Performance evaluation of a proto type weeder with various blades and orientations

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Abstract: Weeding is the removal of undesirable plants in a crop that grow alongside the primary crop. They are formidable agricultural competitors. Farmers confront tremendous challenges in eliminating weeds at various stages of the crop cycle due to a lack of labour. The weed intensity in the field has increased, as has the root length; as a result, different blades were considered when performing the proto type weeder in the cotton crop. As a result, efforts are being made to optimize the blades' alignment. A prototype weeder linked to a high clearance tractor was designed and tested in the field. Three types of blades were designed for the weeding unit, and their performance was tested at various inclinations (50, 150, and 300) and operating depths. It was discovered that the highest weeding effectiveness was 93% with a lower draft force of 76 kg for blade 1 at an angle of 150.

Keywords: high clearance tractor, weeder, blades, orientation, cotton crop

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1 Introduction

Cotton popularly known as ‘white gold’ is an important commercial crop. Nearly 60 per cent of the population depends on agriculture and it is considered as backbone of the country. The country occupies a prominent position in many crops in the world rankings. It sustains the country’s cotton textile industry, which is perhaps the largest segment of organized industries in the country. The chemicals are highly toxic and causes lot of operational discomfort especially cotton grown areas, cotton is majorly under rain fed conditions where in intercultural operation is highly essential, for reducing nutrient competition from weeds, moisture loss from capillary pores and need to be destroyed and also to prune shallow roots so as to force the plant to develop deep roots and explore deep layers of soil for both moisture and nutrients. Weeding is one of the most important farm operations in crop production system (Veerangouda et al., 2010). Weeding accounts for about 25% of the total labour requirement (900–1200 man-h ha^{-1}) during a cultivation season. In India this operation is mostly performed manually with khurpi or trench hoe that requires higher labour input and also very tedious and time consuming process (Manjunathaet al., 2014). Due to urbanization and changed life-style of rural

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population in India, the dearth of agricultural labour-force has emerged and the cotton farmer is in compromise between taking up intercultural operation and loosing of yield. Since both intercultural operations in cotton are labour intensive and without which normal yields cannot be achieved. At this juncture to reduce the dependency on the human labour and perform operations efficiently mechanizing the operations is only the way-out.

In addition, tractorization in India, lead too many changes in basic tractor design and development of many forms of tractor based on the utility emerged. In such development to focus the small and marginal farmers, small holding and its intercultural requirements, small tractors are introduced with both 4 – wheel drive and 2 wheel drive in the range between 18.3 hp and 25 hp. Hence to utilize the principles of mechanization and take up the above crop specific operations the development of self – propelled high clearance tool (or) improvising existing small tractor for the purpose is dire essential. Under the circumstances the study was proposed to develop high clearance setup for small tractor to take up intercultural operations in cotton crop.

2Materials and methods

2.1 Weeder arrangement in high clearance setup

Bearing the importance of mechanical weeding and its administration difficulties, especially in high statured, more row spacing crops like cotton, pigeon pea etc. to incorporate weeding facility in the developed high clearance setup, the main principle of the blade was depend upon the plant (weed) strength. The blade material selection was based load to be with stand, durability, and overall weight. The main concept of the design parameters was easy operation of blade for in field and the energy requirement of the weeder for different operating depths. The mild steel was selected for fabrication of weeder blade and circular hollow pipes were used as member of operating (lifting and lowering) mechanism. Different factors were analyzed for calculating shear stress, bending moment and deflections happened on the blade. The detailed CAD diagram and designed diagram was as shown in the below Figure 1.

(a) CAD View of weeder (b) Developed weeder

Figure 1 CAD view developed blade suitable for high clearance tractor

2.2 Development of weeding unit suitable for high clearance setup

The field test was conducted at RARS tirupathi in the field number 3. The size of the field was 60 × 20 meters and the shape of the field was rectangle. The developed weeding unit was attached to the tractor rear wheels with suitable couplings. The weeds are removed in-between rows of cotton crop. A developed blade works well in during the field operation and penetrates the weeds from the soil. The cast iron material was used for fabricating of weeding unit and is connected to the tractor rear wheels with the help of U shape supporting. This machine was very useful to the farmers in both spraying and weeding operations can be completed in single operation. This operation lead to reduction of total cost as well as fuel consumption of the tractor would also reduce.

2.2.1 Operating lever (handle)

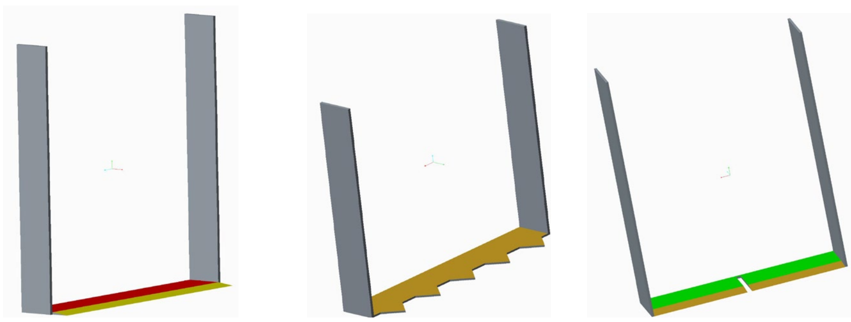
For constructing the handle two square steel flats are required with suitable dimensions like length and thickness was 1000 and 5 mm. These two flats were fastened with bolt and nuts at 90º angles of each other to get leverage effect. These handles are fitted adjacent to the driver well with in hand reach for operating the weeder blade and it is very helpful to the operator during the working in field condition within the rows.

2.2.2 Circular hallow pipe

The circular hallow pipe length was 1200 mm and thickness was 5 mm. This shaft was fitted through the two circular bearings. It distributes the movement of the lever to both weeder blade to move up and down.

2.2.3 Blade

The weeding blades were made from 450 mm length and 50 mm width of mild steel having a thickness of 10 mm. The lower end of the blade was slightly sharpened and slanted with horizontally maintained at least 15° rake angle. This blade attached to a U shape frame by welding process. The blade was positioned so that a maximum cutting depth of 10 cm attained. Blades selected for the weeding member was after testing the three types of shapes and three orientation of the blade with ground. The blades were 1) Plain sharpener at lower end, 2) Blade with shins projecting out of the blade, 3) Half blade i.e. blade with break at the centre. Simultaneously the orientation was selected as 0° with ground 15° and 30° with ground. The three types of blades were indicated in the below Figure2.



(a) Plain blade (b)Shine blade (c) Half blade

Figure 2 CAD views of different types of blades

2.2.4 U-clamps

Mild steel material was used for fabrication of U-clamps with suitable dimensions of length, width and thickness was 100, 100 and 10 mm respectively. The U- clamp gives the support of the weeding frame for free movement of the blade. This clamp was fitted to the tractor rear wheel axle with the help of bolt and nuts, to give better strength and movement of the blade.

2.2.5 Supporting arms

Arms are made of mild steel flat arms of vertical length 500 mm in both sides of the blade and these two are joined with 600 mm length, 50 mm width and 5 mm thickness. It was the complete structure developed weeder and these two blades were attached to each side of the tractor rear wheels. After that the U frames projects the arms with 75cm length of flats fitted to the U-clamps with the help of bushes, bolts and nuts. These bushes are arranged in between clamps for free movement of the weeding blade. This U frame is fitted to the another supporting arm of length 1100 mm. this arm was connected to the L-shape of lever, this lever welded to circular shaft to rotate the whole weeding unit so as to attain lift and lower blade in the system.

2.3 Performance evaluation of different blades of weed unit

The size of the field was 60 m× 20 m and the shape of the field was rectangle. Field test was conducted in 1200 m^2 area with developed weeder and results were noted before and after the weeding operations. A digital stop watch was used to record the weeding time and also excluding the turning time of the weeder. After weeding operations, the parameters like depth and width of cut of weed intensity were measured by using a steel rule. The weed intensity was measured and recorded per unit area before and after weeding operations. The damaged plants were also counted and recorded in the field test.

Figure 3 Performance evaluation of developed weeder

2.3.1 Depth of operation

A different depth conditions the high clearance tractor was operated at a range from 25 mm to 100 mm. It is an adequate weeding operation in the field. The depth of operation was measured at two different speeds of the developed test tractor i.e. 1.8 and 3.2 kmh^{-1}.

2.3.2 Weeding efficiency

Average three observations were considered for calculation of weeding efficiency. The observations were recorded during field operation. The weeding efficiency was calculated by using formula, where w_1 is number of weeds counted before operation and w_2 is weeds counted after the operation in Equation 1(Chavan et al., 2015).

$$\text{weeding efficiency} = \frac{w_1 - w_2}{w_1} \times 100 \qquad (1)$$

2.3.3 Theoretical field capacity (TFC)

It is the rate of field coverage of the implement based on 100 per cent of time at the rated speed and 100 per cent of its rated width in Equation2 (Kumar et al., 2014).

$$TFC(ha\,h^{-1}) = \frac{\text{width(m)} \times \text{Speed(m}h^{-1}\text{)}}{10000} \qquad (2)$$

2.3.4 Effective field capacity (EFC)

It is the actual area cover by the implement based on its total time and its width.

2.3.5 Field efficiency (η)

It is the ratio of the effective field capacity and theoretical field capacity express in percent.

2.3.6 Fuel consumption

The fuel tank was filled with fuel up to mark before operation and after field operation the fuel tank was refueling with fuel and computed the fuel consumption (Anil Kumar et al., 2014).

2.4 Statistical analysis

The obtained data of draft force and weeding efficiency was fitted to RBD full factorial and analyzed in SPSS 16.0 version. ANOVA was analyzed for determining the effect of these parameters (speed, depth, degree and blades) on weeding efficiency and draft force.

3 Results and discussion

3.1 Optimizing the weeding blade size and orientation

Three types of weeding blades are tested in the field and results were presented in Figure 3, 4 and 5.Itshows that three replications are carried out with developed weeder and the data was recorded by counting the number of weeds before and after using the developed weeder. From the Figure 3 weeding efficiency was varied from 86.5% to 90.7% and 86.6% to 91.79%for blade 1 at 5° orientation and a speed of 1.8 kmh^{-1} and 3.2 kmh^{-1} respectively and also blade 1 at 15° and 30° of blade orientation. Similarly, for blade 2 and blade 3 at different angle of orientation was noted.

3.2 ANOVA for weeding efficiency (%)

From the below Table 1 reveal that the parameters of speed, depth, degree and blades are showing significantly different alone. Similarly, the interactions of the speed and depth, speed and blades, speed, depth, blades are significant at 1% level of significance and other interaction combinations i.e. speed and degree, speed, degree and blade are significant at 5% level of significance. It was observed that, there is significant difference at 5% level of significance among the selected blades orientation and operating condition.

Table 1 ANOVA of weeding efficiency

Source	Sum of Squares	df	Mean Square	F
Corrected Model	17469.879[a]	55	317.634	354.113
Intercept	1037849.866	1	1037849.866	1.157E6
Rep	.792	2	.396	.442
Speed	11.896	1	11.896	13.263**
Depth	71.730	2	35.865	39.984**
degree	141.275	2	70.638	78.750**
blades	15587.859	2	7793.929	8.689E3**
speed * depth	6.768	2	3.384	3.773*
speed * degree	32.665	2	16.333	18.208**
speed * blades	2.235	2	1.118	1.246
speed * depth * degree	2.061	4	.515	.694
speed * depth * blades	10.233	4	2.558	2.852*
speed * degree * blades	59.895	4	14.974	16.693**
depth * degree * blades	25.084	8	3.136	3.496**
speed * depth * degree * blades	13.208	8	1.651	1.841
Error	95.081	106	.897	
Total	1055414.826	162		
Corrected Total	17564.960	161		

From the ANOVA table1, it was observed that speed, depth, degree and blade are individually significant different. The speed 3.2 kmh^{-1} is significantly different and having the best weed efficiency is compared with the 1.8 kmh^{-1}. Similarly one of 3 depths i.e. 25 mm, 60 mm and 100 mm depths the 60 mm depth is the best compared with remaining two depths. It is significantly different from the others. Coming to the degrees, from the analysis out of three degrees i.e. 5°, 15° and 30° the 15°is best compared to the others. It is significantly different from others. Similarly from the analysis it was observed that among the three blades i.e. blade 1, blade 2 and blade 3, the blade1 is best compared to the remaining two blades, it is significantly different from the others. Similarly from the Table 1 combinations of variables are observed that i.e. speed*depth, speed*blades, speed*depth*degree and speed*depth*degree and blades are no significantly different. The remaining combinations are speed*degree, speed*degree*blades and depth*degree*blades are significantly different from the others.

3.3 Weeding efficiency

The weeding efficiency was calculated by counting the number of weeds on the field before and after operations of developed weeder on three replications. The speed of operation was observed that at different speeds like 1.8 kmh^{-1} to 3.2 kmh^{-1}and also observed that the weeding efficiency of different blades with different depth conditions was varied.

3.3.1 Weeding efficiency with plain blade

For blade 1 the weeding efficiency varies from5°to 30° orientation was 86.52% to 90.75% at different depths of25 to100 cm condition the weeding efficiency was improved up to 4.25%in a speed of 1.8 kmh^{-1}. Similarly at a speed of 3.2 kmh^{-1}the weeding efficiency was4.1% improvement was observed. Similarly, for blade 1 at 15^{o} of blade orientation at a depth of 60 cm the weeding efficiency was improved up to 2.13% at a speed of 1.8 km/h and also speed of3.2 kmh^{-1} the efficiency was 0.5% was improved. Whereas for blade 1 at 30^{o} of blade orientation was varied from 91.9% to 93.2% and 93.2% to 93.7% at a speed of 1.8 km/h the weeding efficiency was improved 1.5% and 3.2 kmh^{-1}the weeding efficiency was decreased 0.2% respectively. The data values are as shown in Figure 3.

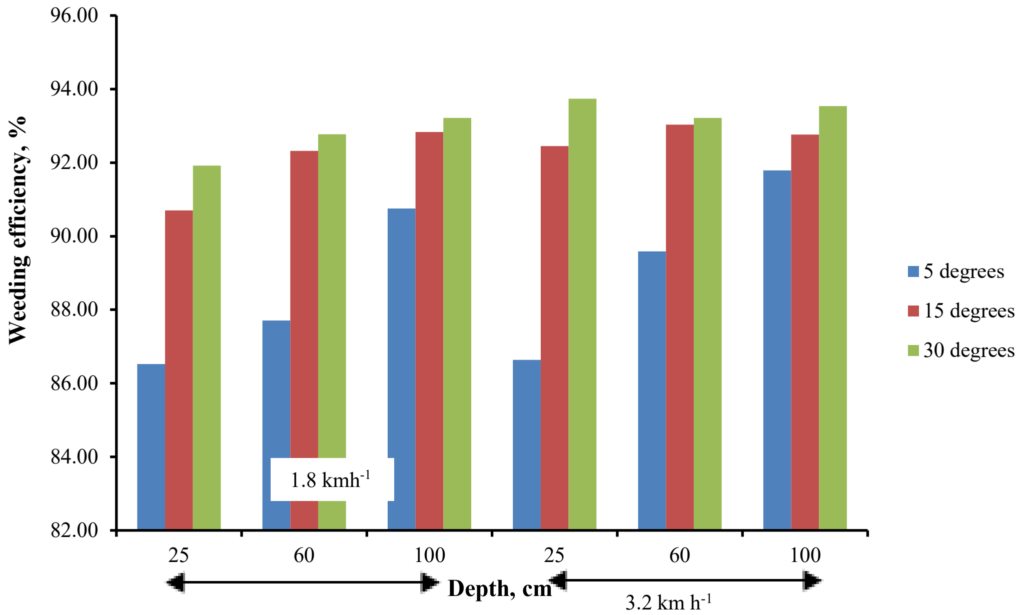


Figure3 Effect of depth of operation on weeding efficiency using blade1 at different angles

3.3.2 Weeding efficiency with shin blade

From the below Figure 4, the field operation of weeder with shin blade gives lesser weeding efficiency as compared to the plain blade. In this case, minimum and maximum weeding efficiency was 78.4%and 83.7% respectively i.e minimum efficiency was recorded at interaction point of 5^{o}, 25 mm depth at 1.8 kmh^{-1}forward speed and maximum at intersection point of 30^{o}, 100 mm depth at 3.2 kmh^{-1}speed. However, similar trend of weeding efficiency was observed with respect to depth, forward speed and blade orientation, but weeding efficiency was recorded lesser as compare to that of in all cases.

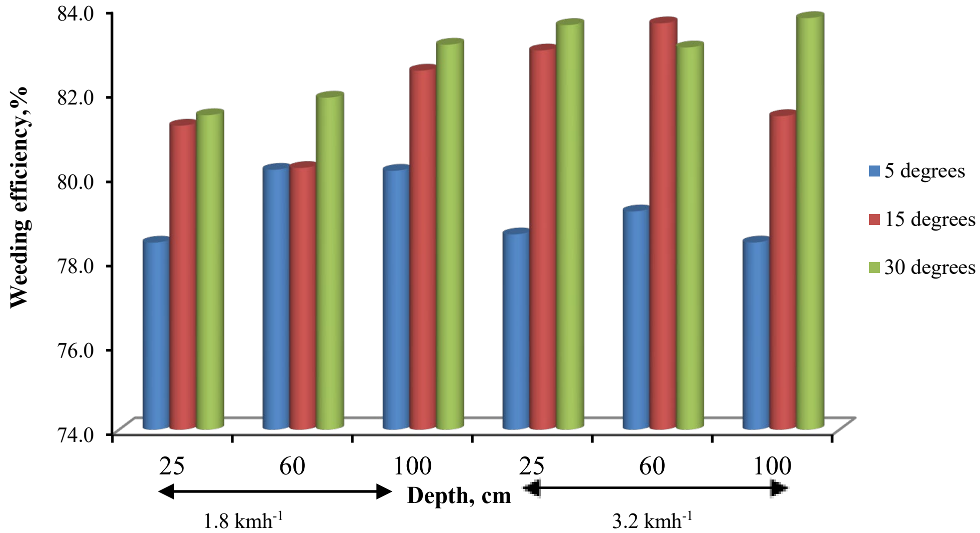


Figure 4 Effect of depth of operation on weeding efficiency using blade2 at different angles

3.3.3 Weeding efficiency with half blade

From the below Figure 5, the operation of weeder with half blade gives lesser weeding efficiency as compared to the plain blade. In this case, minimum and maximum weeding efficiency was 57.4%and 73.9% respectively i.e minimum was recorded at interaction point of 5°, 25 mm depth and 3.2 kmh^{-1}forward speed and maximum at intersection point of 30°, 100 mm depth and 3.2 kmh^{-1}speed. However, similar trend of weeding efficiency was observed with respect to depth, forward speed and blade orientation, but weeding efficiency was recorded lesser as compare to that of in all cases. The field efficiency for developed high clearance tractor was 75% as shown in the Table 3.

Table 2Relation between the speed of operation and effective field capacity

S.No	Speed of operation (kmh^{-1})	Effectivefield capacity(haday^{-1})
1	1.8	3.12
2	3.2	6.24

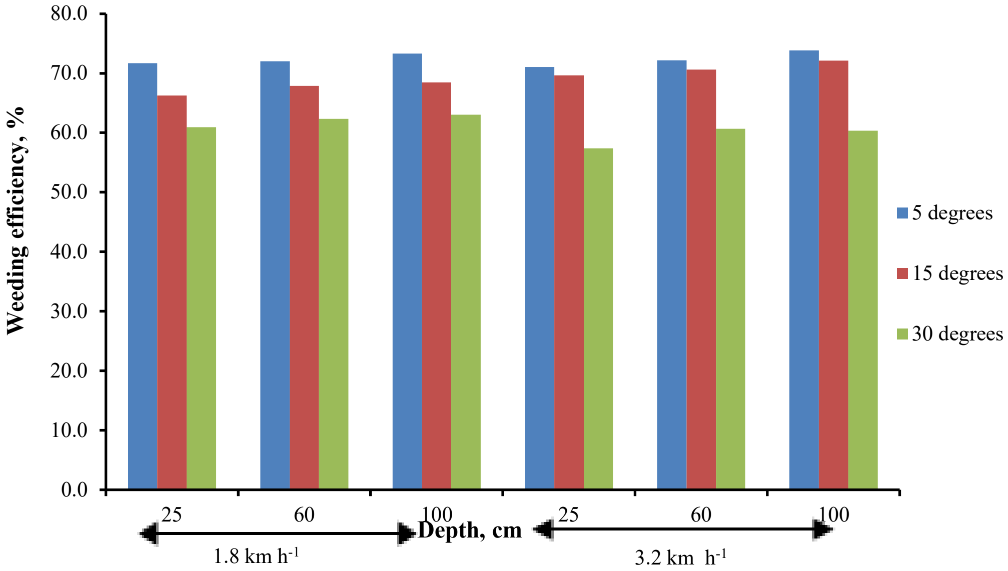


Figure 5 Effect of depth of operation on weeding efficiency using blade3 at different angles

Table 3Performance attributes of weeder in cotton field

S.No.	Particulars	Observation		
1	Crop variety		Bolguard-II	
2	Average crop height,cm		145	
3	Row spacing,cm		120	
		Test-1	Test-2	Average
4	Effective width of weeder,m	0.8	0.8	0.8
5	Width of field, m	20	20	20
6	Length of field, m	60	60	60
7	Area, m^2	1200	1200	1200
8	No. of plants	870	870	870
9	Travelling speed, kmh^{-1}	2.0	4.0	3.0
10	Theoretical field capacity, hah^{-1}	0.52	1.04	0.78
11	Effective field capacity, hah^{-1}	0.39	0.78	0.585
12	Field efficiency,%	75	75	75
13	Fuel consumption, Lh^{-1}	2 -3	2-3	2-3

The performance and evaluation of developed high clearance tractor in cotton crop was in terms of theoretical field capacity and field efficiency. The experiments were conducted with two different forward speeds i.e. 1.8 and 3.2 kmh^{-1}. The field observations were analyzed which gives the performance of developed high clearance tractor was as shown in the Table 3. The intercultural operation was carried out in the experimental field. The average crop height and row spacing was found 145 cm, 120 cm, the effective width of the sprayer and weeder were 260 cm and 80 cm.

3.4 Performance attribute of weeder

Finally from the Table 1shows that, there is significant difference at 5% level of significance among the selected blades orientation and operating condition. It was also observed that, as the speed of operation increases, the weeding efficiency of the weeding unit is increased. It may be due to acceleration of the soil impact and kinetic energy imparted to the soil. Compared to three blades, the blade 1 at 15^o and 30^o there is no much variation of the efficiency.

3.5 Theoretical field capacity

From the Table 2 shows that effective field capacity was found to be 3.12 to 6.24 haday^{-1} at a speed of 1.8 kmh^{-1} and 3.2 kmh^{-1}i.e. the speed of operation was affects the effective field capacity.

3.6 Field efficiency4 Conclusion

In developing countries farm mechanization plays prominent role in agricultural production and productivity. Tractorization in India lead to many changes in basic tractor design and development of many forms of tractor based on the utility emerged. In such development to focus the small and marginal farmers, small holding and its intercultural requirements, small tractors are introduced with both 4wheel drive and 2wheel drive in the range between 18.3 hp and 25 hp. So many field visits and field operations were observed to decide the design parameters of developed high clearance unit for small tractor, which is primarily designed for cotton crop and also be used for long statured crops like cotton, maize and pigeon pea. The developed high clearance unit can be utilized for mechanical weeding along with spraying and process made simple and drudgery free. Mechanical operated tools and equipment's to uproot the weeds, loose the soil surface and ensuring the better aeration. Weeding by tractor operated mechanical device (high clearance unit) not only reduces the cost of labor and also completed in time.

The developed high clearance tractor weeder was operated in the field condition at a depth of 10 cm. Three types of blades were developed for weeding unit and evaluate the performance in various operating depths and at different angles of inclination i.e. 5^o, 15^o and 30^o.Finally the maximum weeding efficiency was achieved by 93% for blade 1 at an angle of 15^o.The developed high clearance tractor weeding operations could be done successfully so that, the developed machine can save the time and labour. This high clearance weeder will work tall crops for intercultural operations. The cost analysis was compared with of existing practice, it was found that 12 percent saving in cost was observed with farmer's existing practice. Finally 199.64 man-hours were saved with high clearance tractor compared with the manual method.

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