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Design a new cutter-bar mechanism with flexible blades and its evaluation on harvesting of lentil

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ABSTRACT

One of the challenging problems of the cutter-bars is the damaging effect of stones on their blades. This problem is much bigger while harvesting short plants. One of the valuable but short height crops is lentil, which can grow well in stony fields. Lentil in most countries especially in West Asia and North Africa (WANA) is harvested by hand.

In order to overcome the problem of blades damaging, a new mechanism was designed and fabricated. Each blade has its own safety mechanism and so can show flexion independently. The harvester was tested in lentil farms which were rein-fed and manually distributing planted. Forward speed, knife speed and carousel speed were the independent variables that their impacts on both product losses and cutting height were evaluated. The obtained data was analyzed by Design Expert software and two quadratic stepwise models with the R^2 of 0.9505 and 0.9046 were obtained for losses and cutting-height respectively. The results showed that forward speed has the greatest impact on both of losses and cutting height.

On the other hand, the new cutter-bar and a conventional one with almost equal blades, working widths and cutting height were tested in lentil farm. The conventional cutter-bar had lost half of its blades after a while but there was not any damaged blade of the new cutter-bar.

Finally, forward speed of 2 kmh^{-1}, carousel speed of 34.83 rpm and knife speed of 476 rpm was recognized as the best working set-up for the testing region.

1. Introduction

Cutter-bars working at low height and especially in stony fields is very challenging (Talebi et al., 2007). If a blade is broken during the harvesting time, it is crucial to replace it with a new one as soon as possible. Because increasing the number of damaged blades will lead to increasing losses. Different designs have been approached to overcome the problem of cutter-bars damaging. Deere and Company (2002) designed a new blade with some holes on it to lesser the damage (Fig. 1). These holes provide a controlled breakage zone so that the blade section can break at different levels. As a result, broken blade will continue to work until it breaks completely and then it must be changed with a new one.

In another design of a lawn mower (Deere and Company, 2005) there is an impact energy absorbing structure on the blades (Fig. 2). When the blade receives an impact from an obstructing object, the section deforms, absorbs the impact and reduces the impending damage to the drive mechanisms. Then this deformed blade must be changed with a new one.

However, short plants harvesting is unavoidable in agriculture. One of these kinds of crops is lentil. It can grow well in stony fields (Papazian, 1982). In West Asia and North Africa (WANA) it is harvested by hand, which is costly and about 40% of its producing cost is spent only on this procedure (Khayrallah, 1981; Gharakhani, 2014). Manual harvesting needs 20 labor workers to harvest 1 ha in a day (Abdollahpour and Gharakhani, 2010). The mean height of the plant is about 142 ± 41 mm above the ground (Khayrallah, 1981; Erskine et al., 1990). In addition, it has a weak stalk and tends to lodge badly. This means that low cut is urgent to minimize the losses (Oplinger et al., 1990).

Using a cutter-bar mechanism for lentil harvesting is the most effective method but the common cutter-bars are not able to work efficiently at a height of less than 10 cm (Behroozi-Lar and Huang,

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Notation

df	degree of freedom
U	peripheral speed of carousel, ms^{-1}
V	forward speed, kmh-1
λ	kinematic Index of the carousel
A	forward speed
B	distance
C	carousel speed
C-D	cutting-depth
w_f	fallen pods on the ground
w_r	remained pods on the plants
w_h	harvested pods in the tank
ω	angular speed of the carousel, $rads^{-1}$
r	radius of the carousel, m
CV	coefficient of variation
distance	forward advancement for each complete cycle of the blades

2002).

The main purpose of this research is to design a new cutter-bar mechanism, which overcomes the disrupting and damaging problems of objects like stones. Such a mechanism should be reversible to work continuously. It means that the part, which is engaged in stones, must reverse to its original form after the procedure of safety mechanism. Based on the investigations, a modified and optimized version of conventional sickle-bar cutter mechanism could be suitable for this purpose.

Since the flexibility and resistance of this cutter-bar while facing with disrupting objects is under discussion, it was tested on lentil farms. Testing the new-cutter bar on lentil farm means to test it at a challenging condition.

2. Design of experimental harvester

2.1. Design and operation

The computational procedure of the design (Gharakhani, 2014) is not discussed here so that only the design of safety mechanism and complementary parts are presented. The new harvester must work continuously on the farm to have a nonstop harvest. Therefore, the best idea is to provide such a system in which every blade has its own safety mechanism. If any stone disrupts a blade, the rest of them continue to work without interruption. In addition, its safety mechanism must provide a reversible feature for the blades. Such a harvester will have the least losses while working in low height and stony fields.

2.1.1. Safety mechanism

Fig. 3 shows the main idea of the new sickle-bar cutting mechanism. If there were an empty space between moving blade and its sickle-bar, it would be possible to provide a safety mechanism in this space.

Fig. 4 shows the designed safety mechanism. In this mechanism a series of moving blades slip on fixed ones. The moving blade and its attachments are designed and fabricated appropriately, whereas the fixed blade is selected from the existent one. The leaf spring allows the moving blade to show flexion. A coil spring pushes the moving blade on the fixed blade to provide a neat cutting.

The moving blade is hinged to the leaf spring by a pivot. This feature allows the moving blade to arise in urgent situations. Therefore, as shown in Fig. 5, while engaged with a stone the moving blade can show flexion both in vertical and horizontal directions to lesser the damage is low as possible.

Fig. 6 shows the operation of the safety mechanism. When an obstructing object is grabbed between a pair of moving and fixed blades, the leaf spring starts to bend by movement of the sickle-bar. After finishing the stroke, sickle-bar turns back and the leaf spring returns to its primary state. Then the grabbed object is released and

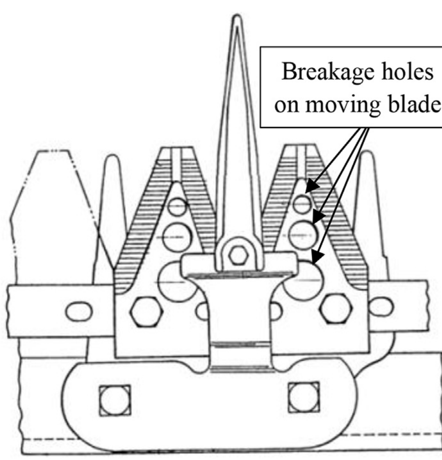

Fig. 1. Cutter-bar with breaking holes (Deere and Company, 2002).

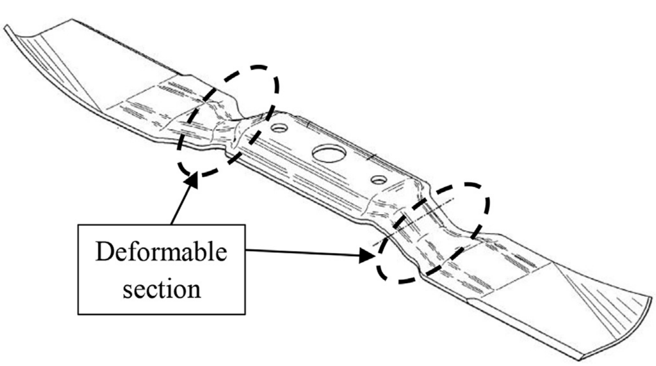

Fig. 2. An impact absorbing structure on the blade of a lawn mower (Deere and Company, 2005).

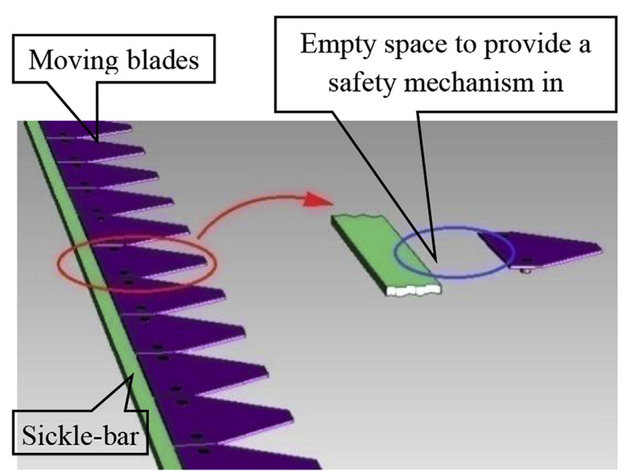

Fig. 3. The main idea of the new mechanism; an empty space between blade and sickle-bar.