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CONTENTS

Effect of tillage, fertilizer placement and nitrogen levels on green foliage, brix, sucrose, juice and ethanol production of sweet sorghum *(Sorghum bicolor* L.) in Mollisols of Uttarakhand 1
MANOJ KUMAR, MAHENDRA SINGH PAL and KEWALANAND

Status and distribution of soil available micronutrients along a hill slope in Ekpoma, Edo State, Nigeria 7
AGBOGUN, LUCKY, EDOSOMWAN, N.L. and AGABI, E.J.

Foliar nutrition for higher soybean productivity in north western plain zone of India 15
AJAY KUMAR, D. K. SHUKLA, AMIT BHATNAGAR and R. K. SHARMA

Soil suitability assessment of a humid tropical soil for pineapple (*Ananas comosus*) and plantain (*musa spp*) cultivation in Port Harcourt, Nigeria 19
PETER, K.D., ORJI, O.A. and ORIAKPONO, I.O.

Land suitability evaluation for avocado pear (*Persea americana* Mill.) and pineapple (*Ananas comosus* L. Merr) in rain forest zone of Edo State, Nigeria 30
OKUNSEBOR F. E., UMWENI A. S., ONAIFO W. and OSAGIE D.

Population studies on various coccinellid beetles from different crop ecosystems of Pantnagar, Uttarakhand 39
M. SREEDHAR, R. P. MAURYA, PARUL DOBHAL and RIYA

Occurrence of leaf feeder *Podontia quatuordecimpunctata* (Linnaeus, 1767) in *Spondias pinnata* (L.f.) Kurz at Kamrup district of Assam, India 44
S. PATHAK and B. DEKA

Morphological characterization of F_1 guava hybrids and varieties 47
SHIKHA JAIN, RAJESH KUMAR, NARENDRA KUMAR SINGH, VIJAY PRATAP SINGH and SATISH CHAND

Report on severe infestation of root-knot nematode, *Meloidogyne incognita* on tuberous *Vigna vexillata* (L.) 53
ZAKAULLAH KHAN, KULDEEP TRIPATHI, BHARAT H. GAWADE and V. CELIA CHALAM

Selection of exotic germplasm of bread wheat against *Puccinia triticina* resistance with analysis of Area Under Disease Progress Curve 58
WAGHAMARE MINAL BHUJANGRAO and DEEPSHIKHA

Land suitability assessment for okra (*Abelmoscus esculentus L.)* and fluted pumpkin (*Telferia occidentalis, L.*) cultivation in Khana Local Government Area of Rivers State, Southern Nigeria 62
PETER, K.D. , UMWENI, A.S. and ORJI, A.O.

A comprehensive study of changed training in SAMETI Uttarakhand mode during Covid-19 pandemic 71
JYOTI KANWAL, B. D. SINGH, ANURADHA DUTTA and ANIL KUMAR SHARMA

Initiation of Farmers University and Farmers Bank in India 76
AVINASH SHARMA, CHOWLANI MANPOONG, SANGEETA SHARMA and MEGHA RAGHAVAN

Reformation of ration shop for below poverty line people in India 83
AVINASH SHARMA, CHOWLANI MANPOONG, SANGEETA SHARMA and MEGHA RAGHAVAN

An empirical analysis of factors influencing agricultural employment intensity of migrant farm households at Almora district of Uttarakhand 90
BHUMIKA GIRI GOSWAMI and ANIL KUMAR

Consumer attitude and behavior towards purchasing agri food: A case study of tomato crop 95
TAMANNA JOSHI and ASHUTOSH SINGH

Checklist and conservation status of freshwater finfishes of KoleWetlands a Ramsar Site in Kerala, India 103
KITTY FRANCIS C. and M. K. SAJEEVAN

Freshwater fish fauna of Peechi-Vazhani Wildlife Sanctuary, Western Ghats of Kerala, India 110
ELDHO. P. S. and M. K. SAJEEVAN

Study of subclinical mastitis in milch breeds of cattle in Western India 117
BEENU JAIN, ANUJ TEWARI, BHARAT BHANDERI and MAYURDHWAJ JHALA

Prevalent mutations in the Delta variants of SARS CoV2 circulating in India 122
BEENU JAIN, ANUJ TEWARI, ALOK KUMAR and PREMA S GODI

An analysis of selective pressure on Delta variants of SARS CoV2 circulating in India 126
BEENU JAIN, ANUJ TEWARI, ALOK KUMAR, PREMA S GODI and SHRADDHA DWIVEDI

AMR status in Uttarakhand 131
NAWAL KISHOR SINGH, A. K. UPADHYAY, T. K. AMBWANI, MAANSI, HIMANI SHARMA, SOURABH SWAMI and AJAY KUMAR

Awareness of the aspects of sun protection among college going girls 142
BEENU SINGH and MANISHA GAHLOT

Development and evaluation of power weeder for narrow row crops 148
T. SENTHILKUMAR, N.S.CHANDEL, P.S.TIWARI, SYED IMRAN S. and G. MANIKANDAN

Data prediction for calibration of seed drill using multiple linear regression 156
SIMRAN TIWARI, PRAMOD MOHNOT and K.B. JHALA

Mapping of ground water potential zone in complex hydrological system of Suyal basin in the Mid-Himalayan Region using Analytic Hierarchical Process 166
RITESH JOSHI, H.J SHIVA PRASAD, JYOTHI PRASAD, P. S. MAHAR, DEEPAK KUMAR and PANKAJ KUMAR

Water quality assessment of Bageshwar Block Springs using Weighted Arithmetic Water Quality Index (WAWQI)method, Bageshwar District, Uttarakhand, India 173
MOHD AZAM, JYOTHI PRASAD and H. J. SHIVA PRASAD

Development and evaluation of power weeder for narrow row crops

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ABSTRACT: Weed growth is a major problem for narrow spaced crops causing a considerably lower yield. At present, manual weeding tools are the only option for narrow spaced crops. Due to the need of an hour, a 1.3 kW petrol engine operated manually guided power weeder with different types of blade for narrow row crops was designed and developed. Operational parameters *viz*., three forward speeds (1, 1.5 and 2 km h^{-1}), two depths of operation (20 and 40 mm) and three types of blade (L-shape, T-shape and C-shape) were selected to evaluate its performance for weeding in field conditions. Power weeder attached to T-type blade with a forward speed of 2 km h^{-1} at 20 mm depth of operation was optimized for his highest performance index (1079) and field capacity (0.251 ha h^{-1}). It shows satisfactory weeding efficiency (88.2%), plant damage (2.5%), fuel consumption (0.88 l h^{-1}) and field efficiency (63%).

Key words*:* Narrow spaced crops, power weeder, women-friendly, weeding efficiency

Weeding is an important but equally labour-intensive agricultural unit operation. In India, this operation is mostly performed manually with khurpi or trench hoe requires higher labour input and is also very tedious and time-consuming process. It is estimated that the weed alone reduces the crop yield up to 16-42 % depending on the crop, location and involves 1/3rd of the cost of cultivation (Rangasamy *et al.,* 1993). At present, there is an increasing interest in the use of low-power mechanical weeders because of their low cost, women-friendly and growing demand for organically produced food. Low power mechanical weeder would reduce drudgery and ensure a comfortable posture of the farmer or operator during weeding.

Tajuddin (2006) developed an engine operated weeder with a sweep blade capable of achieving a depth of operation of 3.9 cm, weeding efficiency 85.85% and effective field capacity 0.1 ha h^{-1}.Srinivas *et al.* (2010) compared three commercially available power weeders for weeding and inter-cultivation in sweet sorghum crop. The weeding efficiency of L shape blade power weeder was found to be 91%, whereas C type and sweep type blade power weeders recorded 87 and 84%, respectively. The performance index of the L shape blade, C type and sweep type blade power weeders were observed as 169.84, 153.23 and 114.3, respectively. Field capacity of sweep-type weeder was 0.12 ha h^{-1} which is more than C type and L type blade power weeder. Weeders having C-type blades perform well at gang speed of 200 rpm and soil moisture content 15.26 ± 0.96 % (d.b) with weeding efficiency, plant damage, field capacity of 91.37 %, 2.66 %, and 0.086 ha h^{-1}, respectively (Thorat *et al.*, 2014). Plant damage increased significantly under higher forward speeds and lower plant spacing (Kumar *et al.,* 2020).

Senthilkumar *et al.* (2014) conducted a study to select the suitable power weeder for pulse cultivation at TNAU fields with three models of commercially available power weeders (Model A, B and C). The three models were compared with conventional method of hand weeding. The working width of the power weeders were 60 cm, 60 cm and 30 cm respectively for Model A, B and C. Manual weeding using hand hoe registered maximum weeding efficiency of 83.10 % (wet basis) and 82.5 % (dry basis). The weeding efficiency of Model A was 74.10 % (wet basis) and 73.45 % (dry basis), Model B recorded 63.49 % (wet basis) and 64.15 % (dry basis) and Model C recorded lowest weeding efficiency of 43.43 % (wet basis) and 43.13 % (dry basis).

Based on the review, performance index, field efficiency and weeder efficiency can be increased with minimal crop plant damage by proper selection of operation of depth, working speed and types of blades. Therefore, the present work has been planned with the power-operated rotary weeder because of its higher ability to mix, roll out and pulverize soil. The rotary weeder was made to operate with selected types of blades, depth of operation and forward speed. Development of narrow row crop weeder will help the majority of farmers since most of them are having small land.

MATERIALS AND METHODS

Development of manually guided power weeder

A machine was designed by keeping in mind the various agronomical requirement of crop like spacing of crop (300 mm) and height of the crop (200 mm) from the ground level. The developed power weeder consists of petrol engine, weeding assembly, weeding blade, depth control wheel and mainframe.

Power source

Soil resistance, width of cut, depth of cut and speed of operation influence the power requirement of weeder. The power requirement for weeding was calculated using the following equations

$P_d = S_r \times d \times w \times v/75$

Where: S_r = soil resistance, kgf cm^{-2} (1.05); d = depth of cut (4), cm; w = effective width of cut (20), cm; v = linear velocity of the tine at the point of contact with the soil, m s^{-1} (1).

Hence, power requirement is estimated as

$P_d = 1.05 \times 4 \times 20 \times 1 \times 0.746 /75 = 0.83$ kW

The total power (Pt) required is estimated as follows

$P_t = P_d /\eta = 0.83/0.8 = 1.03$ kW

where: P_d = Power required to dig the soil; η= Transmission efficiency (0.8)

Hence, A 1.3 kW petrol engine (Honda GK 100) of 97.7 cc, 4-stroke, air cooled, single cylinder was selected as a power source.

Weeder assembly

The weeding assembly consists of two flange, one on the right side and another on the left side. The diameter and thickness of flange was 160 and 8 mm, respectively. Each flange consists of four numbers of weeding blades fixed on a cylindrical flange radially at an equal distance along the flange circumference. The flange set was fixed on the bush which is attached to the common drive shaft from the gear head. The single stage worm gear was used and gear reduction ratio was 44:1. Variable speed throttle was provided to vary the speed of engine with that the weeder rotation speed can be altered.

Weeding blade

Three types of blades namely L-shape, T-shape and C-shaped blades (Fig. 1) were developed to evaluate their performance in actual field conditions. Each blade was made of mild steel flat of 8 mm thick because it is strong enough to sustain the prevailing forces. The blades were sharpened at the cutting end so that it can penetrate the soil at proper angle and desired depth during weeding. Blade radius from the centre of drive shaft and working width of all blade was as 130 and 200 mm, which is kept constant for study the effect of different blade shape. The

Fig. 1: L-shape blade, C-shape blade and T-shape blade

measured weight of L-shape, T-shape and C-shape blades was 4.72, 5.02 and 4.90 kg, respectively.

Depth control wheel

A depth control wheel is attached to the rear of the main frame for depth adjustments of the rotary blades. Two number of commercially available depth wheel made of plastic with rubber tyres used in weeder. The diameter and width of the wheel was 150 and 40 mm, respectively. The depth wheel shaft has an adjustment for raising and lowering the depth wheel to alter the depth of cutting and weeding by the rotary blades.

Main frame

In order to accommodate the petrol engine, weeder assembly, blade, and cutting unit it was decided to have frame of overall dimension of 600 mm in length and 200 mm in width. The frame is made from 35×35×5 mm MS angle section. Also strips of MS plate size of 115×32 mm were welded in between the angle iron as braces and support.

Field experiment

Prototype of power weeder with different blades was tested under field conditions in vertisol soil. The performance evaluation was carried out with different combinations of operation parameters *viz*., blade type (C, L and T), forward speed (1, 1.5 and 2 km $h^{-1)}$ and depth of operation (20 and 40 mm) to study the effect on weeding efficiency, plant damage, fuel consumption, field capacity, field efficiency and performance index. An area of 1200 m^2 of vertisol soil was used to evaluate weeder performance in field condition. The experimental data were analysed statistically using Randomized Complete Block Design (RCBD) for weeding efficiency and fuel consumption. The following performance indicators were calculated using the observed data in the field.

Evaluation of the weeder

Weeding was done when height of weeds were about 20-30 mm. For all the treatments, the weeding efficiency, plant damage, fuel consumption, effective field capacity and field efficiency were recorded to study the effect of selected variable of power weeder. With the recorded data performance index was also calculated.

***A. Weeding efficiency* (*WE*)** was calculated by using the following formula (Goel *et al.,* 2008; Thorat *et al.,* 2013).

$$WE\ (\%) = [(W_1 - W_2)/W_1] \times 100$$

where, WE = Weeding efficiency, %; W_1 = number of weeds per m^{-2} before weeding; W_2 = number of weeds per m^{-2} after weeding.

B. Plant damage (PD) was measured by using

Fig. 2:. Manually guided power weeder

following relation (Yadav and Pund, 2007; Goel *et al.,* 2008)

PD (%) = {1- (Q/P)} × 100

where, PD = plant damage, %; Q = Number of plants in a 10 m row length after weeding; P= Number of plants in a 10 m row length before weeding

C. Fuel consumption (FC) was measured by using top fill method

FC (l ha^{-1}) = fuel consumption, l / area covered, ha

D. Effective field capacity (EFC) was computed by recording the area weeded during each trial run in a given time interval (Thorat *et al.,* 2013; Senthilkumar *et al.,* 2014).

EFC (ha h^{-1}) = Area covered, ha / Time taken to cover test area, h

E. Field efficiency (FE) *was* calculated by using following formula (Srinivas *et al.,* 2010; Senthilkumar *et al.,* 2014).

FE (%) = (EFC / TFC) × 100

Where, TFC = Theoretical field capacity, ha h^{-1}

F. Performance Index (PI): The performance of the weeders was assessed by using the following relation (Srinivas *et al.,* 2010).

PI = (EFC × PD × WE) / P_t

Where: EFC = effective field capacity of weeder, ha h^{-1}; PD = plant damage, %; WE = weeding efficiency, %; p = power required to operate the weeder, hp

RESULTS AND DISCUSSION

Weeding efficiency

The ANOVA showed that the weeding efficiency was significantly influenced by main factors (blade type, forward speed and working depth). However, interaction effect shows non-significant (Table 1). The F-value of 66.40 indicated that the model was highly significant ($P<0.01$). The coefficient of determination was recorded 0.96, which indicated the goodness of the model. The response surface plot showed the effect of different blades with different forward speeds at constant working depth of 40 mm on weeding efficiency (Fig. 3a). In Fig. 3b. graph shows the effect of different blades and working depth at constant forward speed of 2 kmh^{-1} on

Table 1: ANOVA for the response surface model on WE

Source	Sum of squares	Df	Meansquare	F-value	p-value	Test result
Model	3570.41	17	210.02	66.40	< 0.0001	S
A-Blade type	2966.73	2	1483.37	485.51	< 0.0001	S
B-Forward speed	383.29	2	191.65	62.73	< 0.0001	S
C-Operational depth	193.42	1	193.42	63.31	< 0.0001	S
AB	15.70	4	3.93	1.28	0.2922	NS
AC	2.61	2	1.30	0.4265	0.6557	NS
BC	0.3126	2	0.1563	0.0512	0.9502	NS
R^2						**0.96**

SD : 1.78 C.V : 2.29 %

Table 2: ANOVA for the response surface model on FC

Source	SS	Df	Meansquare	F value	p-value	Test result
Model	0.5016	13	0.0386	85.33	< 0.0001	S
A-Blade type	0.0903	2	0.0452	99.89	< 0.0001	S
B-Forward speed	0.0874	2	0.0437	96.61	< 0.0001	S
C-Operational depth	0.2875	1	0.2875	635.82	< 0.0001	S
AB	0.0013	4	0.0003	0.7106	0.5895	NS
AC	0.0078	2	0.0039	8.67	< 0.0007	S
BC	0.0273	2	0.0136	30.16	< 0.0001	S
R^2						**0.96**

SD: 0.0218 C.V: 2.66 %

weeding efficiency.

It was observed that, the weeding efficiency increases as the forward speed and depth of operation increase irrespective of types of blades. This might be due to high soil inversion and pulverizing with an increase in forward speed and depth of operation. Similar findings were reported by Srinivas *et al.* (2010).

The maximum value of weeding efficiency was 90.70%, recorded for T - type blade at forward speed of 2 km h^{-1} and operation depth of 40 mm. This may be due to increased soil contact and soil inversion capacity of the blade shape. It was observed that the mean maximum weeding efficiency of 90.70, 85.00 and 72.80 % for T-shape, L-shape and C-shaped blades, respectively. The minimum weeding efficiency was found to be 62.20% for C-type blade at forward speed of 1 km h^{-1} and working depth of 20 mm. This might be due to more uncut soil compared to other blades, which was visually observed in the field. Similar findings were reported by Jafar and Singh (2009).

Fuel consumption

The ANOVA showed significant effect of blade type, forward speed and operational depth on fuel consumption (Table 2). The F-value of 85.33 indicated that the model was highly significant ($P<0.01$). For the fitted model, the coefficient of determination was recorded 0.96, which indicated the goodness of the model. The interaction effect was also found to be significant except blade type (A) and forward speed (B). The effect of forward speed and blades type on fuel consumption at 40 mm depth of operation are presented in Fig. 4a. Fig 4b shows the effect of different blade and working depth at constant forward speed of 2 km h^{-1} on fuel consumption. It was observed that the fuel consumption increased as the forward speed and working depth increased for all types of blades. The minimum value of fuel consumption was 0.58 l h^{-1} recorded for C - type blade at forward speed of 1 km h^{-1} at working depth of 20 mm. This is due to less soil cut and low forward speed of power weeder. The maximum fuel consumption was found to be 0.94 l h^{-1} for T-type blade at forward speed of 2 km h^{-1} and working depth of 40 mm. This might be due to increase in depth increase in the cut and disturbance of high volume of soil compare to low depth and low speed.

Plant damage

Effect of operational parameters *viz*., blade type, forward speed and depth of operation on plant damage are presented in Fig. 5a and 5b. It was observed the plant damage percentage increased with the increase in forward speed irrespective of blade. It was also observed that no damage occurred (zero

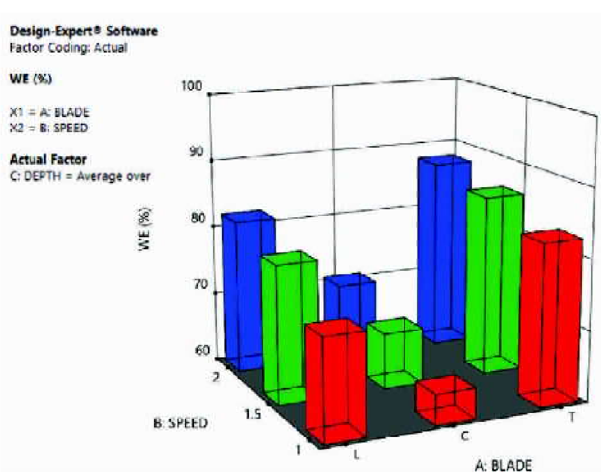
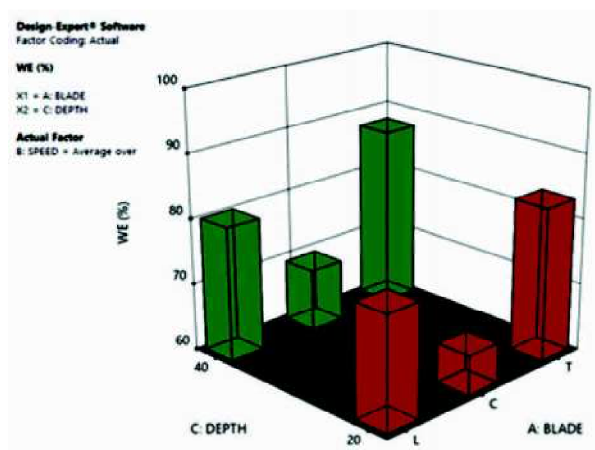


Fig. 3a: Effect of blade and speed at constant working depth of 40 mm on WE



3b: Effect of blade and working depth at constant forward speed of 2 km h^{-1} on WE

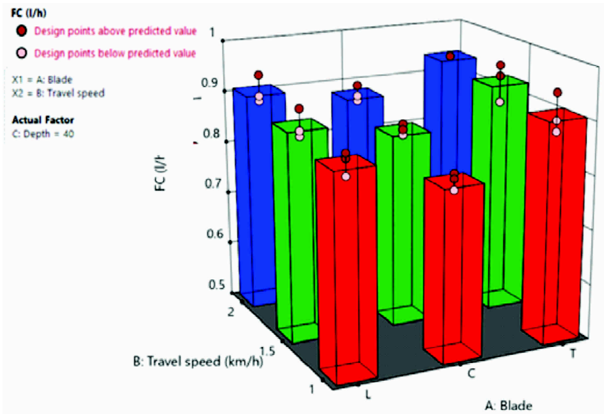
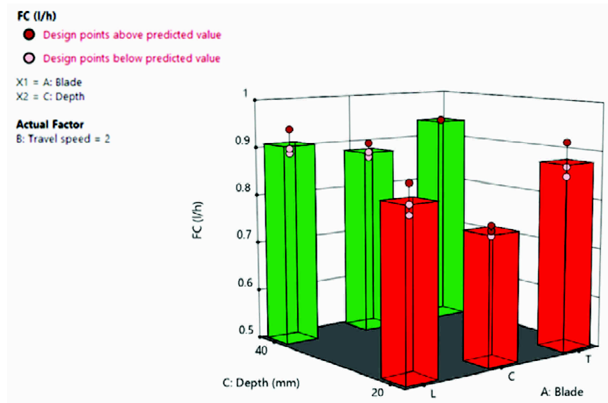


Fig. 4a: Effect of blade and speed at constant working depth of 40 mm on FC



4b: Effect of blade and working depth at constant forward speed of 2 km h^{-1} on FC

%) at forward speed of 1.0 km h^{-1} for C and T blade at operational depth of 20 mm and C type blade at working depth of 40 mm. The maximum value of plant damage percentage was 3.75% recorded for 2.0 km h^{-1} forward speed at working depth of 40 mm. Higher percentage of plant damage was found in case of T type blade as compared to other blades, followed by C blade and least was observed for L blade types. High plant damage in L type blade might be due to longer projected part of the blade. Similar findings were reported by Manjunatha *et al.* (2015).

Effective field capacity

Effect of operational parameters *viz.* blade type, forward speed and depth of operation on effective field capacity are presented in Fig. 6a and 6b. The effective field capacity increases with increase in forward speed and decrease in depth of operation for all types of blade. Similar findings were reported by Manuwa *et al.* (2009). A maximum effective field capacity of 0.25 ha h^{-1} was recorded at a forward speed of 2.0 km h^{-1} with depth of operation of 20 mm while it was minimum of 0.13 ha h^{-1} at forward speed of 1.0 km h^{-1} with depth of operation of 40 mm. It was observed that the effective field capacity of L-type blade was lowest followed by C-type blade and highest was recorded for T-type blade irrespective of depth of operation.

Field efficiency

Effect of operational parameters *viz.* blade type, forward speed and depth of operation on field

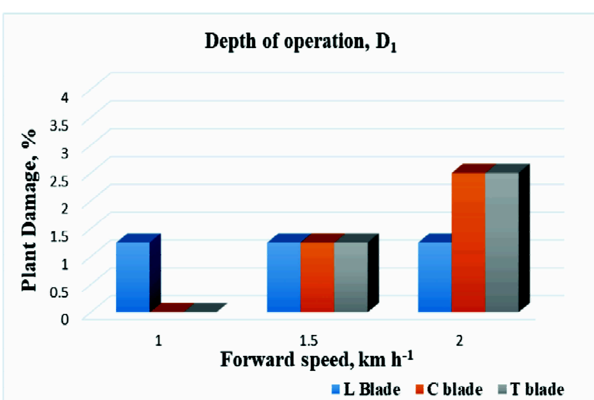


Fig. 5a: Effect of different blade and speed on plant damage at working depth of 20 mm

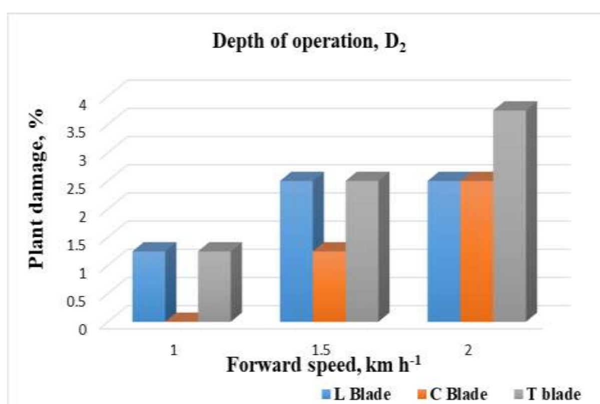


Fig. 5b: Effect of different blade and speed on plant damage at working depth of 40 mm

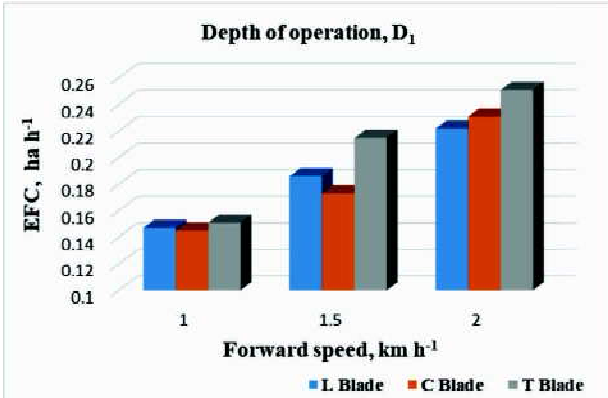


Fig. 6a: Effect of different blade type, forward speed on EFC at working depth of 20 mm

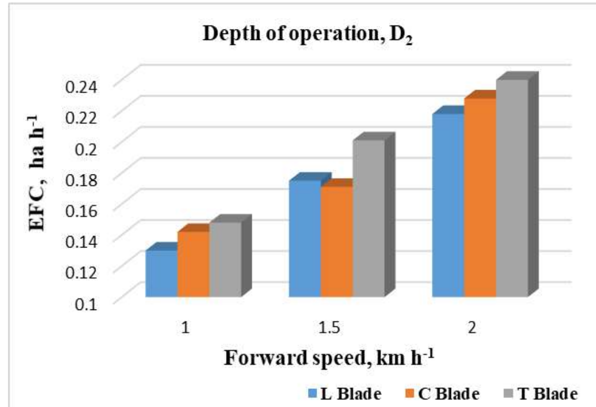


Fig. 6b: Effect of different blade type, forward speed on EFC at working depth of 40 mm

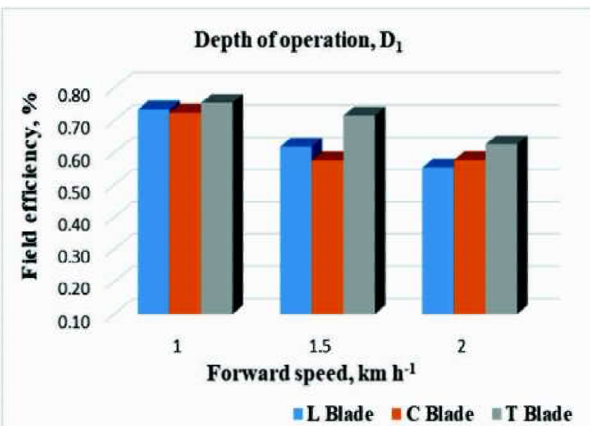


Fig. 7a: Effect of different blade type, forward speed on FE at working depth of 20 mm

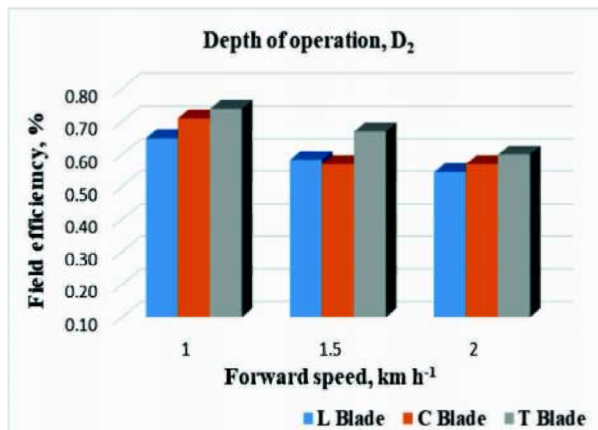


Fig. 7b: Effect of different blade type, forward speed on FE at working depth of 40 mm

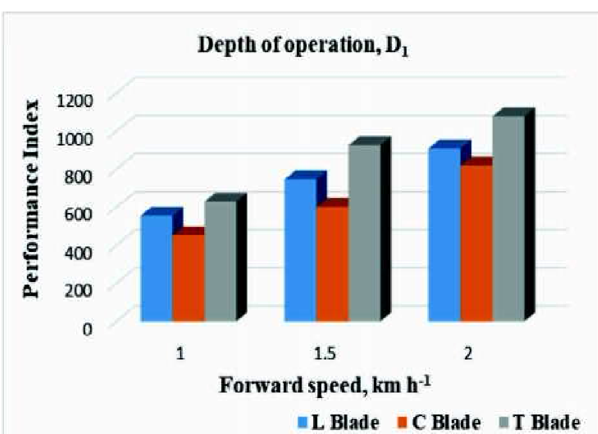


Fig. 8a: Effect of different blade type, forward speed on PI at working depth of 20 mm

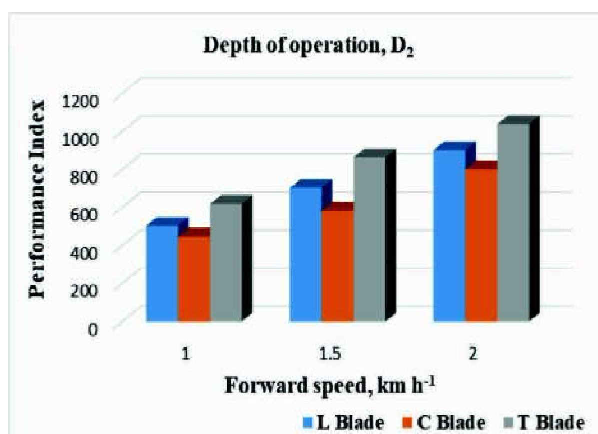


Fig. 8b: Effect of different blade type, forward speed on PI at working depth of 40 mm

efficiency are presented in Fig. 7a & 7b. The field efficiency decreased with increase in forward speed and increase in depth of operation for all types of blade. It was observed that the field efficiency was highest for T-type blade followed by C-type blade and lowest was recorded for L-type blade irrespective of depth of operation.

Performance index

Performance index of T-type, L-type and C-type blade weeder was found in range of 631 to 1079, 555 to 90, 453 to 820 and 620 to 1041, 505 to 902, 448 to 803 at 20 and 40 mm depth of operation, respectively. The highest performance index was observed for T-type blade at forward speed of 2 km h^{-1} and operation depth of 20 mm. It was observed performance index increased with increase in forward speed and decreased with decrease in depth of operation (Fig. 8a and 8b).

CONCLUSION

A manual guided rotary power weeder operated by a 1.3 kW petrol engine was developed and evaluated in narrow row crop (soyabean crop). T - type blade with forward speed of 2 km h^{-1} at 20 mm depth of operation in field condition was found to be superior than the other level of selected variable with high performance index (1079) and high field capacity (0.251 ha h^{-1}) and it shows satisfactory weeding efficiency (88.2 %), plant damage (2.5 %), fuel consumption (0.88 l h^{-1}) and field efficiency (63 %).

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