Nile Valley University Publications

Nile Journal for Agricultural Sciences (NJAS)

(ISSN: 1585 – 5507)

Volume 10, NO. 01, 2025

https:// nilevalley.edu.sd

Research paper

Performance Evaluation of Tractor Mounted Inter Row Weeder Provided with Three Different Types of Weeding Tools on Okra Production

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Abstract

Weeding is an important practice to be carried out during the initial stages of crop growth especially for controlling the weeds competing with the crop, stirring the soil for aerating the crop root zones and for burying the weeds into the soil. Efficient weeding aids and equipment for weed control seems highly necessary to minimize the time consumption, labor requirement and cost. The objective of the study was to evaluate a tractor operated inter-row weeder with three different types of blades for weeding in okra cultivation and compared to manual weeding method. The weeder is suitable for crops having considerable row spacing up to 80 cm, the width of the weeder is adjustable according to the crop row spacing. The modified weeder was evaluated at different test fields for okra plant and can be used in any vegetables plant with a maximum height of about 35cm. A randomized complete block design with three replications was used. Plot size was 4 m × 120 m. Results showed that there was highly significant difference (p=0.05) of weeding efficiency, grain yield and field efficiency. The weeding efficiency for V-shape lade1 was 93.7%, field efficiency was 83%, plant damage was 0.83 % and a yield of 365.7 kg/ha. Curved blade recorded 83.5 % weeding efficiency, 74 % field efficiency, 2.1% plant damage and a yield of 253.7kg/ha. The shank blade has a weeding efficiency of 59.2 %, field efficiency of 72 % and plant damage of 32 % and a yield of 127.2/ha. The manual weeding has a weeding efficiency of 99.9%, field efficiency of 35 % and damage factor of zero percent and a yield of 526.2kg/ha. These studies concluded and suggest that weed control on okra production could be best carried out by mechanical weeding method with V-shape blade and curve blade. For future study further research is needed to develop curve shaped blade with different design patterns and apply with different crops for better field efficiency and lower cost.

Keywords: *cultivation, Weed control, weeder, Field efficiency.*

تطويروتقييم أداء عز اقة بين الصفوف محمولة على الجرارومزودة بثلاثة أنواع من الأسلحة على إنتاج البامية

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المستخلص

العزيق عملية مهمة ويجب إجراؤها في الأطوار الأولى من نمو النبات خاصة للتحكم في الحشائش التي تنافس المحصول. وتحريك التربة من أجل تهوية منطقة الجذور ودفن الحشائش. معدات العزيق ضرورية لتقليل الزمن والعمالة والتكلفة. الهدف من هذه الدراسة هو تقييم أداء عزاقة بين الصفوف بثلاثة أسلحة مختلفة لعزيق البامية ومقارنتها بالعزيق اليدوي. العزاقة مناسبة للمحاصيل التي لها مسافة بين الصفوف حتى 80سم وعرض العزاقة قابل للضبط حسب المسافة بين الصفوف. تم تقييم العزاقة بعدد من الاختبارات الحقلية لمحصول البامية ويمكن استخدامها لمحاصيل الخضر الأخرى بأقصى ارتفاع **35**سم. تم اختيار التصميم العشوائي بثلاثة تكرارات. مساحة الحوض 4×120 متر. أوضحت النتائج فروق معنوية عالية (P=0.05) في كفاءة العزيق والإنتاجية والكفاءة الحقلية. الكفاءة الحقلية للسلاح شكل **V** كانت **93.7**% والكفاءة الحقلية **83**% ونسبة تلف النبات 0.83% والإنتاجية **365.7**كيلوجرام للهكتار. سجل السلاح المنحني كفاءة عزيق **83.5**% وكفاءة حقلية **74**% ونسبة تلف النبات **2.1**% والإنتاجية **235.7** كيلوجرام للهكتار. السلاح المستقيم أعطى كفاءة عزيق **59.2**% وكفاءة حقلية 72% وتلف النباتات 32% وإنتاجية قدرها 127.2كيلوجرام للهكتار. أعطى العزيق اليدوي 99.9% و 35**%** و 0% و 526.2 كيلوجرام للهكتار لكفاءة العزيق والكفاءة الحقلية وتلف النباتات والإنتاجية على التوالي. خلصت الدراسة انه يمكن التحكم في الحشائش في محصول البامية بالطرق الميكانيكية باستخدام سلاح على شكل V والسلاح المنحني. تقترح الدراسة تطوير السلاح المنحني بأنماط مختلفة وتجربته في محاصيل مختلفة لتحسين الكفاءة الحقلية وتقليل التكلفة.

كلمات مفتاحية: العزيق، التحكم في الحشائش، العزاقة، الكفاءة الحقلية

Introduction

Weeds are robbers and farmer has ton destroy them to save crop. Control of weeds and grasses are most labor and time intensive operations. Weed control in farms is a serious concern. Weeds pose major problem during warm and humid climate especially affecting crops. The problem of weed control is more acute in black soil during rainy season. Weed control is one of the most expensive operations in crop growth, (Swenson and Moore, 2009). Weeds waste excessive proportions of farmers' time, thereby acting as a brake for the development, (Nagesh *et al*, 2014)

Weeding is an important but equally labor-intensive agricultural unit operation. Weed control is one of the most expensive operations in crop growth. The high cost of weeding can be understood from a comparative study of the losses in the farm due to various causes.

Infection of weeds is more in rainy than in winter season. often weeding is incomplete or delayed as a result there is significant loss of 20% or more. Weeds increase cost of production and lower the quantity as well as the quality of the crop. Depending on the weed density, 20-30% loss in grain yield is the quite usual which may increase to 50%, when crop management practices are not properly followed. In production technology plant protection is a key in increasing the productivity of crop. Under plant protection, weed control plays an important role for increasing the yield. Weed alone was found to be reducing the yield to the extent of 58-85%. Weed control is generally neglected even though it's a crucial factor due to negligence in weed management crop yield loses 20-27% are recorded (Biswas *et al*. 2000).

Methods of weed control are grouped into cultural, mechanical, chemical and biological practice. Mechanical weeding is one of the oldest practices, but the most common methods of weed control in upland crops. Although it has undergone a spectacular advancement, yet hand weeding with simple weeders is common. These simple weeders are cheap, more efficient and suitable for farmer's situation to reduce the cost of crop production and improve crop yield to a great extent. It is not only safe to the environment, but also safe to the user. The physiological demand in using weeders was relatively higher than in manual weeding. However, the efficiency of the work in terms of area covered was significantly better with the weeder than with manual weeding. The energy demand in manual weeding is about 27%, whereas for weeding with different weeders the energy goes up to 56%. The strain was relatively less in case of wheel push type weeder (Rajasekar, 2002). However, performance evaluation of a tractor multi row mechanical weeder to ensure that there is a suitable replacement to either energy sapping method of manual hoe of weeding operation or expensive foreign weeders which are beyond of peasant farmers to gain. Evaluation of performance of an implement shows the level of its effectiveness and it adoption to a particular function which indicates the output in relation to specific time, (Rajasekar, 2002). The objective of this article is to evaluated a modified tractor mounted inter row weeder provided with three different types of weeding tools.

Materials and methods

The work was carried out at the workshop of Agricultural engineering department and experimental farm of the Faculty of Agricultural Sciences, university of Gezira, Sudan, at a latitude of 14° 21' N, longitude 29° 33' E and altitude 405 m above mean sea level. The local climate of Gezira is classified as semi-arid, annual rainfall of about (342 – 424 mm) the mean temperature is about (25 -39^{o}c), for about 7 months of the year there is no rainfall. The site is composed of a heavy clay soil which develop deep crack during the dry season. The soil are alkaline with high pH of about (8.42 ± 0.21) with some saline patches and they are characterized by their high clay content of up to 50 to 70% silt between 15 to 30%, fine sand between 10 to 20%, high exchangeable sodium low permeability low Chroma in low lying spot (Ishag *et al.* 1985).

Equipment

To complete the following work various materials and equipments were used to fulfill the objectives.

Tractor

A Tafe tractor model no: 8502 was used to operate the weeders, and some of the tractor specifications are shown below.

Specifications of the tractor used in the test

No.	Parameters	Description
1	Manufacturer	Trademark of agro S.P.A
2	Power source	83.6 hp
3	Model no	8502
4	Drive wheel	2
5	Fuel	Diesel with an adjustable rear wheel tread
6	Cooling system	Water

The evaluated weeders

Three different types of cutting blades were used as the requirement of the weeding operation, which are made of cast iron. These blades were mounted to a light frame separately and adjusted according to the spacing between ridges. Each weeder includes four types of blades.

Other equipment and tools

An auxiliary tank was used to measure the fuel consumed during work. The tank was coupled with transparent tube at both terminals. **A** stopwatch was used to measure time required for one turn and turning of a tractor. Time measured in minutes and calculated for hours. **A** measuring tape was used for measuring and marking in the field. A steel foot ruler was used for measuring depth of operation, height of crop, height of weeds. A 100kN capacity Dynamometer for measuring draft required to operate the unit in the field. A sensitive balance to weigh the samples was used. Labors equipped with locally made hoes were hired for manual weeding. A metallic frame or steel quadrate 1m^2 was used to count the number of weeds / m^2 and weed ground cover.

Experiment

The experiment consists of the mechanical weeding with V-shape blade (fig1.b), mechanical weeding with curve blade (fig.1b), mechanical weeding with shank type blade (fig.1c) and manual weeding.

Fi g.1a. V-shape blade

Fig.1.b Curve shape blade

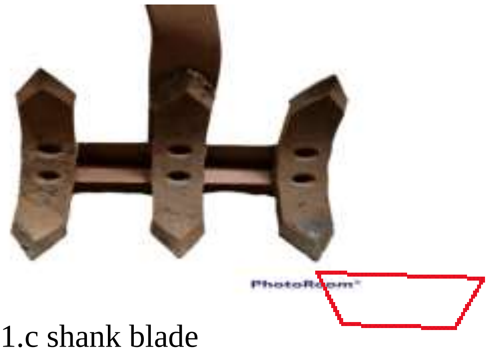

Fig. 1.c shank blade

Weeding Efficiency (WE %)

Weeding efficiency refers to the ratio of removed weeds to the total weed count and it can be found as follows:

$$WE = \frac{W1-W2}{W1} \times 100 \quad (1)$$

Where,

W_1 = Number of weeds before weeding

W_2 = Number of weeds after weeding.

Damage factor (DF %)

Quality of work done is the measure of damage on crop plants. While weeding operations is denoted by the expression given below:

$$DF\ \% = \frac{Q2}{Q1} \times 100 \quad (2)$$

Where

Q_1= Number of plants before weeding

Q_2= Number of plants after weeding.

Draft measurement

The draft required to operate the unit in the field was measured by using dynamometer of 5000 kg capacity, mounted in between the test tractor that hitched with weeder and hauling tractor. The test tractor was run in neutral position of transmission system with the PTO and the hydraulic system in fully operating conditions. The dynamometer was hitched to ensure horizontal pull. First, the draft required (F_2) to pull the test tractor along with weeder in working position was measured. Second, the draft required (F_1) to pull the tractor without any load was measured. (See plate1) Then, the draft required to operate the weeder was calculated as follows.

$$Draft\ (kg) = (F_2 - F_1) \quad (3)$$

Forward speed (S)

The forward speed of the tractor was calculated by measuring the distance covered and time taken to covered the same distance in seconds and was computed by the below formula:

$$S = \frac{D}{T} \qquad (4)$$

Where: S = forward speed (m/s)

D= distance covered (m)

T= time taken in second (s)

Theoretical field capacity (FCT)

The theoretical field capacity was calculated based on the formula (5) given by (Nkakini *et al*., 2010)

$$\text{FCT} = s \times w \times 0.36 \qquad (5)$$

Where: FCT = theoretical field capacity (ha/hr)

S= forward speed (m/s)

w = working width (m)

Measurement of Effective field capacity

The area cover during the test was calculated. The effective field capacity was then calculated by using following formula (Nkakini et al., 2010)

$$FC_e = \frac{A}{10^4} \times \frac{3600}{T} \qquad (6)$$

Where: FC_e = actual field capacity (ha/hr)

A = area weeded (m^2)

t = time taken to weed (sec)

Measurement field efficiency

The field efficiency was calculated by dividing the effective field capacity by theoretical field capacity as described in the following equation:

$$FE = \frac{\text{effective field capacity}}{\text{theorotical field capacity}} \times 100 \qquad (7)$$

Fuel consumption

Fuel consumption per hectare was measured for the mechanical weeding methods using the methods used by (Ibrahim, 2013). The tractor tank was substituted by an auxiliary graded fuel tank and it was filled to a specific level the auxiliary tank was equipped with a transparent hose. At the completion of the tested area, the drop in fuel level was measured with the aid of a plastic ruler. The consumed fuel was measured by converting the number of millimeters that represented the drop in fuel level on the transparent tube to fuel volume. The fuel consumption in L/ha for the tested are determined by the equation 8 (Ibrahim, 2013).

$$f.c = \frac{v \times 10000(\frac{m^2}{ha})}{A(m^2)} \quad \text{.......(8)}$$

f.c = Fuel consumed, (L/ha)

V= Volume of fuel consumed for Litter per plot area

A= Tested Plot Area m^2

Economic cost

The cost of operation of the weeder was estimated out and compared with manual weeding.

Results and discussion

Weeding efficiency at 4-5 weeks after sowing

The result of weed control percentage at 4-5 weeks and the analysis of variance for individual treatment and interaction effect on weeding efficiency according to the number of weeds before weeding and after weeding were summarized in Table 1. The analysis of variance showed that there was significant difference between the treatments. The highest weeding efficiency was recorded in manual weeding method which recorded 99.8 %. It was showed excellent result and followed by 93.7 % and 83.5 %weeding efficiencies when using V-shape blade and curve shape, respectively. However, the lowest weeding efficiency was 59.2% percent which was recorded on shank blade. These results evaluated as very good control according to the scale mentioned by Senthilkumar *et al*. (2014).

Weeding efficiency at 9-10 weeks after sowing

The analysis of variance for the number of weeds before weeding and after weeding at 9-10 weeks after sowing were summarized in (Table 2).The result shows that there was highly significant difference between the treatments in which that the highest percentage was recorded to manual weeding 99.9 % weeding efficiency which was an excellent result, followed by V-shape blade and curve shape which found to be 94.6% and 82.9% weeding efficiency, respectively. The lowest weeding efficiency was recorded by shank Blade which equal to 74.7 %.

Table 1. Weeding efficiency at 4-5 weeks after sowing

Treatment	No of weed befo weeding	No of weed af weeding	Weeding efficien %
Manual	4857	6	99.8 a
V-shape blade	5546	304	93.7 b
Curved blade	5165	914	83.5 c
Shank blade	5406	2106	59.2 d
LS			S
SE±			0.85
CV%			1.2

Where:
LS=level of significance at (0.05%). CV= coefficient of variation. LS= least significant difference.

Table 2 Weeding efficiency at 9-10 weeks after sowing

Treatment	No of weed before weed	No of weed af weeding	Weeding efficie
Manual	5206	3	99.9 a
V-shape blade	4611	201	95.6 b
Curved blade	5333	911	82.9 c
Shank blade	4965	1252	74.7 d
LS			S
SE±			0.75
CV			1.04

Where:
LS=level of significance at (0.05%). CV= coefficient of variation. LS= least significant difference.

Effect of weeding methods on damage factor

The results of okra on plant damage factor during weeding operation were shown in Table 3. The highest percentage of damage was recorded by shank blade which represents 23%, followed by curved blade and Blade1 were recorded 2.1 % and 0.84%, respectively. The manual weeding method recorded zero percent damage. This result is in line with the results obtained by Shekhar*et al*. (2010) and it was accepted as an excellent result.

Table 3. Effect of weeding method on damage factor in okra plant

Treatmen	No of plant before w	No of plant after w	%Damage facto
Manual	801	801	0 a
V-shape blade	827	820	0.84 b
Curved blade	835	813	2.1 c
Shank blade	808	621	23 d

Where:
CV= coefficient of variation. Sig= level of significance of mean differences at (0.05%). .

Effect of weeding methods on plant population

The analysis of variance for individual and interaction effect of variables on plant population shows that there were no significant differences between them, as shown by LSD Test at significant difference of (p=0.05). This indicated that the weeding blades used have no effect on plant population for both weeding interval as shown in Table 4. This indicated that, blades used as a mechanical weeding had no effect on plant damage.

Table 4 Effect of weeding methods on plant population on okra plant at 4-5 And 9-10 weeks after sowing

Treatmen	Plant population (m^2)			
	4-5 weeks		9-10 weeks	
	No of plant Be	No of plant Af	No of plant Be	No of plant A
Manual	801	801 a	801	800 a
V-shape blade	827	820 a	820	813 a
Curved blade	835	813 a	813	789 a
Shank blade	808	621 a	621	587 a
Sig		NS		NS
SE±		33.63		19.95
CV%		16.19		9.22

Where:
CV= coefficient of variation. Sig= level of significance of mean differences at (0.05%).

Effect of Weeding Methods on Plant Height

The range of plant height that was measured is between 10 -13cm at first weeding and 18 -22cm for second weeding. In this regard the analysis of variance showed that there was no significant differences (p=0.05) among the mean. This shows that the methods of weeding had no effect on plant height before and after for the both weeding intervals as shown in Table 5. In this regard the highest plant height value 22cm was obtained with manual weeding method; this was due to its excellent weeding efficiency followed by a good result attained by V-shape blade and curve shape blade at 19 cm, the lowest value of plant height was obtained by shank blade with 18cm.

Table 5 ANOVA for plant Height on okra at 4-5 and 9-10 weeks

Treatment	Plant height (cm)	
	4-5 weeks	9-10 weeks
Manual	12 a	22 a
V-shape blade	13 a	19 a
Curved blade	13 a	19 a
Shank blade	12 a	18 a
Sig	NS	NS
SE±	1.33	1.38
CV	13.24	19.917

Where:
Sig =level of significance at (0.05%). SE± = Standard error. CV% = coefficient of variation.

Effect of weeding methods on okra yield

The analysis of variance for individual and interaction effect of variables on okra yield is summarized in Table 6. The analysis shows that there were highly significant level of difference at (p=0.05) the highest yield was by manual method of weeding at (526.2kg) then followed by V-shape blade at (365.7kg/ha) then curved blade at (253.7kg/ha) then finally the least yield by shank blade at (127.2kg/ha).These results indicated that, the less weed, the higher the productivity of okra crop.

Table 6 Effect of weeding methods on okra yield

Treatment	Weeding efficiency	Plant yield (kg/ha)
Manual	99.9 a	526.2 a
V-shape blade	95.6 b	365.7 b
Curved blade	82.9 c	253.7 c
Shank blade	74.7 d	127.2 d
Sig	S	S
SE±	0.75	0.5949
CV	1.04	14.39

Where:
Sig =level of significance at (0.05%). SE± = Standard error. CV% = coefficient of variation.

Theoretical and effective field capacity

The analysis of variance for theoretical field capacity and effective field capacity is summarized in Table 7. The statistical analysis shows no significance difference between the mechanical treatments. The range of mechanical weeding blades on theoretical field capacity was between 0.5- 0.7 ha/hr. Although the manual weeding method differs from the mechanical, but according to LSD All-Pairwise Comparisons Test still shows no significant difference between the treatments. Likewise in terms of effective field capacity, it ranged between 0.61-0.66 ha/hr.

Table 7 Machine theoretical field capacity and effective field capacity

Treatmen	Theoretical field ca (ha/hr)	Effective field capa (ha/hr)
Manual	0.045	0.016
V-shape blade	0.789	0.6648
Curved blade	0.842	0.6233
Shank blade	0.854	0.6149
Sig	NS	NS
SE±	0.012	0.0073
CV	2.35	1.87

Where:
Sig =level of significance at (0.05%). SE± = Standard error. CV% = coefficient of variation.

Field efficiency percentage

The analysis of variance for field efficiency is shown in Table 8. The analysis showed that all means were significantly different from each other with highest percentage for V-shape which represents 84% followed by curved blade at 74%, and then shank blade at 72%. The lowest percentage of field efficiency was recorded for manual weeding method at 35% due to low speed of the labor which consume too much time. This finding agrees with that stated by Shekhar *et al*. (2010).

Fuel consumption

The result of analysis of variance for fuel consumption as shown in Table 8 indicates that, there were highly significant differences between the treatments. The comparison of means for mechanical weeding methods showed that the highest consumption came from V-shape Blade (1.51 L/ha) followed by curve Blade with (1.4 L/ha) and then shank Blade (1.1 L/ha).

Table 8 Field efficiency and fuel consumption of the machine

Treatment	Field efficiency %	Fuel consumption
Manual	84 a	**
V-shape blade	74 b	1.51 a
Curved blade	72 c	1.4 b
Shank blade	35 d	1.1 c
Sig	S	
SE±	0.4082	0.0078
CV	0.75	2.70

Where:
Sig =level of significance at (0.05%). SE± = Standard error. CV% = coefficient of variation.

Time consumed during weeding

The result for analysis of variance on time consuming during weeding operation is shown in Table.9. The manual weeding method resulted in highest time consumption of 41.68 hr/ha, therefore to weed a hectare of land in a single day need 13 person or a single person need 13 days to weed a hectare of land. Mechanical Blade1 and Blade2 have the average time consumption of 0.755 to 0.710 hr/ha, whereas the Blade3 recorded the lowest time consumption with 0.68 hr/ha. This might be due to its low performance in weeding efficiency. These results indicated that the time consumed during weeding increases when using the hand labor and decreases when using the machines. The time saved when using mechanical weeding represent up to 98% in comparison of manual weeding. This result agrees with the finding of Rangaswamy *et al.* (1993).

Table 9 Effect of weeding method on time consumption

Treatments	Time consumption during weeding
Manual	41.68 a
V-shape blade	0.755 b
Curved blade	0.710 bc
Shank blade	0.68 c
Sig	NS
SE±	0.0412
CV	18.76

Where:
Sig =level of significance at (0.05%). SE± = Standard error. CV% = coefficient of variation.

Ridge height after sowing

The result showed that there was no significant difference (p=0.05) between the treatments on the ridge height after sowing as shown in Table 10.The result indicated that there was the homogeneity of seedbed preparation in the experimental area.

Ridge height after weeding

The statistical analysis showed that there were no significant difference between the treatment at (p=0.05) which was shown in Table 10. The height of the ridge was almost identical to each other with less difference between the treatments. The highest ridge shown in manual weeding (14cm) due to rebuild of the ridge when weeded by the labor, then Blade1 (13 cm) that rebuilt the ridge almost near to that of manual during weeding. The lowest ridge height was obtained by shank blade due to its low performance in weeding efficiency and couldn't be able to rebuild the ridge.

Table 10 Ridge height After Sowing and after Weeding

Treatment	Ridge height (cm)	
	After sowing	After weeding
Manual	15.5 a	14 a
V-shape blade	15.5 a	13 ab
Curved blade	15.2 ab	11 b
Shank blade	14.9 b	8 c
LS	NS	NS
SE±	0.2449	0.9129
CV	1.96	10.16

Economic cost

The economic cost was calculated based on the law of fix cost and variable cost as shown in Table 1.The result was compared between mechanical and manual weeding methods. The result showed that there was almost 48% saving in cost when using mechanical weeding in comparison to manual weeding. The finding agrees with that of Rangaswamy *et al.* (1993).

Table 11 Cost of mechanical weeding and manual weeding

Treatment	Estimated labor cost per hectar (USD)
Manual weeding	52,000
V-shape blade	20,000
Curved blade	29,000
Shank blade	29,000

Draft requirement

The draft requirement for the weeders was calculated with dynamometer device. And the result showed that lowest draft was recorded with curve shape blade 75.5kg due to its light weight and easy maneuvering, and then followed by shank blade 79.8kg and the highest draft force was recorded with V-shape blade 87.6kg.

Table 12 draft force requirement

Treatment	Draft force (kg)
V-shape blade	87.6
Curved blade	75.5
Shank blade	79.8

Where:

Conclusion

Base on the results obtained the following conclusions are stated as follow:

1. Mechanical weeding control with treatment with V-shape blade and curved blade give an excellent result compared to shank blade in terms of weeding efficiency, grain yield and plant damage.
2. All treatments gave higher weeding efficiency and improve yield when compared with shank blade.
3. Mechanical weeding control methods gave higher field efficiency and effective field capacity when compared to manual weeding.

Recommendation

1. Some of the major advantages of mechanical V-shape blade are high weeding efficiency, high grain yield, low plant damage but has high draft requirement. It's recommended to work in a minimizing draft requirement.
2. Major advantages of mechanical curve shaped blade are low initial cost, low time consumption and low draft force.
3. Curved blade is recommended in weeding as a new design because it resulted in higher weeding efficiency, low plant damage and high grain yield.
4. For future study further research needed to develop curve shape blade with different design pattern and apply to different crops for better field efficiency and low cost.
5. Study the effect of the optimum soil moisture content in good weeding operation.

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