Effect of tillage methods and seeding by a bent leg grain drill on wheat yield in rainfed conditions

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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 opener (bent leg grain drill) and also determine the effect of these implements on soil moisture conservation and rainfed wheat yield in dry soil conditions. Treatments were seeding wheat by a bent leg grain drill in four tillage application of direct seeding (no-tillage), bent leg tillage (reduced tillage), bent leg tillage + disc (reduced tillage), and chisel plough + disc (conventional tillage). Results indicated that tillage methods and seeding wheat by the bent leg grain drill affected residue remained on the soil surface, soil bulk density, soil moisture, seedling emergence percent and wheat yield. Reduce tillage by the bent leg tillage implement and seeding by the bent leg grain drill increased residue remained on the soil surface (31%), seedling emergence (26%), soil moisture conservation before harvesting (22.9%), and wheat yield (19.8%) compared to the conventional tillage. 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 soil moisture conservation and wheat yield in rainfed conditions.

Keywords: no tillage, reduced tillage, soil moisture, bent leg opener

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1 Introduction

Due to the recent droughts in Iran, choosing proper implements to reduce clod in dry soil conditions is still under investigation. Soil moisture content has an important effect on tillage quality (Solhjou and Alavimanesh, 2023). Previous studies showed that clod mean weight diameter (MWD) increased with decreasing soil moisture content (Solhjou and Alavimanesh, 2020).

In Iran, the conventional tillage is considered as the moldboard plough followed by disc harrow which damage soil. Also, tillage using moldboard plough creates large clods size in dry soil conditions which requires using several times of disc harrow to break them down. Tillage intensity could be declined in Iran (Solhjou et al., 2022). No-till may not produce suitable crop production; therefore, some degree of

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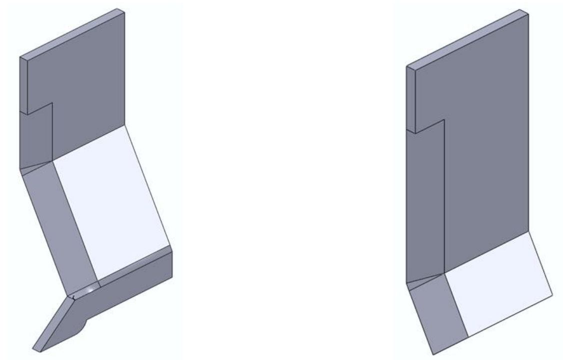
soil disturbance is necessary (Sarikhani Khorami et al., 2018; Afzalinia et al., 2019). Previous studies showed that the chisel plough was an alternative for the moldboard plough in Iran (Jafarian et al., 2022). Primary studies about reduced tillage implements have indicated low penetration ability in dry and heavy soils and tyre slippage for medium power tractors due to high draft force requirements (Solhjou and Alavimanesh, 2023).

The factors previously identified in the literature influencing soil disturbance include: soil conditions such as texture, moisture and structure, tool setting like working depth, forward speed and tool geometry (Barr et al., 2020; Aikins et al., 2021; Solhjou et al., 2022). One of the important factors which affect soil disturbance is the geometry of the tool such as rake angle. The rake angle affects draft force, soil failure and mixing of soil layers (Aikins et al., 2021; Sang et al., 2022). Increasing rake angle increases draft force and reduces the cross-sectional area of furrow (Barr et al., 2020; Sang et al., 2022). 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 furrow cross-sectional area and the opener critical depth.

Solhjou et al. (2014) quantified the soil disturbance and soil translocation of a bent leg opener design in a soil bin. As shown in Figure 1, 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 (Figure 1a) developed by a South African farmer (Barr et al., 2020), who scaled down the concept of bent leg subsoilers aiming to reduce draft force and surface soil disturbance (Aikins et al., 2021). Solhjou et al. (2014) found that the bent leg opener without a foot and shank offset of 45 mm had the potential to increase the furrow cross-sectional area with less soil translocation and soil mixing (Figure 1b). 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 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 seeding system showed that increasing forward speed from 8 to 12 $km\ h^{-1}$ had no penalty to wheat emergence. However, increasing forward speed of seeders using straight opener reduced wheat emergence by 31% (Barr et al., 2019).



(a) Footed bent leg opener (b) Footless bent leg opener

Figure 1 Bent leg openers (left) with a foot component and (right) without a foot component (Solhjou et al., 2014)

Bent leg subsoiler made reducing soil compaction in deep layers (about 30-50 cm) and breaks hard pan (Raoufat and Mighani, 1999; Esehaghbeygi et al., 2005). However, bent leg tillage implement made working in shallow depth (10-15 cm) that reduces clod (MWD) in the field (Solhjou and Alavimanesh, 2023) and declines draft force (Solhjou and Shaker, 2022).

No-till increases wheat yield compared to reduced tillage or conventional tillage under rainfed conditions (Ali et al., 2019; Santín-Montanyá et al., 2017). Some researchers found that conventional tillage increases rainfed wheat yield compared to no-till or reduced tillage (Armstrong et al., 2018; Koocheki et al., 2020). However, some researchers indicated that there was no significant difference between tillage methods from the rainfed wheat yield point of view (Heidari and Soltani, 2016; Souissi et al., 2020). The objective of this study was to evaluate the effect of tillage methods and seeding by a grain drill with footless bent leg opener on soil moisture conservation and rainfed wheat yield in dry soil conditions.

2 Material and methods

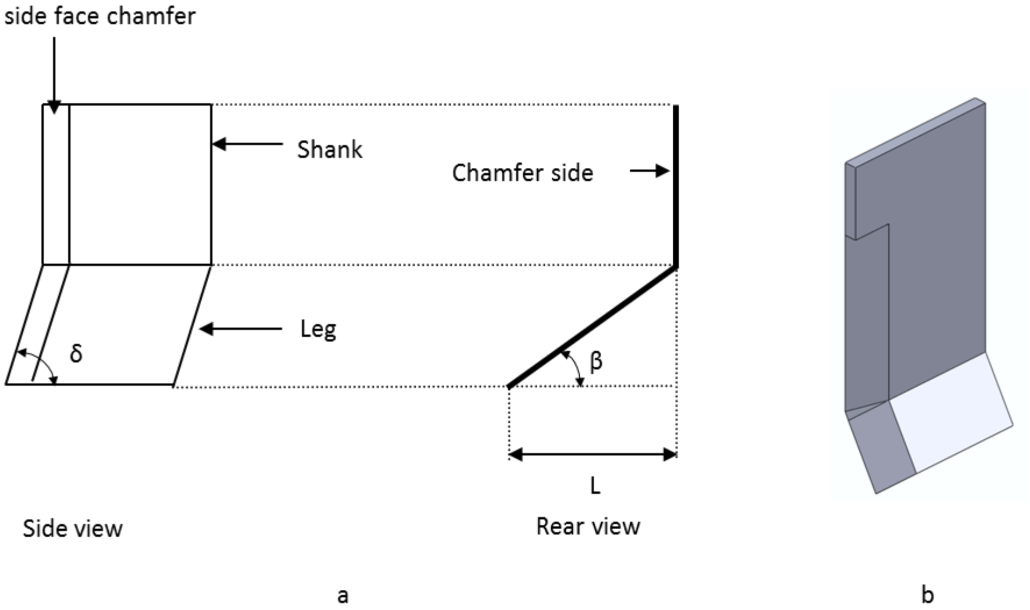
The experiments were undertaken in the field conditions (sandy loam, 73.6% sand, 16.0% silt and 10.4% clay) in Mamassani region of Fars province, Iran in 2021-2022. The site is located at latitude 30°01´N and longitude 51°57´E. This study was a randomized complete block experimental design with four treatments and four replications to determine the suitable tillage method for a grain drill with bent leg opener (bent leg grain drill) and also determine the effect of these implements on soil moisture conservation and rainfed wheat yield in dry soil conditions (1.5%, based on dry basis). Treatments were seeding winter wheat by a grain drill with bent leg opener (Figure 2) in four tillage practices of no-tillage (NT), bent leg tillage- reduced tillage (RT), bent leg tillage + disc- reduced tillage (RT1), and chisel plough + disc- conventional tillage (CT). The area of each plot was 5 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 opener. The RT1 plots were prepared with one pass of the bent leg tillage implement + one pass of disc harrow and seeding wheat by a grain drill with the bent leg opener. The bent leg tillage implement made of 10 blades with lateral blade spaces of 17 cm and working at depth of 13-15 cm (Figure 3). 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° (Figure 4). 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 2). Seed bed preparation was performed for treatment of CT with operating one pass of chisel plough which made in Fanavaran Mehvar of Iran and two times of disc harrow to reduce clods in dry soil conditions. Also, 120 kg ha^{-1} wheat seeds (Karim 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, soil moisture, 1000 seeds weight, and wheat yield.

Figure 2 The grain drill with bent leg furrow opener

Figure 3 The bent leg tillage implement

Residue remained on the soil surface was determined for the samples taken from area of 0.5 by 0.5 m with three replications in each plot. Soil bulk density was measured with taking samples at the soil depths of 0-10 cm and 10 cm -20 cm using core samplers and drying samples at 105˚C for 24 hours in oven. Soil moisture content (dry weight basis) was measured at soil depths of 0-10, 10-20 and 20-30 cm with three replications in each plot and in three stages of: after seeding wheat, at stemming stage and before harvesting wheat. 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. To determine wheat yield, an area of 5 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.



(a) Geometry of bent leg blade (b) Isometric view

Figure 4 Bent leg blade

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

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 82.40% and the lowest of it was obtained at CT with amount of 51.38%. The residue remained on the soil surface at NT and RT increased 60% and 31% compared to the CT, 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 CT was due to the geometry of bent leg blade which can decrease soil layer mixing and also soil translocation (Solhjou et al., 2014; Barr 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	82.40^a	1.39^a	1.61^a
RT	67.40^b	1.33^a	1.50^b
RT1	63.53^b	1.35^a	1.50^b
CT	51.38^c	1.36^a	1.50^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 cm -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 (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 cm -20 cm was measured at NT with 1.61 $g\ cm^{-3}$ because in spite of other treatments, openers of direct seeder did not disturb the soil 10 cm -20 cm depth layer in NT treatment. The lowest of soil bulk density was obtained at the CT with 1.50 g cm^{-3} which was not significantly different from those of RT and RT1. Reduced tillage 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) compared to three passes of tractor in CT can be another advantage for the bent leg tillage implement in dry soil conditions.

3.3 Soil moisture content

As shown in Table 2, tillage methods and seeding wheat by the bent leg grain drill did not affect soil moisture content after seeding wheat. However, tillage methods and seeding wheat by the bent leg grain drill influenced soil moisture content at stemming stage and before harvesting wheat. Overall, NT and RT increased soil moisture conservation at soil depth of 0-30 cm compare to CT. Results indicated that at stemming stage, seeding wheat by the bent leg grain drill in plots NT and tilled by the bent leg tillage implement (RT) increased soil moisture conservation at soil depth of 0-30 cm by 6.4% and 5.6% compared to CT, respectively. Also, at stage of before harvesting wheat, seeding wheat by the bent leg grain drill in plots NT and tilled by the bent leg tillage implement (RT) raised soil moisture conservation by 15.5% and 22.9% compared to CT, respectively. The bent leg blade reduces the mixing of soil layers (Solhjou et al., 2014; Barr et al., 2019) and reducing the mixing of soil layers can increase residue remained on the soil surface which can increase soil moisture conservation.

Table 2 Mean comparison of tillage methods for soil moisture content after seeding wheat, at stemming stage and before harvesting wheat

Soil depth (cm)	Soil moisture (%)			
	NT	RT	RT1	CT
After seeding wheat				
0-10	16.83[a]	17.48[a]	17.68[a]	16.53[a]
10-20	17.28[a]	17.18[a]	17.18[a]	17.58[a]
20-30	18.38[a]	19.28[a]	18.00[a]	17.78[a]
Stemming stage				
0-10	11.90[a]	11.53[ab]	11.70[ab]	11.00[b]
10-20	13.75[a]	13.50[a]	13.43[a]	12.63[b]
20-30	14.23[ab]	14.53[a]	14.15[ab]	13.83[b]
Before harvesting wheat				
0-10	5.38[a]	5.33[ab]	4.50[bc]	4.10[c]
10-20	6.23[b]	6.88[a]	5.45[c]	5.43[c]
20-30	5.60[b]	6.13[a]	5.30[b]	5.38[b]

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

3.4 Seedling emergence

Tillage methods and seeding wheat by a grain drill with bent leg opener affected seedling emergence (Table 3). The maximum seedling emergence of 69.65% was obtained from NT and the minimum one was obtained from the CT with 50.23%. This showed that seeding wheat by the bent leg grain drill in the plots no-tillage and tilled by the bent leg tillage implement (NT and RT) increased seedling emergence by 39% and 26% compared to the CT, respectively. Overall, seeding wheat by the bent leg furrow opener (NT) and using the bent leg tillage implement (RT) can increase seedling emergence percent relative to the CT that were tilled by the chisel plough. The bent leg blade reduces the mixing of soil layers (Solhjou et al., 2014; Barr et al., 2019) and 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 CT. Also, Solhjou and Alavimanesh (2020) reported that reducing clods by the bent leg blade can improve the conditions of seeding for planters which can increase seedling emergence.

Table 3 Mean comparison of tillage methods for seedling emergence, 1000 seeds weight, water consumption and water productivity

Treatments	Seedling emergence (%)	1000 seeds weight (g)
NT	69.65[a]	29.08[a]
RT	63.28[ab]	29.36[a]
RT1	56.90[bc]	29.27[a]
CT	50.23[c]	29.38[a]

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.

3.5 1000 seeds weight

As shown in Table 3, tillage methods and seeding wheat by the bent leg grain drill did not influence 1000 seeds weight. The 1000 seeds weight was measured at CT with 29.38 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 (Asoodar et al., 2018).

3.6 Wheat yield

Tillage methods and seeding by a bent leg grain drill influenced rainfed wheat yield (Figure 5). The highest wheat yield was measured in RT with 1184 kg ha^{-1} and the lowest yield was obtained from CT with 988 kg ha^{-1}. Overall, RT and NT increased rainfed wheat yield compared to the conventional tillage. Other researchers reported that rainfed wheat yield increased by reduced tillage and no-tillage relative to the conventional tillage (Ali et al., 2019). Results indicated that seeding wheat by the bent leg grain drill in plots tilled by the bent leg tillage implement (RT) or without tilling (NT) increased rainfed wheat yield by 19.8% and 16.7% compared to CT, respectively. Since tilling with the bent leg tillage implement (RT) increased seedling emergence percent, residue remained on the soil surface, and soil moisture conservation and also reduced soil bulk density at soil depth of 10-20 cm, RT had the highest rainfed 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.

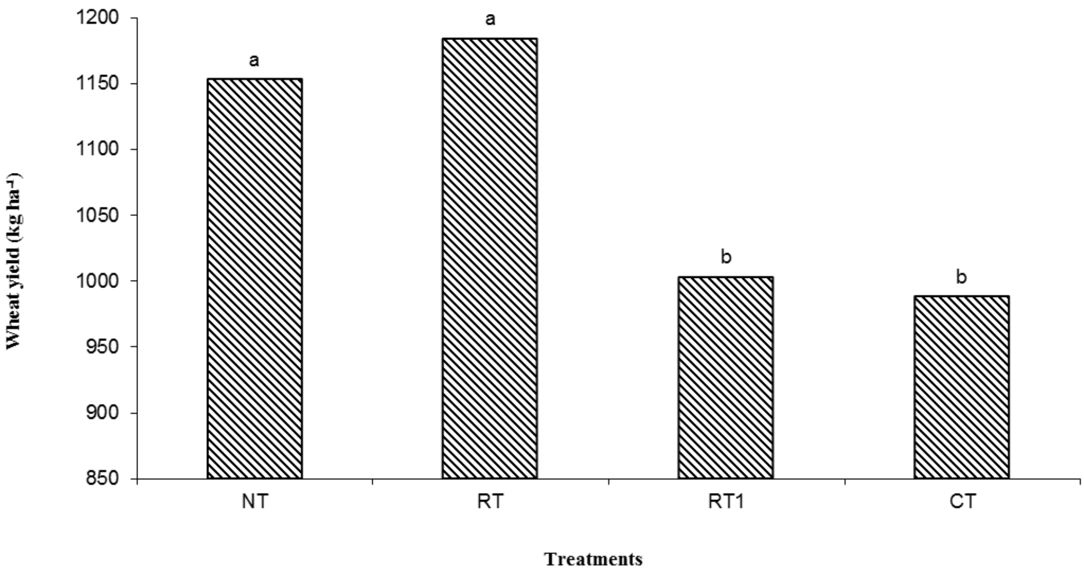


Figure 5 Effect of tillage methods on wheat yield

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, soil moisture conservation, seedling emergence, and rainfed wheat yield. Results also indicated that the bent leg grain drill can plant wheat in different tillage methods. The reduced tillage by the bent leg tillage implement and seeding wheat by the bent leg grain drill increased residue remained on the soil surface, soil moisture conservation, seedling emergence, and wheat yield relative to conventional tillage. 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 conventional tillage for seedbed preparation with less passes of tractor in dry soil conditions and also reduce the cost of tilling. The findings indicate that the technology of bent leg tillage and bent leg grain drill have the potential to increase soil moisture conservation and rainfed wheat yield. Further work should also necessary to evaluate the effect of the grain drill with bent leg opener under adhesive no-till soil conditions under different environment and management.

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