J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 9 (12): 817 - 820, 2018

Development of a Combine Hoeing Machine for Flat and Ridged Soil

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ABSTRACT

This study aims to develop a suitable hoeing machine for the crop planted at flat and the ridged soil with ridges reforming, and evaluate it by studying some effective factors such as blades shape, kinematic indices, crop planting methods and power requirements. The experiments were carried out in the Rice Mechanization Center at Meet El Deeba, Kafr El-Sheikh Governorate. The results indicated that using the developed machine using L-shaped blade increased the weeding efficiency by about 4%, plants damage about 0.8%, operating power requirement about 1.6% in comparison with C-shaped blade. In addition increasing the kinematic index increased the weeding efficiency and also plants damage percentage using L and C-shaped blades and crop planting methods.

Keywords: Hoeing machine, flat soil, ridged soil, weeding efficiency.

INTRODUCTION

Mechanical weed control method is not only effective in controlling weeds, but also it benefits the crop by ;breaking up the surface crust, aeration of the soil, stimulating the activity of the soil microflora, reducing the evaporation of soil moisture, facilitating the infiltration of irrigation. Generally, the most important advantage of this method is being environmentally friendly. Weed control is still the most difficult challenge in the production of any crop, where weeds compete with plants for nutrients, light, space and water especially in the early stages of plant growth. In Egypt, maize ranks the third of the most important cereal crops after rice and wheat crops, where the area harvested of maize crop is about 2.447 million feddans with a yield average of about 3.195 tons per feddan and producing yearly about 7.818 million tons (FAO, 2016). Maize plants required to be cultivated twice throughout the growth period; the first is done after 21 days and the second after 36 days of planting (Ministry of Agriculture - Egypt, 2005). Victor and Verma (2003) developed a power-operated rotary weeder for weeding wetland paddy. Four L-shaped standard blades were used for cutting the soil. It recorded 71% field efficiency and 90.5% weeding efficiency. Senanarong and Wannaronk (2006) developed an off-set rotary cultivator (80 cm cutting width) operated with 7 kW two-wheeled tractor for cultivating mango orchards. Using the machine with forward speed (1.78 km/h) and rotational speed (178 rpm) recorded 88.3% field efficiency and 92.09% weeding efficiency. Manuwa *et al.* (2009) developed a row-crop power weeder. It has four L-shaped blades with 0.24 cm cutting width. Using the machine with rotational speed of the cutting blades 800 rpm achieved 95% weeding efficiency, 0.053 ha/h effective field capacity and 0.7 l/h fuel consumption. Rathod *et al.* (2010) developed an inter-row rotary weeder. The field tests conducted at three forward speeds (1.1, 1.2 and 1.5 km/h) using four L-shaped blades with rotational speed 257 rpm. The results revealed that the effective field capacity, the field efficiency and the weeding efficiency were 1.43 ha/day, 86.34% and 92.23%, respectively. Moreover, the developed weeder saved in cost by 68.70% and saved time by 70%. Srinivas *et al.* (2010) assessed the performance of three types of blades i.e., C-shaped blade, L-shaped blade and Sweep blade for inter-row cultivation in sweet sorghum crop. The results illustrated that plant damage percentages were 5.1%, 3.4% and 1.2% for L, C and Sweep type blades, respectively. Weeding efficiency of L-shaped blade was found to be 91%, whereas C type and Sweep type blades recorded 87% and 84%, respectively. Olaoye *et al.* (2012) developed an indigenous rotary weeder to minimize the drudgery and assure a comfortable position of the operator during weeding operation. Using the developed machine recorded 73% weeding efficiency and reduced the operating cost about 77.5% compared with manual weeding. Mahilang *et al.* (2017) developed a power operated rotary weeder. The cutting unit contains 3 hubs each one containing 2 standard L-shaped blades were fitted on the rotary shaft. The results found that field capacity of the power weeder was 0.14 ha/h with weeding efficiency of 91% and 60% field efficiency.

The objective of this study is to develop and evaluate a combine machine for hoeing the flat and the ridged soil and reforming the ridges.

MATERIALS AND METHODS

The field experiments were carried out in the Rice Mechanization Center at Meet El Deeba, Kafr El-Sheikh Governorate, Egypt, during the agricultural season of 2018 for maize crop variety of triple hybrid 324. The experimental area was about 1 feddan, it divided into two equal parts, the first part was planted on flat soil and the second part was planted on ridged soil. The cultivation operations were conducted twice, the first and the second cultivations carried out after 21 and 36 days of sowing, respectively.

Materials:

1: The developed cultivation machine:

The developed cultivation machine for hoeing flat and ridged soil is shown in Fig. 1. The developed cultivation unit consists of the following parts:

Main frame:

The main frame was made from a U-shape steel section, T-shape steel section, steel flat bars and iron pipes with dimensions of 800 x 100 x 45, 350 x 39 x 36 with a thickness of 8 mm for U and T-shape steel sections, respectively. Steel flat bars with a width of 38.1 mm and thickness of 10 mm were welded in the main frame as supports. Two iron pipes with an external diameter of 32 mm and a length of 50 mm were fastened from their ends.

Power supply source:

The power is transmitted from a rice transplanter or a small tractor PTO shaft to two rotor shafts through a bevel gearbox.

Hoeing unit:

The hoeing unit consists of two steel rotor shafts with 200 mm length and 39.5 mm diameter. Two flanges slip on each rotor shaft and fixed by screwing the bolt to adjust the cutting width. Four cutting blades were fixed at each flange. Two different shapes of cutting blades were used in this study, the first is L-shaped and the second is C-shaped blade. A steel shank was fixed to the main frame for hoeing the distance between rotary shafts in the flat soil and hoeing the ridge bottom in the ridges soil.

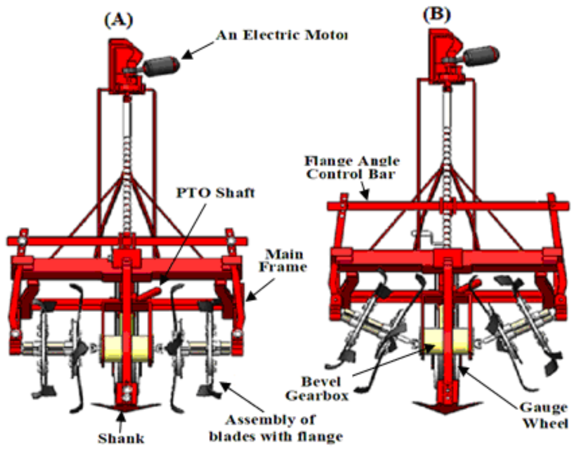

Fig. 1. Sketch of the developed cultivator for the flat soil (A) and the ridged soil (B).

The tilt angle of ridges side was adjusted by using a 12V DC electric motor that rotates the threaded rod subsequently raising or lowering the flange angle control bar, which was connected with the end of the rotor shafts by a bolt for each shaft.

Hoeing depth:

Hoeing depth was controlled manually by using an iron gauge wheel with dimensions of 200 mm diameter and 70 mm width.

Methods:

1: Studied factors:

The experiments were carried out to study some factors affecting on the performance of a developed cultivator such as:

(a) **Blade shape**: Two different shapes of the rotary blades, i.e., C-shaped blade and L- shaped blade.

(b) **Kinematic index (λ):** Five kinematic indices, i.e., 5.85, 6.76, 7.54, 8.32 and 8.84.

(c) **Planting method**: Two different methods of seed planting, i.e., planting in the flat soil and planting in the ridged soil.

2: Methods and measuring instruments:

a - **Weeding efficiency:** It is calculated by the following equation according to Hemeda and Ismail (1992).

$$\text{Weeding efficiency \%} \quad \frac{W_1 - W_2}{W_1} \qquad (1)$$

Where,

W_1: Total number of weeds between two crop rows in a unit area before cultivation; and

W_2: Total number of weeds remaining immediately after cultivation and 5 days after irrigation in the same unit area.

b - **Plant damage percentage:** It is calculated by the following equation according to Hemeda and Ismail (1992).

$$\text{Plant damage \%} = \frac{N_1 - N_2}{N_1} \qquad (2)$$

Where,

N_1: Total number of the maize plants in a 10 m distance before cultivation, and

N_2: Total number of non-injured maize plants immediately after cultivating and 5 days after irrigation in the same 10 m distance.

c - **Rotary blades speed**: The rotary blades speed was measured by using handheld digital non-contact tachometer (Japanese manufacture) ranged from 60 to 20000 rpm with accuracy of (± 0.1 rpm).

d- Power requirements:

The required power was calculated by using the following formula according to Embaby (1985).

$$EP = Fc \times \left(\frac{1}{60 \times 60}\right) \rho_f \times L.C.V \times 427 \times \frac{1}{75} \times \frac{1}{1.36} \times \eta th \times \eta m, \text{ (kW)} \qquad (3)$$

Where:

EP = Engine power;

Fc = Fuel consumption, l/h;

ρ_f = Density of the fuel (0.73 kg/l for gasoline fuel);

L.C.V. = Lower calorific value of fuel (11030 kcal/kg for gasoline fuel);

427 = Thermo – mechanical equivalent, kg.m/kcal;

ηth = Thermal efficiency of engine (30% for gasoline engine) and

ηm = Mechanical efficiency of engine (80% for gasoline engine).

RESULTS AND DISCUSSION

The results obtained from this study are discussed under the following points:

1: Effect of the kinematic index (λ) on weeding efficiency:

The results in Figs. (2 and 3) showed that increasing the kinematic index increased the weeding efficiency by using the different blades shape at the flat and the ridged soil.

Fig. (2) showed that increasing the kinematic index from 5.85 to 8.84 increased the weeding efficiency about 7.7 and 5.6% after the hoeing directly and about 7 and 6% after 5 days of irrigation in the flat land. Whereas, at the ridged soil the weeding efficiency increased about 7.7 and 4.3% after the hoeing directly and about 9.7 and 6.9% after 5 days of irrigation (Fig.3).

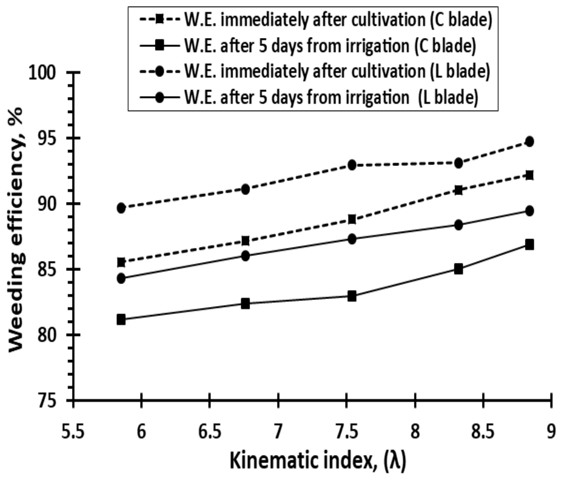

Fig. 2. Effect of kinematic index on weeding efficiency by using C and L-shaped blades at the flat soil.

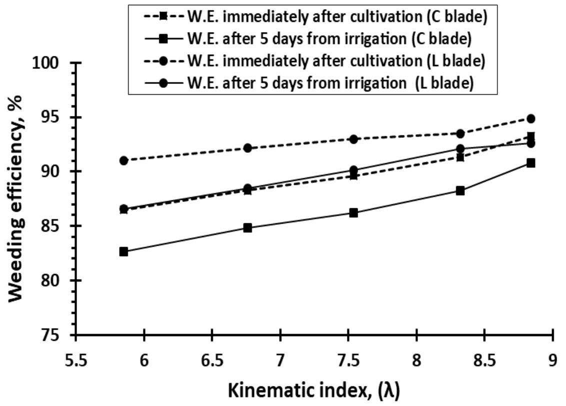

Fig. 3. Effect of kinematic index on weeding efficiency by using C and L-shaped blades at the ridged soil.

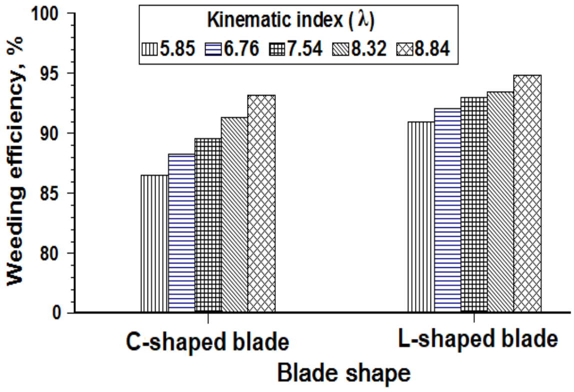

Fig. 4. Effect of blades shape on weeding efficiency at the flat soil.

2: Effect of blades shape on weeding efficiency:

Figs. (4 and 5) showed that using L-shaped blade increased the weeding efficiency in comparison with C-shaped blade in the flat and the ridged soils at different kinematic indices.

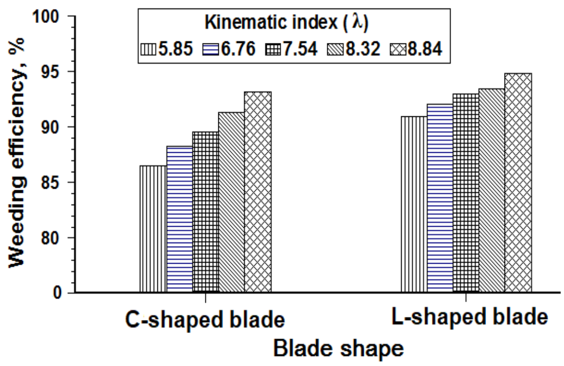

Fig. 5. Effect of blades shape on weeding efficiency at the ridged soil.

The results in Fig. 4 showed that using L-shaped blade increased the weeding efficiency about 2.1 to 4.1% as compared with C-shaped blade at the flat soil. While, the results in Fig. 5 showed that using L-shaped blade increased the weeding efficiency between 1.7 and 3.8% as compared with C-shaped blade at the ridges soil.

3: Effect of blades shape on plant damage:

Data in Figs. (6 and 7) showed effect of blades shape on plants damage. The results indicated that using L-shaped blade increased the plants damage in comparison with C-shaped blade in the flat and the ridged soils at different kinematic indices.

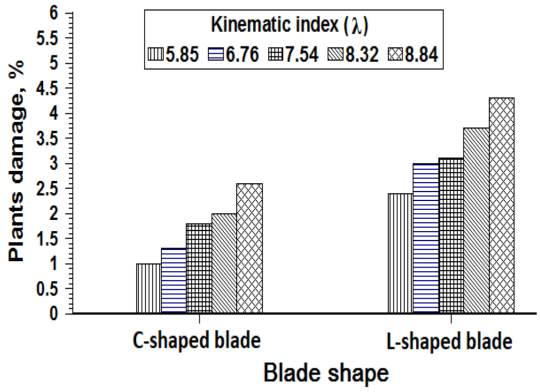

Fig. 6. Effect of blades shape on plants damage at the flat soil.

The highest value of damaged plants was obtained by using L-shaped blade at kinematic index of 8.84, which were 4.3 and 4.7% in the flat and the ridged soil, respectively. While, using C-shaped blade at the same kinematic index recorded 2.6 and 3.1% plants damage in the flat and the ridged soil, respectively.

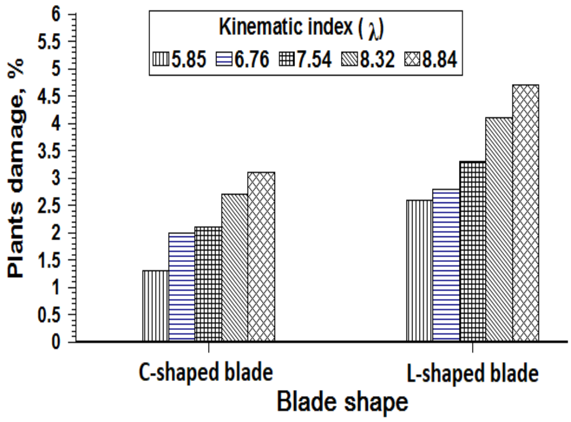

Fig. 7. Effect of blades shape on plants damage at the ridged soil

4: Effect of blades shape and planting methods on power requirements:

The experiments results showed that no effect of the kinematic index on fuel operating consumption. While, the blades shape and planting method have an obvious impact on fuel consumption rate and thus on the amount of power requirement for operation.

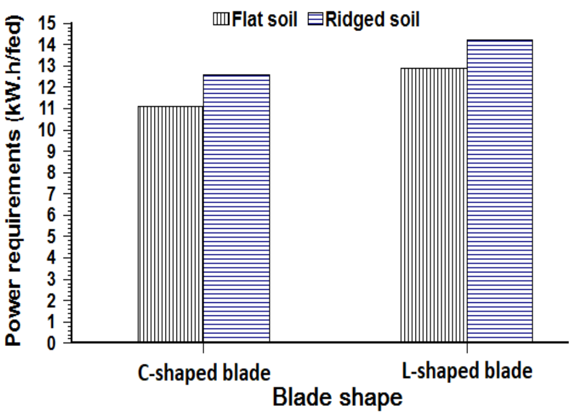

Fig. 8. Effect of blades shape on power requirements at the flat and ridged soil.

The results in Fig. 8 indicated that using L-shaped blade increased the power requirements about 16.2 and 12.7% in comparison with C-shaped blade in the flat and the ridged soil. Whereas, the power requirements increased about 13.5 and 10.1% by using C and L blades shape at the ridged soil in comparison with the flat soil, respectively.

CONCLUSION

The results obtained from this study showed that increasing the kinematic index increased the weeding efficiency by using C and L shaped blades at the flat and the ridged soils. L-shaped blade recorded high percentage of weeding efficiency and low percentage of plant damage and operating power requirements in comparison with C-shaped blade.

Therefore, the developed combined machine is a suitable machine for hoeing with L-shaped blade and kinematic index of 7.54 in the flat and the ridged soil.

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تطوير آلة مجمعة لعزيق النباتات في الأراضي المستوية وذات الخطوط وإعادة تشكيلها

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تم تطوير وتصنيع آلة مركبة للعزيق في مركز ميكنة الأرز – ميت الديبة – محافظة كفر الشيخ – التابع لمعهد بحوث الهندسة الزراعية. أجريت التجارب العملية خلال الموسم الزراعي لمحصول الذرة عام 2018م على مساحة تجريبية حوالي واحد فدان في مزرعة مركز ميكنة الأرز بميت الديبة بهدف تقييم أداء آلة العزيق المجمعة والمطورة لعزيق المحاصيل المزروعة على أرض مستوية وأيضا المحاصيل المزروعة على خطوط مع إعادة تشكيلها. تم تقسيم أرض التجربة إلى جزأين متساويين وتم زراعتها بمحصول الذرة، حيث تم زراعة الجزء الأول كأرض مستوية بينما تم زراعة الجزء الثاني بعد تخطيطه. تم تقييم الآلة المطورة من خلال دراسة مجموعة من العوامل يمكن توضيحها كما يلي: 1- شكل سلاح العزيق: تم اختبار نوعين من الأسلحة أحدهما على شكل حرف L والآخر منحنى على شكل C. 2- معامل كينماتيكي: تم اختبار خمس معاملات كينماتيكية (5,85، 6,76، 7,54، 8,32، 8,84). 3- نظم الزراعة: تم اختيار نظامان للزراعة، الأولى زراعة في أرض مستوية والثانية الزراعة في خطوط. تم التوصل لمجموعة من النتائج يمكن توضيحها فيما يلـي: 1- زيادة المعامل الكينماتيكي يزيد من كفاءة مقاومة الحشائش مع نوعي الأسلحة وطريقتي الزراعة. 2- استخدام سلاح شكل L يزيد من كفاءة مقاومة الحشائش بمتوسط 5% بالمقارنة إلى سلاح شكل C. 3- استخدام سلاح شكل L يزيد من نسبة النباتات التالفة بمتوسط 1% بالمقارنة إلى سلاح شكل C. 4- زيادة متطلبات القدرة اللازمة لتشغيل الآلة مع الأسلحة شكل L بمقدار 16,2، 12,7% بالمقارنة لمتطلبات القدرة اللازمة لتشغيل الآلة مع الأسلحة شكل C. 5- زيادة متطلبات القدرة اللازمة لتشغيل الآلة في أرض الزراعة في خطوط بمقدار 13,5، 10,1% بالمقارنة للزراعة في أرض مستوية باستخدام الأسلحة شكل L وشكل C على التوالي. وبناءاً على ما تم التوصل اليه يوصى باستخدام الآلة المجمعة والمطورة باستخدام سلاح شكل L مع معامل كينماتيكي مقداره 7.54 في الأرض المنزرعة على أرض مستوية أو ذات الخطوط.