coefficient in every irrigation season. Finally, considering the irrigation efficiency of 90%, wheat water requirement was applied evenly on the plots by the volume counter after deducting of effective rainfall (USDA method). To control weeds, the same herbicide was used for all treatments. To determine wheat yield, an area of 10 m^2 was harvested in each plot and weight of grain was considered as wheat yield. The 1000 seeds weight was measured by taking a random sample of whole grains using a grain counter. All the statistical analyses were performed using SAS software and Duncan Multiple Range Tests ($p= 0.05$) were used to compare the treatments means.

Figure 1 The grain drill with bent leg furrow opener

Figure 2 The bent leg tillage implement



(a) geometry of bent leg blade (b) isometric view

Figure 3 The bent leg blade

Note: L= shank lateral offset, β= side bend angle and δ= leg forward angle

Figure 4 The conventional grain drill with inverted T furrow opener

3 Results and discussion

3.1 Residue remained on the soil surface

Results indicated that tillage methods and seeding by a bent leg grain drill affected residue remained on the soil surface (Table 1). The highest residue remained on the soil surface was obtained at NT with amount of 80.55% and the lowest of it was obtained at control (C) with amount of 16.43%. The residue remained on the soil surface at NT and RT by the bent leg tillage implement (RT) increased 64% and 45% compare to the control treatment (C), respectively. Results showed that tillage methods strongly influenced residue remained on the soil surface percent (Table 1). Increasing residue remained on the soil surface at NT and RT compared to the control (C) was due to the geometry of bent leg blade which can decrease soil layer mixing and also soil translocation (Solhjou et al., 2014, 2017; Bar et al., 2020).

Table 1 Mean comparison of tillage methods for residue remained on the soil surface and soil bulk density

Treatments	Residue remained on the soil surface (%)	Soil bulk density (g cm^{-3})	
		0-10 cm	10-20 cm
NT	80.55[a]	1.37[a]	1.58[a]
RT	61.50[b]	1.31[a]	1.48[b]
CT	18.98[c]	1.32[a]	1.48[b]
C	16.43[c]	1.33[a]	1.47[b]

Note: Means followed by the same letter in the same column are not significantly different at the 5% level by the Duncan Multiple Range Test.

3.2 Soil bulk density

As shown in Table 1, tillage methods and seeding wheat by grain drill did not influence soil bulk density at soil depth of 0-10 cm. Because, all tillage tools and planters worked at soil depth of 0-10 cm. Other researchers showed that surface soil bulk density (0-10 cm) was not affected by tillage methods (Afzalinia et al., 2012; Zarifneshat et al., 2019). However, tillage methods affected soil bulk density at the soil depth of 10-20 cm (Table 1). The highest soil bulk density at soil depth of 10-20 cm was measured at NT with 1.58 g cm^{-3} because in spite of other treatments, openers of direct seeder did not disturb the soil 10-20 cm depth layer in NT treatment. The lowest of soil bulk density was obtained at the control (C) with 1.47 g cm^{-3} which was not significantly different from those of RT and CT. RT by the bent leg tillage implement declined soil bulk density at soil depth of 0-20 cm similar to CT. This showed that the bent leg tillage implement can reduce soil bulk density and increase residue cover compared to CT. Seed bed preparation with one pass of tractor by the bent leg tillage implement (RT) compare to three passes of tractor in CT can be another advantage for the bent leg tillage implement in dry soil conditions.

3.3 Seedling emergence

Tillage methods and seeding wheat by a grain drill with bent leg furrow opener affected seedling emergence percent (Table 2).

Table 2 Mean comparison of tillage methods for seedling emergence, 1000 seeds weight, water consumption and water productivity

Treatments	Seedling emergence (%)	1000 seeds weight (g)	Water consumption (m^3 ha^{-1})	Water productivity (kg m^{-3})
NT	72.50[ab]	44.08[a]	5573.33	0.87[c]
RT	75.00[a]	45.08[a]	5573.33	1.01[a]
CT	70.22[bc]	44.70[a]	5573.33	0.94[b]
C	66.56[c]	44.08[a]	5573.33	0.91[b]

Note: Means followed by the same letter in the same column are not significantly different at the 5% level by the Duncan Multiple Range Test.

The maximum seedling emergence of 75% was obtained from RT and the minimum one was obtained from the control treatment (C) with 66.56%. This showed that seeding wheat by the bent leg grain drill in the plots tilled by the bent leg tillage implement (RT) increased seedling emergence by 13% compared to the control (C). Overall, using the bent leg tillage implement (RT) and seeding wheat by the bent leg furrow opener (NT) can increase seedling emergence percent relative to the CT and C that were tilled by the combined tillage implement. The bent leg blade reduces the mixing of soil layers (Solhjou et al., 2014; Bar et al., 2019). Reducing the mixing of soil layers can reduce residue burial into seed zone and increase seeds contact with soil; thus, the bent leg blade can increase seedling emergence compare to the control (C). Also, Solhjou and Alavimanesh (2019) reported that reducing clods by the bent leg blade can improve the conditions of seeding for planters which can increase seedling emergence.

3.4 1000 seeds weight

As shown in Table 2, tillage methods and seeding wheat by the bent leg grain drill did not influenced 1000 seeds weight. The 1000 seeds weight was measured at RT with 45.08 g which was not significantly different to other treatments. Other researchers obtained the same results for the effect of tillage methods on 1000 seeds weight (Afzalinia et al., 2012; Asoodar et al., 2018).

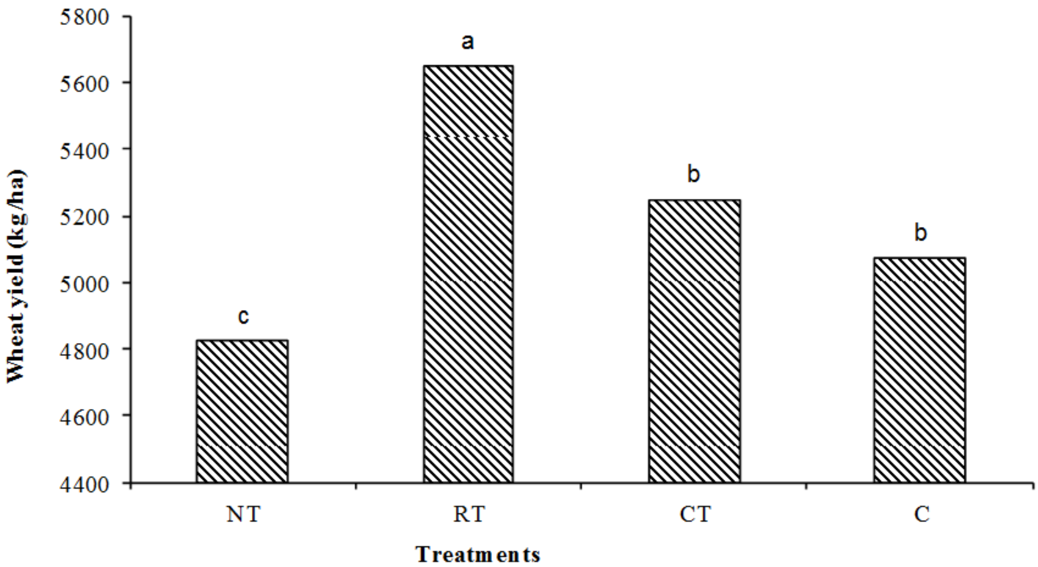


Figure 5 Effect of tillage methods on wheat yield

3.5 Wheat yield

Tillage methods and seeding by a bent leg grain drill influenced wheat yield (Figure 5). The highest wheat yield was measured in RT with 5650 kg ha^{-1} and the lowest yield was obtained from NT with 4824 kg ha^{-1}. Overall, RT increased irrigated wheat yield compared to the no-tillage. Other researchers reported that irrigated wheat yield increased by RT method relative to the no-tillage (Pittelkow et al., 2015; Sarikhani et al., 2018; and Afzalinia et al., 2019). Results indicated that seeding wheat by the bent leg grain drill in plots tilled by the bent leg tillage implement (RT) increased wheat yield by 17% and 11% compared to NT and the control (C), respectively. Since tilling with the bent leg tillage implement (RT) increased seedling emergence percent and residue remained on the soil surface, and also reduced soil bulk density at soil depth of 10-20 cm, RT had the highest wheat yield compared to other treatments. Increasing residue remained on the soil surface raised soil moisture conservation and also decreasing soil bulk density increased root development in soil which can increase wheat yield.

3.6 Water productivity

As shown in Table 2, tillage methods and seeding wheat by the bent leg grain drill affected water productivity. The greatest water productivity was obtained in RT with 1.01 kg m^{-3} and the lowest of it was obtained from NT with 0.87 kg m^{-3}. Seeding wheat by the bent leg grain drill in plot tilled by the bent leg tillage implement (RT) increased water productivity by 11% relative to the control (C). Because of tilling by the bent leg tillage implement (RT) raised wheat yield (Figure 5) compare to other treatments.

4 Conclusions

The effect of seeding wheat by the bent leg grain drill in various tillage methods was evaluated in dry soil conditions. Results of this study showed that seeding wheat by the bent leg grain drill in different tillage methods of NT, RT and CT affected residue remained on the soil surface, soil bulk density, seedling emergence, wheat yield and water productivity. Results also indicated that the bent leg grain drill can plant wheat in different tillage methods. The RT by the bent leg tillage implement and seeding wheat by the bent leg grain drill increased residue remained on the soil surface, seedling emergence, wheat yield and water productivity relative to CT. This shows that the bent leg tillage implement can prepare a suitable seedbed preparation for seeding wheat in dry soil conditions, due to the geometry of bent leg blade. Therefore, the bent leg tillage implement can use instead of CT for seedbed preparation with less passes of tractor in dry soil conditions. The findings indicate that the technology of bent leg tillage and bent leg grain drill have the potential to increase wheat yield and water productivity. Further work should also lie in the validation of the bent leg grain drill benefits under no-till in rainfed conditions. Further work is also necessary to evaluate the effect of the grain drill with bent leg furrow opener under adhesive no-till soil conditions under different environment and management.

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