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Effect of operating speed, moisture content of soil and approach angle of sweep on specific draft and weeding efficiency

[1,] U. S. Kankal, [2,] V.P.Khmabalkar, [3,] D.S.Karale, [4,] S.M.Nage
[1, 2, 3, 4,] *Department of Farm Power and Machinery,*
Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola

--ABSTRACT--
The highest cost of weeding contributes more losses due to various reasons. To overcome of weeding problem, self propelled low cost drag type weeder was designed, developed and tested at the College of Agricultural Engineering, University of Agricultural Sciences, Raichur. Three ranges of approach angles 60^0, 70^0 *and* 80^0, *forward speeds viz. 0.28 m/s, 0.42 m/s and 0.56m/s and moisture contents 13%, 15% and 18% were optimized on the basis of lowest specific draft and highest weeding efficiency. An approach angle of 70 degree at a forward speed of 0.42 m/s at 15% moisture contents of soil was optimized as it resulted in lowest specific draft as 0.619 N/mm and highest weeding efficiency as 89.58%.*

KEY WORDS: *Approach angle***,** *moisture content, specific draft, weeder*

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I. INTRODUCTION

The highest cost of weeding contributes more losses due to various reasons. The losses due to insect and disease were 35.8 per cent, while losses due to weed are assessed to be 33.8 per cent and losses due to soil erosion are assessed to be 13.6 per cent. In India about 4.2 billion rupees are expended every year for controlling weeds in production of major crop. Farmers and researchers are putting up combined effort to tackle this problem of weed removal. In the past, there were no proper mechanical weeders to fight those enemies and farmer had to use their hands to pull out those weed. Introduction of effective mechanical weeders is expected to encourage subsistent farmers leading to increased production and reducing poverty. In case of dry land, where the moisture availability with the soil limited, the weed compete more for soil moisture unlike in irrigated crops. The yield losses in dry land crops due to the weeds have been estimated to be very high. For Control of weeds following methods are generally followed.

Control practices to reduce or suppress the weeds may not necessarily result in the elimination of any particular weed species. There are four general methods for weed control *viz*. physical, cultural, mechanical and biological. The weed removal involving the use of physical energy through implement either manually or bullock power or mechanical power. The adverse soil condition as too dry or too wet will limit the use of power source. Hand pulling or hand weeding using khurpi, burning, flooding, smothering etc. are examples of physical weed management. Cultural practice like ploughing of land with mould board plough during summer season for uprooting of weeds exposed to hot sun rays. Good cropping practice can change the condition such a way to enable the crop plants to compete with the weeds successfully or to reduce their interference to the minimum and thus prevent them from acting as impediment to increase in crop production. Quality seed with good germination will give the crop a vigorous and close stand, and would enable the crop plants to compete over the weeds. Some crops can compete better with weeds. For instance, the crop like sorghum, cowpea are good competitors, where as other crops such as groundnut, lentil are poor competitors. Close row crop compete better with the weeds than wide row crops. Similarly, the crops and varieties having early and faster growth compete better than those growing slow during the early part of the growth like pigeon pea. Intercropping, particularly fast growing crop such as cowpea, soybean etc, in wide spaced crops like maize, sugarcane would reduce weed competition. This shows, there is an urgent need to introduce mechanical weeder in Indian farm. Engine operated drag type weeder was undertaken to study present investigation with the following objectives. To effect of operational parameters on specific draft and weeding efficiency in field conditions.

II. MATERIALS AND METHODS

The soil of North Karnataka is characterized under 2 and 3 region as black soil that contains predominantly montmorillonite clay. The soil has good moisture holding capacity and it swells considerably with moisture content. When dry, soil shrinks and forms cracks. The soil used for testing of sweep in field has clay texture with 1.84% fine sand, 12.95% coarse sand, 30.51% silt and 54.70% clay.

Three different shapes of sweeps were tested in field condition to obtain design parameters of sweeps under black soil. It was observed that sweep was most suitable soil working tool under black soil conditions (Sail *et al.*, 1978; Tiwari *et al.*, 1993 and Biswas *et al*., 1993). Barnacki *et al.* (1972) recommended that the apex angle should be in the range of 60 to 90 degree. Three ranges of approach angles 60^0, 70^0 and 80^0 were selected for study are presented in fig.1.

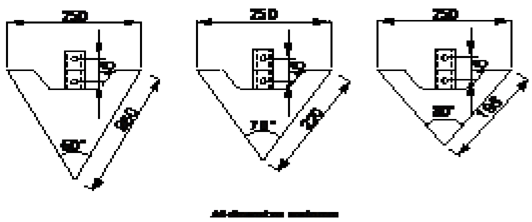


Fig. 1 different shape of sweep

It was decided to test the weeder with different geometry of sweep that had small width but in gang instead of single sweep. A gang width of 300mm was selected for study. The range of speed was selected from 0.28 m/s to 0.56 m/s which was ergonomically based suited for walking behind implements (Yadav *et al.,* 2007). The workable range of moisture 13% to 18 % considering the field capacity and wilting point. The dependent variables taken were specific draft and weeding efficiency. The levels of variables for evaluation of sweeps were selected for study are presented in Table1.

Table 1. Levels of variables for evaluation of self propelled low cost drag type weeder

Sl. No.	**Parameters**	**Levels**	**Symbols**
	Independent		
1.	Approach angle	3	$\theta_1, \theta_2, \theta_3$
2.	Forward speed	3	S_1, S_2, S_3
3.	Moisture content	3	M_1, M_2, M_3
	Dependent		
4.	Specific draft	…..	S_p
5.	Weeding efficiency	…..	E_w

The field was leveled and compacted. Water was sprinkled on the soil to maintain desired soil moisture. A hand held cone penetrometer was used to measure the cone penetration resistance of the soil. The penetrometer had a angle of 30^0 and base area of 491.1 mm^2. Readings were taken up to a depth of 100 mm. The value of cone penetration resistance was reasonably uniform and ranged from 0.120 to 0.121 N/mm^2. The plan layout of experiment is shown in fig 2. The experiment was conducted in MARS field. The moisture of soil was maintained at nearly 13%. The sweep of 60^0 approach angle were mounted on tool frame by giving gang 300 mm. The auxiliary mini power tiller was hitched to self propelled weeder with the help of hook joint. A hydraulic dynamometer was connected in between self propelled weeder and auxiliary power tiller. The no load draft was calculated without fixing the sweeps to tool frame. The load draft was calculated fixing the sweeps to tool frame.

Total draft exerted on the wedding tool (sweep) was computed using the formula. Anon. (1995)

$$D = D_1 - D_2 \qquad \text{----------1)}$$

Where,

D = draft of sweep, kg

D_1 = draft of sweep when sweep in operating condition, kg

D_2 = draft of sweep when sweep not operating condition, kg

The total draft computed (D) was divided by gang width to obtain draft per working width termed as specific draft.

The weeds allow to grow naturally in field. Depth of operation was mentioned at 50 mm. The horizontal force was recorded by using hydraulic dynamometer. The self propelled weeder pulled at 0.28 m/s speed. The undisturbed weeds were counted. After weeding undisturbed weed and disturbed weed were counted from one sq. m. test plot area and measured. The weeding efficiency was calculated by using the formula.

$$\mathrm{E_W} = \frac{\mathrm{W_1}}{\mathrm{W_1} + W_2} \times 100 \qquad \text{……2)}$$

Where,

E_w = Weeding efficiency, %

W_1 = No. of weeds disturbed after weeding in one meter square area

W_2 = No. of weeds undisturbed in one meter square area.

The next field maintains 13% moisture content. The same procedure was repeated with at the speed of at 0.42 m/s and in another field of 0.56 m/s and so on. After the completion of test, at all three speeds. The identical test was conducted with the approach angles $60^0, 70^0$ and 80^0 tools at 15% and 18% moisture content. The experiment was replicated thrice for each combination of approach angle, forward speed and moisture content for specific draft and weeding efficiency. The details of treatments combination are presented in Table 2.

Table 2. Variables selected for experiment

Sl. No.	**Moisture content, %**	**Speed, m/s**	**Approach angle, degree**		
1.	13	0.28	60	70	80
		0.42	60	70	80
		0.56	60	70	80
2.	15	0.28	60	70	80
		0.42	60	70	80
		0.56	60	70	80
3.	18	0.28	60	70	80
		0.42	60	70	80
		0.56	60	70	80
4.	Replications	Three			
5.	Total number of treatment	3(M) x 3(S) x 3(θ) = 27			

The geometry of weeding tool was selected having a lower draft and higher weeding efficiency at optimum approach angle, speed and moisture content. The optimum dimensions of weeding tool was computed and fixed to prototype self propelled weeder.

R-I

$M_1S_1\theta_1$	$M_1S_3\theta_3$	$M_1S_2\theta_2$
$M_1S_2\theta_1$	$M_1S_1\theta_3$	$M_1S_3\theta_2$
$M_1S_1\theta_2$	$M_1S_3\theta_1$	$M_1S_2\theta_3$

$M_2S_2\theta_2$	$M_2S_3\theta_3$	$M_2S_2\theta_3$
$M_2S_3\theta_2$	$M_2S_2\theta_1$	$M_2S_3\theta_1$
$M_2S_1\theta_2$	$M_2S_1\theta_1$	$M_2S_1\theta_3$

$M_3S_3\theta_3$	$M_3S_2\theta_3$	$M_3S_3\theta_2$
$M_3S_2\theta_1$	$M_3S_1\theta_1$	$M_3S_2\theta_2$
$M_3S_1\theta_3$	$M_3S_3\theta_1$	$M_3S_1\theta_2$

5 m

10 m

$$M_1 = 13\%, M_2 = 15\%, M_3 = 18\%$$
$$S_1 = 0.28m/s, S_2 = 0.42m/s, S_3 = 0.56m/s$$
$$\theta_1 = 60^0, \theta_2 = 70^0, \theta_3 = 80^0$$

Fig. 2. Plan of layout of the experiment

R-II

$M_1S_1\theta_1$	$M_1S_3\theta_3$	$M_1S_2\theta_2$
$M_1S_2\theta_1$	$M_1S_1\theta_3$	$M_1S_3\theta_2$
$M_1S_1\theta_2$	$M_1S_3\theta_1$	$M_1S_2\theta_3$

$M_2S_2\theta_2$	$M_2S_3\theta_3$	$M_2S_2\theta_3$
$M_2S_3\theta_2$	$M_2S_2\theta_1$	$M_2S_3\theta_1$
$M_2S_1\theta_2$	$M_2S_1\theta_1$	$M_2S_1\theta_3$

$M_3S_3\theta_3$	$M_3S_2\theta_3$	$M_3S_3\theta_2$
$M_3S_2\theta_1$	$M_3S_1\theta_1$	$M_3S_2\theta_2$
$M_3S_1\theta_3$	$M_3S_3\theta_1$	$M_3S_1\theta_2$

$M_1S_3\theta_1$	$M_1S_3\theta_3$	$M_1S_2\theta_2$
$M_1S_2\theta_1$	$M_1S_1\theta_3$	$M_1S_3\theta_2$
$M_1S_1\theta_2$	$M_1S_1\theta_1$	$M_1S_2\theta_3$

R-III

$M_2S_2\theta_2$	$M_2S_3\theta_3$	$M_2S_2\theta_3$
$M_2S_3\theta_2$	$M_2S_2\theta_1$	$M_2S_3\theta_1$
$M_2S_1\theta_2$	$M_2S_1\theta_1$	$M_2S_1\theta_3$

$M_3S_3\theta_3$	$M_3S_2\theta_3$	$M_3S_3\theta_2$
$M_3S_2\theta_1$	$M_3S_1\theta_1$	$M_3S_2\theta_2$
$M_3S_1\theta_3$	$M_3S_3\theta_1$	$M_3S_1\theta_2$

Result and Discussion

Effect of operational parameters *viz.* approach angle, forward speed and soil moisture content on weeding efficiency of developed weeder are presented in Table 3.

From Table 3. it was observed that, the specific draft at forward speed of 0.28, 0.42 and 0.56 m/s for 60 degree approach angle were found to be 0.425, 0.440 and 0.458 N/mm, respectively at 13% moisture content. Whereas these values were 0.399, 0.410 and 0.431 N/mm for 70 degree approach angle and 0.455, 0.469 and 0.480 N/mm for 80 degree approach angle. It were found to be for approach angle of 60 degree and at 15% moisture content the specific draft were 0.642, 0.658 and 0.670 N/mm, respectively while it were recorded as 0.590, 0.619 and 0.628 N/mm for 70 degree approach angle and 0.650, 0.669 and 0.681 N/mm for 80 degree approach angle. At 18% moisture content, specific draft was observed for 60 degree approach angle as 0.770, 0.791 and 0.815 N/mm, respectively. Similarly, it were recorded as 0.665, 0.678 and 0.690 N/mm for 70 degree approach angle and 0.811, 0829 and 0.841N/mm for forward speed of 0.28, 0.42 and 0.56 m/s for 80 degree approach angle, respectively. The increase in draft with speed is reported by Sail and Harrison (1978). Similar finding reported by Yadav *et al.* (2007).

Effect of approach angle and forward speed on specific draft at 13%, 15% and 18% moisture content have been presented in Fig. 3, 4 and Fig. 5, respectively. It is evident from these figures that the specific daft was lower for 70^0 approach angle sweep for the all forward speed and all moisture content. The lowest draft at 70^0 approach angle due to physico mechanical properties of soil, trihedral wedge theory, theory of rupture and cutting theory given by Goryachkin (1968) and Sineokow (1977). Change in approach angle causes change in flow pattern of the soil along tool surface. The change inflow pattern causes significant variation in draft (Girma, 1992). To prevent sticking, the direction of cut can be made normal to the working face of the wedge, for that is necessary that $\Psi = 90^0 - \alpha$, Where, Ψ = is the angle of the internal friction and α = is cutting angle. The forces acting on the implements are i) Forces causing forward travel of the weeder (P) which acting at right angle to the horizontal ii) Weight of the implement (W) iii) The resistance of the working surface iv) The reactions of the supporting surfaces, R. The reaction of the supporting surfaces, (R) which includes normal and tangential frictional forces.

The frictional forces can be eliminated by changing the inclination of the working and supporting planes by angle of the friction. The resultant of the all above forces must lie in same line. For the minimum draft, the forces causing forward speed must make an angle with the horizontal equal to the angle of the friction. The draft in present study was the lowest for 70 degree approach angle, which might be fulfilling of this condition. The results are agreement with the findings reported by Biswas *et al.* (1993) and Tewari *et al.* (1993).

It was observed that the relation between specific draft and forward speed is linear. In result observed that specific draft was lower at 0.28m/s. Specific draft increased with the forward speed increased. The increase draft with speed might be explained by change in zone of influence and strain hardening (Sial and Harison 1978). Also, soil strength become as the larger as the rate of the shear increased. When the sweep tool was operated at higher speed, instead of inverting and throwing the soil, sweep carried soil along with it, which results in bulking and heaving of soil the implement base. Increase in specific draft requirement with increase in speed has been reported by Shrestha *et al.* (2001).

The specific draft was lower for 13 % moisture content and higher for 18% moisture content at all the speed in result. The relation between specific draft and moisture content found linear. Specific draft increased with moisture content. Specific draft to a particular limit, the increase of moisture increased the friction coefficient. The increase in friction of coefficient with the moisture content increase was explained by the growth in the forces of molecular attraction of the soil particle to the surface. With increase in unit pressure on the surface of contact, adhesiveness increased, which depend on the furrow slice weight. Therefore, increase in frictional coefficient and adhesiveness might be the reason for higher specific draft at higher soil moisture. Specific draft was moderate at 13% and 15% moisture content can be considered optimum as it gives reasonably higher working range.

Table 3. Effect of moisture content (M), forward speed (S) and approach angle (θ) for specific draft

Sl. No.	Moisture content (M), %	Forward speed(S), m/s	Specific draft, N/mm Approach angle, (θ) 60^0	70^0	80^0
1.	13	0.28	0.426	0.399	0.455
		0.42	0.440	0.410	0.469
		0.56	0.458	0.431	0.480
2.	15	0.28	0.642	0.590	0.650
		0.42	0.658	0.619	0.669
		0.56	0.670	0.628	0.681
3.	18	0.28	0.770	0.665	0.811
		0.42	0.791	0.678	0.829
		0.56	0.815	0.690	0.841

The effect of approach angle, forward speed on specific draft at 13%, 15% and 18% moisture content have been presented in Fig. 3, 4 and Fig. 5, respectively. It is evident from these figures that the specific draft increased as the forward speeds increased for all approach angle of sweep. However, the lowest specific draft were observed at forward speed of 0.28 m/s for an approach angle of 70 degree. Similar results were observed for all soil moisture contents.

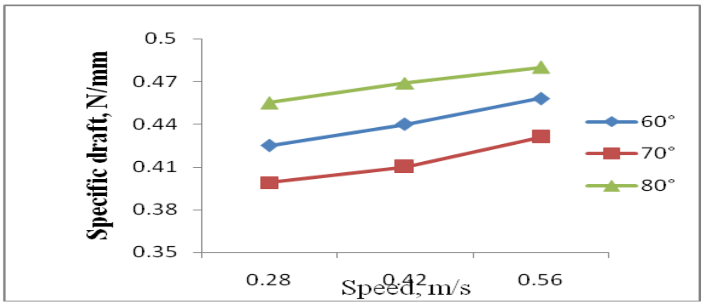


Fig. 3 Effect of forward speed and approach angle on specific draft at 13% moisture content

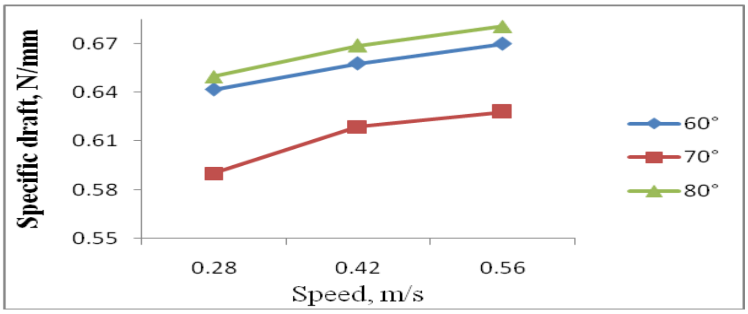


Fig. 4. Effect of forward speed and approach angle on specific draft at 15% moisture content

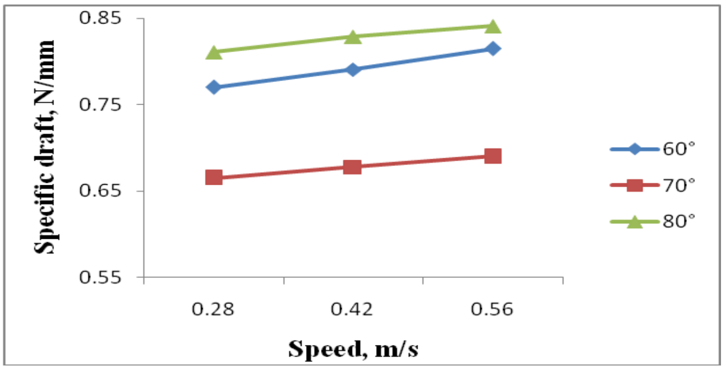


Fig. 5. Effect of forward speed and approach angle on specific draft at 18% moisture content

Effect of operational parameters *viz.* approach angle, forward speed and soil moisture content on weeding efficiency of developed weeder are presented in Table 4.

From Table 4, it was observed that, the weeding efficiency, for forward speed of 0.28, 0.42 and 0.56 m/s for 60 degree approach angle were found to be 77.00, 79.20 and 75.23%, respectively at 13% moisture content. Whereas these values were found to be 81.13, 85.21 and 81.00% for 70 degree approach angle and 79.20, 81.56 and 77.51% for 80 degree approach angle, respectively. The weeding efficiency were noted as 60 degree approach angle of 80.07, 83.76 and 76.23% while it were found to be 85.23, 89.58 and 82.00% for 70 degree approach angle and 81.37, 85.19 and 80.00% for 80 degree approach angle, respectively at 15% moisture content. It was also observed that the weeding efficiency for 60 degree approach angle were found to be 75.13, 76.99 and 73.57% where as it were found to be 80.00, 83.23 and 78.9% for 70 degree approach angle and 75.67, 79.38 and 76.08% for 80 degree approach angle, respectively at 18% moisture content. Similar findings reported by Yadav *et al.* (2007).

Effect of approach angle, forward speed on weeding efficiency at 13%, 15% and 18% moisture content have been presented in Fig. 6, 7 and 8, respectively.

It is evident from these figures that the weeding efficiency is higher for 70^0 approach angle sweep for the all forward speed and all moisture content. Similar findings reported by Yadav *et al*. (2007). The weeding efficiency was higher for 70 degree approach angle sweep therefore sweep of 70 degree approach angle is considered to be optimum.

Weeding efficiency decreased as increased in moisture content. The main cause behind it was that when moisture content increases slippage of ground wheel of self propelled weeder which considerably effect on turning length of the weeder. From the field results weeding efficiency was more in case of 13 % and 15 % moisture contents when compared to 18 % moisture content. Therefore weeding efficiency is moderate at 13% and 15% moisture content as considered optimum as it gives reasonably higher working range. Weeding efficiency is higher for 300 mm gang width in all the moisture content due to higher gang width may be due to more area coverage in between the rows. As the moisture content increased, the weeding efficiency decreased.

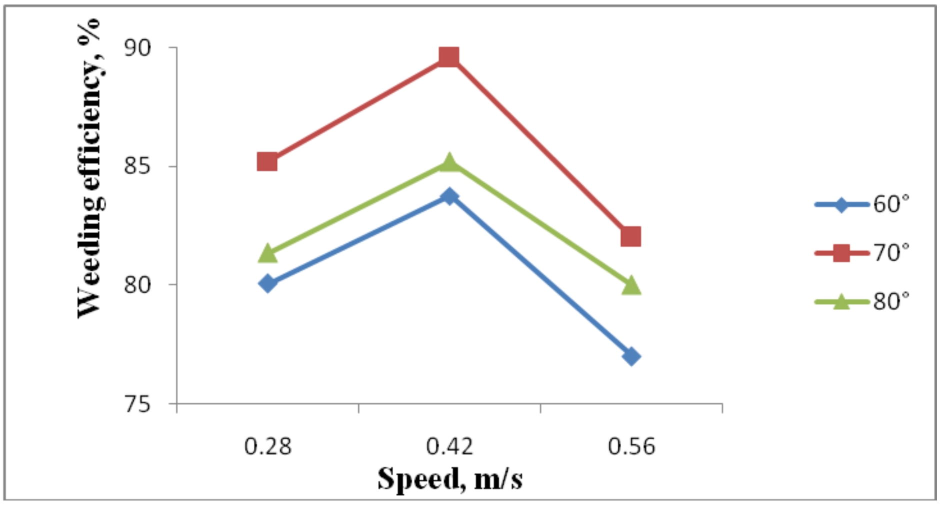
Weeding efficiency was found to be lower in case of higher forward speed but it was higher at 0.42 m/s forward speed as compared to other forward speed at all moisture content and all approach angle. Since forward speed 0.42 m/s of weeder was considered to be optimum.

Table 4. Effect of moisture content (M), forward speed (S) and approach angle (θ) for weeding efficiency

Sl. No.	**Moisture content (M), %**	**Forward speed(S), m/s**	**Weeding efficiency, % Approach angle, (θ)**		
			60^0	70^0	80^0
1.	13	0.28	77.00	81.13	79.20
		0.42	79.20	85.21	81.56
		0.56	75.23	81.00	77.5
2.	15	0.28	80.07	85.23	81.37
		0.42	83.76	89.58	85.19
		0.56	76.23	82.00	80.00
3.	18	0.28	75.13	80.00	75.67
		0.42	76.99	83.23	79.38
		0.56	73.57	78.9	76.08

The effect of approach angle, forward speed on weeding efficiency at 13%, 15% and 18% moisture content have been presented in fig.6., fig. 7, fig. 8, respectively. It is evident from these figures that the weeding efficiency decreased as the forward speeds increased for all approach angle of sweep. However higher weeding efficiency were observed at forward speed of 0.42 m/s for approach angle of 70 degree. Similar results were observed for all soil moisture contents.

Fig. 6. Effect of forward speed and approach angle on weeding efficiency at 13% moisture content



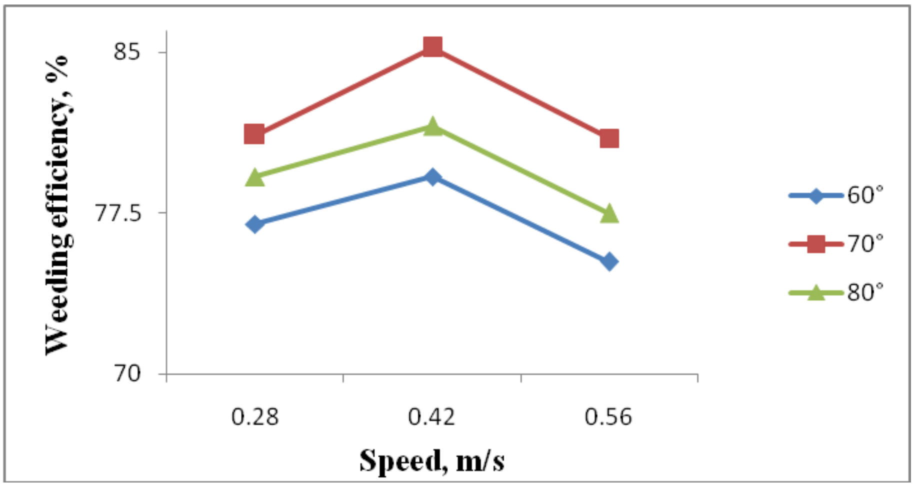


Fig.7. Effect of forward speed and approach angle on weeding efficiency at 15% moisture content

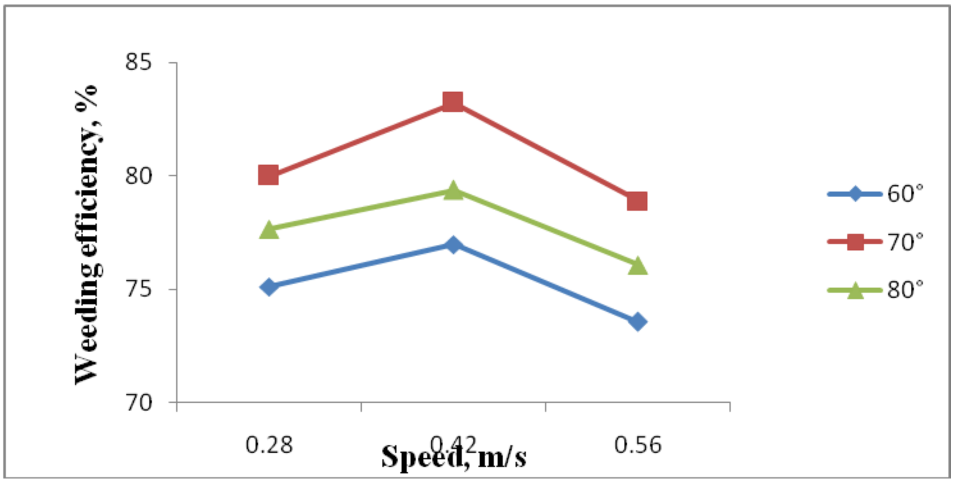


Fig.8. Effect of forward speed and approach angle on weeding efficiency at 18% moisture content

Optimization of forward speed, approach angle and moisture content for sweep

The design and operational parameters of sweep were optimized based on lower specific draft and higher weeding efficiency is presented in Table 5. The specific draft was lower and weeding efficiency was higher for 70^0 approach angle sweep. Therefore sweep of 70^0 approach angle sweep was considered as optimum. The weeding efficiency was higher at 0.42 m/s speed since it provides higher field capacity and also gives more weeding efficiency so it was considered to be optimum. Similarly specific draft and weeding efficiency was moderate at both 13% and 15% moisture content but 15% moisture content can be considered optimum as it gives reasonably higher working range. Similar findings reported by Yadav *et al.* (2007).

Table 5. Optimum design and operational parameters of self propelled weeder

Sl. No.	Particulars	Optimum dimensions
1.	Approach angle, (degree)	70 degree
2.	Forward speed, (m/s)	0.42 m/s
3.	Moisture content (%)	15 %

CONCLUSIONS.

- Based on field tests, the following conclusions were drawn.
- The specific draft lower and weeding efficiency was higher for 70^0 approach angle at all forward speed and all moisture content.
- The specific draft increased as moisture content increased. Specific draft was moderate at 13% and 15% moisture content can be considered optimum as it gives reasonably higher working range.
- Weeding efficiency was found to be lower in case of higher forward speed but it was higher at 0.42 m/s forward speed as compared to other forward speed at all moisture content and all approach angle.
- The forward speed 0.42 m/s of weeder was considered to be optimum. The weeding efficiency decreased as moisture content increased.

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