The Modelling, Development and Evaluation of a Rotary Harrow

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Abstract: The objective of this study involves the development of a soil-working implement in the area. For seedbed preparing, a rotary harrow was modelled to disintegrate clods and loosen soil by the rigid tines. The cutting tools, 2 double-ended narrow blades which manipulated by the soil-implement interaction, were fabricated on the two shafts to shape an offset rotary harrow with the gang angle of 15 degrees. The blade design factors are the depth/width ratio of 3.1 and rotary speed of 60 rpm. The rotary harrow performance was compared with an offset disk harrow regarding to tillage depth and mean weight diameter (MWD) of clod fragments in a sandy loam soil. The degree of clod disintegration, expressed by the MWD, was not significantly different in the disk and the rotary harrows. But the working depth in rotary harrow was 0.19 m which was 0.11 m more than that of disk harrow. The blade width of 0.032 m produces 1.44 m total width for the mounted implement. This produces the machine field capacity of 0.6 ha/h in forward speed of 6 km/h.
Key words: Disk harrow, mean weight diameter (MWD), narrow blades, tillage, seedbed

INTRODUCTION

Tillage implements break the soil clods into small aggregates but the clods would be loosened by secondary tillage implements. Although harrows are the conventional tools used to soil fragmentation process but disk harrows are the unique implements used to prepare seedbed in Iran.

Harrows are employed for the preparation of seedbeds, covering of seeds, destruction of weeds and aeration of pastures. Culpin (1992) reported a ground-driven rotary harrow which has a pulverizing effect on the surface layers and is self-cleaning. Each rotary cutter consists of two double-ended blades arranged at right-angles in the form of a cross. The design of an offset rotary harrow was reported for seedbed preparing (Golpira, 2011).

According to Manuwa (2009), narrow tines have working depth far greater than the width, with an aspect ratio (depth/width) between 1.0 and 6.0. Depth/width ratio (d/w) and rake angle are two major variables in the design and selection of the appropriate geometry for given tillage implements (Godwin, 2007). It seems that switching from disk to blade (tines) shape would optimize the loosening performance for the machine.

This study aims to model and develop an offset rotary harrow. Its performance was compared with the conventional disk harrows regarding to the working depth and mean weight diameter (MWD) of clod fragments.

Modelling of a Rotary harrow

A model was considered for the fabricated of a rotary harrow for loosening clods. The model was designed using Solid works 2009 for the development of the harrow (Fig. 1).

The fabricated experimental harrow is shown in (Fig. 2). Narrow blades arranged on two shafts with the gang angle of 15 degrees. The blade width of 0.032 m produces 1.44 m total width for the offset rotary harrow.

32 double-ended blades (narrow tines) welded on 16 square plates which mounted on two shafts. Each shaft consists of 8 plates with two double-ended blades to form a cross (Fig. 3). The proposed blade design factors are the depth to width ratio of 3.1, gang angle of 15 degrees, and blade rotation speed of 60 rpm.
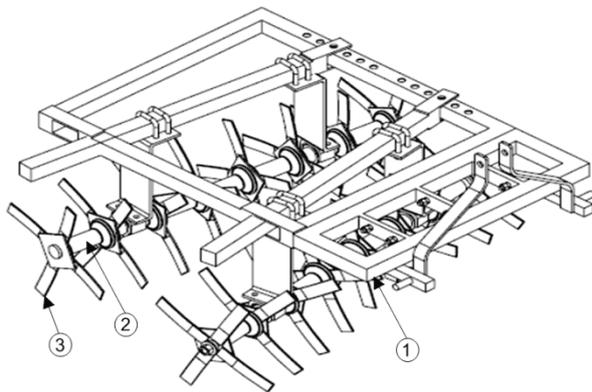
Figure 1. The model of a rotary harrow for secondary tillage (1: Frame, 2: Spacer, 3: Blade)

Figure 2. The rotary harrow fabricated for soil loosening

This arrangement produces a rotary cutter with 580 mm diameter. The rotary cutters, manipulated by the soil-implement interaction, were fabricated on the two shafts to shape a mounted implement.
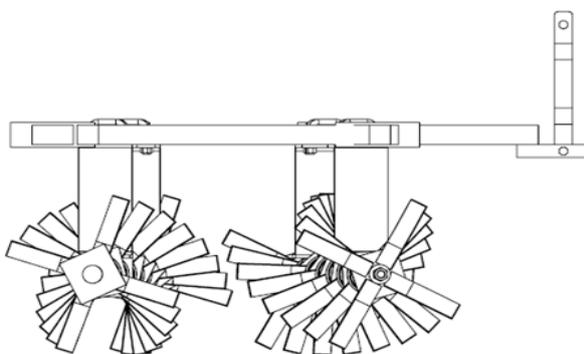
Figure 3. The blade arrangement for the rotary cutters

MATERIALS and METHOD

The experiments were conducted on the Dooshan farm of University of Kurdistan during the summer of 2005. The soil was tilled using a moldboard plow, followed by disk and rotary harrowing.

Each experimental plot was 2×2 m^2 in area, and the clod sampling was performed using a 50×50 cm^2 frame. The center of the frame was located at the center of the plot, and the MWD of clod fragments were determined. The tractor used for testing the harrows was a U-650 (Iran Tractor Plant Co.).

Two different types of harrows, rotary and disk harrow, with respect to clod fragmentation and tillage depth were studied in three replication. The experimental data were analyzed using a variance analysis to determine the machine performances. The means of the treatments (MWD and working depths) were compared with Duncan's multiple range tests at a 5 percent level of significance for the disk and rotary harrows.

The rotary harrow performance was compared with an offset disk harrow regarding to mean weight diameter (MWD) of clod fragment and tillage depth in sandy loam soil in the field. The width, weight, disk diameter (16 disks by 580 mm diameter) and gang angle were the same for the two harrows.

The tillage working depth is a factor which affects the seedbed preparation. To determine the tillage depth, the tractor was stopped and the rotary cutter and disk penetration depth in soil was measured.

The degree of clod fragmentation, expressed by the MWD, calculated as in the following (Berntsen and Berre, 2002).

$$MWD = \frac{\sum_{i=1}^{n} w_i \overline{d_i}}{G} \qquad (1)$$

In this equation d_i value is calculated as below:

$$\overline{d_i} = \frac{1}{2}\left(d_i + d_{i+1}\right) \qquad (2)$$

Where, w_i is the weight of aggregates obtained between two sieve openings d_i and d_{i+1}, G the weight of the total mass and n is the number of sieves used the experiment.

RESULTS and DISCUSSION

The results of the variance analysis from the machine evaluation experiment indicate that there is difference between working depths for the rotary and

disk harrows. The blade has a significant effect on the working depth which is related to the blade shape (Table 1).

Table 1. Variance analysis for the tillage depth in the rotary and disk harrows

Source of variation	Degrees of freedom	Sum of squares
Horrow types	1	339.1[*]
replication	2	0.35
Error	5	

[*] Differences at a 5 percent level of significance

A comparison of the means indicated that the rotary harrow's performance is better than the disk harrow related to working depth. working depth For the disk harrow was less than for the rotary harrow. For the disk harrow, the reaction force (upward direction) on disks intensified due to large contact surface between disks and soil, more than that for the rotary harrow.

As seen from Figure 4, the mean depth in rotary harrow was 0.19 m which is more than 0.08 m for disk harrow. The reason for a big difference between two harrow's tillage depth is considered to be normal since the tine blades have a tendecy to penetrate in soil more than disks.

The analysis of variance (ANOVA) results for determining the MWD demonstrate that the degree of clod fragmentation is the same for the rotary and disk harrows. As the rotary and disk harrows weight's are the same, the MWD are not different for the two harrows. The machine weight is the main factor which affects the clod fragmentation. Thus the cutter tools dose not affects the MWD for the rotary and disk harrows (Table 2).

Table 2. Variance analysis for the clod fragmentation in rotary and disk harrows

Source of variation	Degrees of freedom	Sum of squares
Horrow types	1	2.8[ns]
Replication	2	0.35
Error	5	

[ns] not different at a 5 percent level of significance

Field Capacity

The field capacity of the rotary harrow depends on the soil condition and machine characteristics. It can be obtained from the following equation (Hunt, 2001):

$$c_a = \frac{vwe}{10} \tag{3}$$
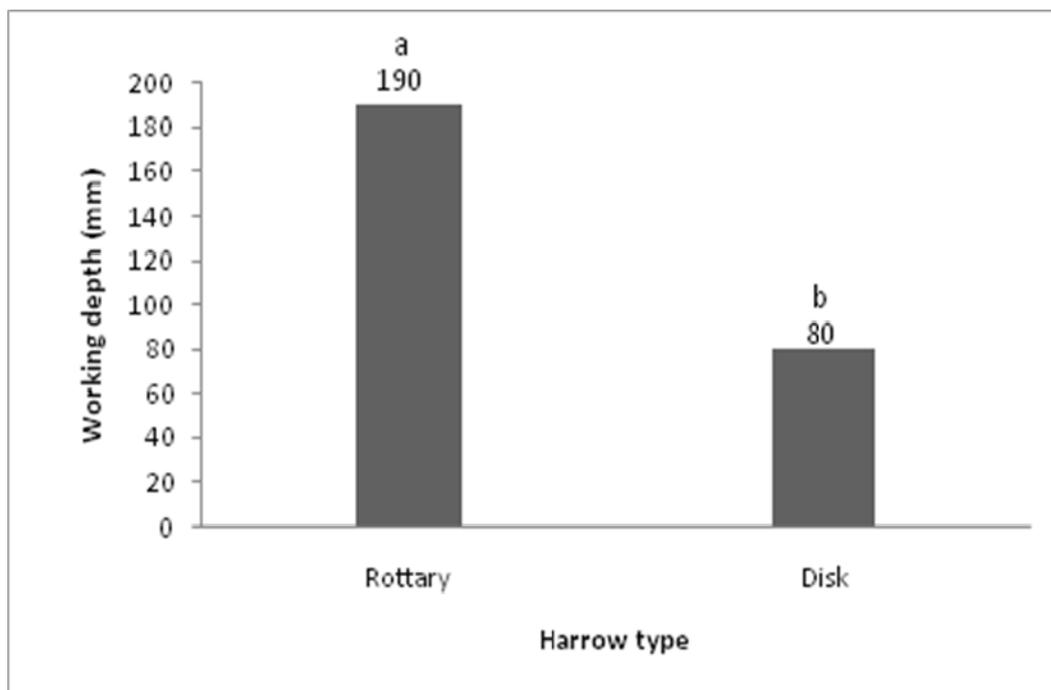
Figure 4. Comparison of the means of the working depth in rotary and disk harrows
Columns with the same letter are not different at a 5 percent level of significance.

where c_a is the field capacity in ha/h, v is the forward speed in km/h, w is the efficient working width in m and e is the field efficiency. For a field efficiency of 70% (Hunt, 2001), a forward speed of 6 km/h and a 1.44-m working width in Equation 3, the field capacity of the rotary harrow was obtained 0.6 ha/h.

CONCLUSIONS

A rotary harrow was modelled and fabricated to perform the secondary tillage. The performance of the developed machine regarding to tillage working depths and MWD of clod fragments were analyzed. The followings were concluded from the study:

- The working depth in the rotary harrow was 0.19 m which was 0.11 m more than that for the disk harrow.
- The degree of clod fragmentation, expressed by MWD, was not significantly different in the disk and rotary harrows.

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