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Comparative performance evaluation of intercultural implements in cotton field

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Abstract

Cotton (*Gossypium*) is an essential oil seed and fabric cash crop, lifeline for textile and palm-oil industry of Pakistan. It is planted during "summer" season from April to June, mainly in two provinces with Punjab 75% and Sindh 25% of the total area. Major cause of low productivity in cotton is the heavy weed infestation. Effective weed control is vital, as weeds uses most of space, sunlight, water and nutrients due to their fast growth habits. Various kinds of pre and post emergence herbicides are under use in cotton. Their excessive use degrading air, water, soil environment and quality of produce. To protect environment and to attain sustainable development goals a small scale intercultural implement suitable for small farmers under existing condition of cotton was developed during 2018-19. Three shapes of blades (L, C, and J) were designed and fabricated. Implement performance was tested under local condition of South Punjab for cotton at Maher-Rab-Nawaz-Sial Agriculture Farm, Mukhiana tehsil and district Jhang. Field performance was tested for weeding efficiency, plant damage, speed, depth, theoretical field capacity, effective field capacity, field efficiency, fuel consumption and operational cost. Its performance was compared with the available rotary weeder. The data recorded for each parameter was statistical analyzed using Randomized Complete Block Design. Statistical software 8.1 was used for ANOVA and treatment means were compared at 5% level of probability. It was concluded that the performance of L-shaped blade was better in cotton field as compared to other types of blades.

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Introduction

Pakistan's selling cotton 8 million 480lb bales in year 2019/20, up to 500,000 bales were estimated from the studied in year 2018/19 estimate. This projected production reproduces a diffident increase in the area due to recent government incentives to increase cotton production in the country. Yield was estimated to be higher than last year based on abundant water and certified seed availability. About 95 percent country cotton crop is bioengineered. Textile mill consumption is forecast slightly higher at 10.7 million bales as demand for cotton products is expected to rise with the government's support for textile exports. With mills having strong interest in higher-grade quality cotton to meet demand for higher quality products, the import forecast is 3 million 480 lb bales. Its Pakistan developed a biotechnology and seed regulatory structure, investment and implementation would facilitate the introduction of improved cotton seed in the country (Bean, 2019). Cotton is one of the most essential cash crops of Pakistan like maize, rice and sugarcane. It contributes to about 6.9% of the value added in the agriculture and about 1.4% to (GDP) and 60% to the foreign exchange earning of the country. Country ranks fourth, third, and fourth in total production, carry across, and consumption of cotton in the world. Cotton is grown on an area of 2689 thousand hectares with an annual production of 11460 thousand bales and taking an average seed cotton yield of 725kg ha^{-1} (Anonymous, 2011). The manual weeding requires huge labour force and interpretations near about 25% of the total labor requirement. In India, this operation is commonly performed manually with cutlass or dig out that requires high labour input, very cloudy and time wasting process. Moreover, the labour requirement for weeding depends on weed plants, weed intensity, time of weeding, and soil moisture at the time of weeding and efficiency of worker (Rajashekar *et al.*, 2014).

In weeding operation; recently power weeders are introduced with rotary tillage equipment having 3.7-5.5kW capacity and engine weight of 300-400kg. These implements are not become popular due to clogging of weeds in between tines and intermediate cleaning is required when used in higher moisture content (Karnkal, 2013). Present pattern of row cropping concept widely adopted by Indian farmers and development of self-propelled sweep or drag type weeder is the need of the day. In this view, self-propelled small engine operated weeder is better option due to its medium cost and small size implying better manoeuverability in the small land holdings. The rotary tillage operation because of its higher ability to mix, roll out and pulverize soil. The rotary weeder can be made to operate various working depths, widths and soil conditions. The rotating blades cut and mix the residues regularly throughout the working depth compared to any other mechanism. Weeders are mechanical implements which are used for weed removal (Gavali *et al.*, 2014). Weeders was a implement used for weed deduction. Mechanical preparing is one of the prominent methods of weed removal. Smaller weeding implements normally known as moveable weeders are solely used for weed removal in agricultural fields, gardens etc. Unlike tractors, weeders are non-conventional as for as, the movement of labour is concerned. In promoting weeders especially considering the fact that the majority of growers are having small land. So they can hardly accomplish to pay for expensive tractors (Chavan *et al.*, 2015).

The designed and developed a tractor operated 3 row turning weeder for red gram crop. The weeder was designed using computer supported design and a proto type was made-up. The operational parameters selected for the study were three forward speeds 2.0, 2.5 and 3.0kmh^{-1} and two rotary speeds of 210 and 240rpm. Three types of blades were used in the rotary weeder tests i.e., L, C and J-type blades (Majunatha *et al.*, 2016). A ridge profile power weeder have 2.20kW petrol-start kerosene-run engine. The weeding efficiency ranged from 74.47 to 93.89% and plant damage varied from 0.88-7.33% for different soil-implement interaction parameters combinations. Actual field capacity was 0.069hah^{-1}. The performance index was observed to be maximum 192.34 in case of C- type blade and lowest 153.94 for flat- type blades (Thorat, 2014). During his experimentation that tractor operated L-shaped blades performs better as compared to C and J type blades in trashy conditions as they are more effective in killing weed and they do not pulverize the soil as much (Jeevarathinam & Velmurugan, 2014).

Keeping in view above cited statements, the objective of experiment was to test different shapes of intercultural blades in cotton field.

Materials and methods

Study Area

This study was focused to develop a power operated manually propelled small scale intercultural implement. During experimentation, the performance was tested for available rotary weeder and locally developed small scale new intercultural implement with three different shapes of blades (L, C & J). Shape of implement blades were designed according to pertinent crop parameters like crop species, row spacing, plant height etc. The design and fabrication of implement has been carried out during 2018-19 at Malik Engineering workshop, Dudiyal, Chakwal with collaboration Faculty of Agricultural Engineering and Technology, PMAS Arid Agriculture Rawalpindi. The implement was tested for cotton at Mahr-Rab-Nawaz-Sial Agriculture Farm, Mukhiana tehsil and district Jhang, province Punjab Pakistan. The implement was tested for three shape of blades (L, C, and J) for following parameter.

Weeding Efficiency

It can be defined as the ratio between the number of weeds removed during weeding process to the number of weeds present in a unit area before weeding and expressed as a percentage.

$$\text{Weeding efficiency} = \frac{N1 - N2}{N1} \times 100$$

Where;

N_1 = Number of weeds existing per unit area before weeding operation.

N_2 = Number of weeds calculated in same unit area after weeding operation.

Plant Damage

It is the ratio of the number of plant destroyed after weeding operation in a unit area to the number of plant present before operation in the same unit area. It is expressed in percentage.

$$R = \frac{q}{p}$$

Where;

R = Plant damaged (%).

p = Total number of plants per unit area before the weeding operation.

q = Total number of plants damaged in the same unit area after the weeding.

Field Capacity

The intercultural implement was tested on the experimented soil to calculate the field capacity. It is expressed the total area that a implement can cover per unit time can be calculated by using formula.

$$\text{Field Capacity (ha/h)} = \frac{66}{t} \times \frac{A}{10{,}000}$$

Where;

A = Area covered (m^2),

t = Time taken in minutes

Depth of Operation

After the operation of implement in field, depth of cut was measured randomly with the help of scale from five different places in the field. Average depth of tillage operation for each blade was calculated using average formula.

$$\text{Depth of operation} = \frac{d1+d2+d3+d4+d5}{5}\ \text{mm}$$

Where;

d = Depth (mm),

Forward Speed of Implement

Marked 75 m distance in the cotton field, time required to cover the marked distance was calculated with the help of stop watch. The forward speed of operation was measured by the following equation (Islam, A.S 2017).

$$\text{Forward speed (m/s)} = \frac{D}{t}$$

Where;

D = Distance (m),

t = time (s),

Theoretical Field Capacity

It is maximum possible capacity obtainable at a given speed, assuming the implement is using its full width.

It can be defined as the product of work width (W) of implement and speed of operation (V_f). Area covered per unit time denoted in hectare per hour and it is calculated by using formula

Theoretical field capacity (ha/hour) $= \frac{W \times V_f \times 3600}{10000}$

where,

W = Rated width of implement (m)

V_f = Forward speed of implement (m/s)

Actual Field Capacity

The number of hectares actually covered our a long period of time. Time required to complete tillage work productive time (T_p) and that lost for other activities such as turning at head handle, blade cleaning when clogging with weeds unproductive time (T_c) was recorded with the help of stopwatch and calculated by using formula.

$a = \frac{A}{(Tp + Tc)}$ (ha/hr)

Where,

a = actual field capacity (ha/h)

A = area cover ha,

T_p= Productive time

T_c = Unproductive time, h

Field Efficiency

The ratio of actual field capacity and theoretical field capacity. It is calculated by using the following equation.

$e = \frac{\text{Actual field capacity}}{\text{Tharotical field capacity}} \times 100$

Fuel Consumption

To determine the fuel consumption of implement, the fuel tank filled with known quantity of fuel and marked on the graduated scale and interculture operation performed in the field of cotton for period of one hour. After the interculture operation, stop the engine and the fuel tank was refilled at the marked level before experimentation. Amount of fuel needed to refill the fuel tank up to marked level after one hour of interculture operation.

Fuel consumption was calculated by using standard method as follow

$F_c = \frac{q}{t}$

Where;

F_c = Fuel consumption (L/hr)

q = Quantity of fuel (L)

t = Consumption time (min)

Operational Cost

Cost of operation was calculated by considering repair and maintenance, fuel cost, lubrication cost and operator wages for interculture implement during its working.

Results and discussion

The present Study was conducted to design and developed small scale interculture implement for intercultural operation in cotton field. Data was recorded for different parameter and analyzed statistically. Performance of the intercultural implement were expressed in terms of weeding efficiency, plant damage, actual field capacity, theoretical field capacity, depth of operation, forward speed of implement, field efficiency, fuel consumption and operational cost. The data collected during experimentation was statistically analyzed by using Randomize Complete Block Design (RCBD) at 5% level of probability. Results for various parameters are discuss as.

Field Parameters measured before Weeding Operation

Soil Texture

Soil samples were taken with help of auger from three difference location for cotton field. Soil texture of samples were measured before weeding operation. The soil texture for cotton field was loam with electrical conductivity 1.68 dsm^{-1}, pH 7.30, organic matter (0.59%), Available phosphorus 4.4 ($mgkg^{-1}$), available potassium 120 ($mgkg^{-1}$) and saturation (39%) respectively.

Moisture Content

The moisture content of soil sample was measured with help of gravimetric method. Three Samples were collected from cotton field. The moisture content of those samples was measured. The average moisture content was found from cotton field (9.49%). Moisture content in trial field was almost same because all the treatment blocks were taken from same field. Research result are in line with Hegazy, R. A *et al.*, 2014 who found of range (7.7-12.13%).

Bulk Density

Bulk density of soil sample was measured according to oven dry method. Samples were collected from three different places from cotton field. The bulk density was calculated from cotton field 1.775 (g/cm3).

Weeding Efficiency (%)

(Table 1) shows that the effect of mean values of different shapes of blades and days after sowing on weeding efficiency of cotton crop were found that for days (25,45 & 60) DAS (83.5. 85.3 & 86.5%). The weeding efficiency was maximum in the third experiment at 60 DAS because (83.5%) weeds were controlled or removed at first time implement was operated in cotton crop 25 DAS and remaining weeds remove at second time (85.3%) and therefore, third time implement weeding efficiency was (86.5%). For blades (C, J, L & R-shape) values were (83.7, 79.1, 94.4 & 83.3%). Weeding efficiency of L-shape blade was maximum (94.4%) as compared to other shapes of blade because the L-shape blade pulverizes maximum soil. However, weeding efficiency J-shape was minimum results, less pulverize soil and it was mostly use for disturbed the soil surface. Mean value of treatment for weeding efficiency shows that C and R shape blades are non-significant while J and L shape blades are significant with each other at 5% level of probability. However weeding efficiency in the three experiment (25, 45 & 60) DAS were significantly different with each other at 5% level of probability. The results of site-B are in line with the G. Kishore Kumar *et al.*, 2018 who found weeding efficiency 78% of power weeder.

Table 1. Effect of different shape of blades with different time interval after sowing on weeding efficiency (%).

Shape of Blades	25 DAS	45 DAS	60 DAS	Mean
C	82.2 EFG	84.1 CDE	85.1 CD	83.7 B
J	77.8 I	79.2 HI	80.4 G	79.1 C
L	93.2 B	94.6 AB	95.6 A	94.4 A
R	81.8 FG	83.1 DEF	85.2 C	83.3 B
Mean	83.7 C	85.2 B	86.5 A	

Plant Damage (%)

(Table 2) showed the effect of mean values of types of blade and days after sowing on plant damage of cotton crop were found for (25, 45 & 60) DAS (19.50, 9.56 & 5.35%). The plant damage was maximum (19.50%) at 25 DAS because the height plants were equal to weeds at initial stage as compared other two experiment. Plant damage decrease in second experiment (9.56%) 45 DAS and minimum plant damage was observed (5.35%) in third experiment. For different shapes of blades (C, J, L & R) plant damage was calculated (11.53, 17.31, 7.61 and 9.01%). Plant damage of J- shape blade was maximum (17.31%) as compared to other shapes of blade because the J-shape blade is more feasible just to disturb the soil surface in undesired able minors. During the first experiment soil surface was undisturbed therefore the J-shape did not perform well. Plant damage of L-shape blade was minimum (7.61%) because it effectively pulverize the soil. While the plant damage in R-shape blade was (9.01%). Mean value of treatment for plant damage shows that L and R shape blades are non-significant while C and J shape blades are significant with each other at 5% level of probability. However weeding efficiency in the three experiment (25, 45 & 60) DAS was significantly differs from each other at 5% level of probability. The research results are not in line with the finding of Tewari *et al.*, 2014 who found the plant damage of self-propelled rotary power weeder 4.86%.

Table 2. Effect of different shapes of blades with different time interval after sowing on plant damage (%).

Shape of Blades	25 DAS	45 DAS	60 DAS	Mean
C	18.40 B	10.60 D	5.60 EFG	11.53 B
J	31.60 A	12.40 CD	7.21 EF	17.31 A
L	12.20 CD	7.01 EF	3.61 G	7.61 C
R	13.80 C	8.12 E	5.21 FG	9.01 C
Mean	19.50 A	9.56 B	5.35 C	

Depth of Operation (mm)

(Table 3) showed that effect of mean values of different shapes of blades and days after sowing on operational depth of cotton. The effect of days after sowing (25,45 & 60) DAS were calculated as (52.45, 51.15 & 49.95mm). In first experiment depth of operation was maximum (52.45mm) at 25 DAS, while the depth of operation decreases (51.15mm) at 45 DAS and minimum depth of operation (49.95mm) at 25 DAS. For blades (C, J, L & R-shape) values were calculated

(50.33, 44.93, 58.66 & 50.33mm) the depth of operation of L-shape blade was maximum (58.66mm) as compared to other shape of blade because the L-shape blade was more pulverized soil due to its shape and J-shape blade was minimum depth of operation (44.93mm) because it was used for undisturbed surface of soil. The effect of different shape of blades on mean value of depth of operation was observed C and R shape blades are not significant while L and J shape blades are significant with each other at 5% level of probability. However, depth of operation in three experiments (25, 45 & 60 DAS) was significantly differs from each other at 5% level of probabilities. The research results are not alike with the finding of Hegazy, R. A *et al.*, 2014 who found depth of operation of small-scale power weeders (40mm).

Table 3. Effect of different shape of blades with different time interval after sowing on depth of operation (mm).

Shape of Blades	25 DAS	45 DAS	60 DAS	Mean
C	53 BC	50.60 C	47.40 DF	50.33 B
J	43.20 F	44.80 EF	46.80 E	44.93 C
L	61.80 A	59.20 A	55.20 B	58.66 A
R	51.80 C	50.32 CD	50.60 CD	50.33 B
Mean	52.45 A	51. 15 B	49.95 C	

Fuel Consumption (liter/hr)

Effect of difference shapes of blades on mean value of fuel consumption and days after sowing of fuel consumption in cotton field (Table 4). Days after sowing (25, 45 & 60) data collected from the and fuel consumption was found (1.22, 1.23 & 1.27Liter/hr). The fuel consumption was maximum (1.27liter/hr) at 60DAS as the soil lost moisture while minimum fuel consumption(1.22liter/hr) was observed at 25 DAS as soil has optimum moisture for operating interculture implement. The fuel consumption was recorded (1.23liter/hr) at 45DAS. For different shape of blades (C, J, L & R) fuel consumption were recorded in field (1.23, 1.25, 1.27 & 1.26liter/hr) respectively. The fuel consumption of L-shape blade was maximum (1.27liter/hr) as compared to other shape of blade as the performance of L-shape blade was comparatively better on undisturbed soil as compared to other. It also more pulverized the soil, well weeding efficiency and less plant damage due to its shape. The value of fuel consumption decrease C-shape blade was recorded (1.23liter/hr) such as J-shape blade was calculated (1.25liter/hr) and fuel consumption value was recorded of R- shape blade (1.26liter/hr). The effect of different shape of blades on mean value of fuel consumption was observed (C , J, L and R) are non-significant with each other at 5% level of probability. However, fuel consumption in the three experiments (25, 45 & 60) DAS was significantly differ with each other at 5% level of probability. The results are contradictory with the finding of Patange *et al.*, 2015 who finding fuel consumption of self-propeller rotary weeder in cotton field was 1.68 (Liter/hr).

Table 4. Effect of different shape of blades with different time interval after sowing on fuel consumption (Liter/hr).

Shapes of Blades	25 DABF	45 DABF	60 DABF	Mean
C	1.15 E	1.19 CD	1.24 CD	1.21 C
J	1.19 CDE	1.20 C	1.25 BC	1.22 9A
L	1.20 DE	1.23 CD	1.29 CD	1.25 BC
R	1.17 CD	1.22 C	1.33 B	1.23 AB
Mean	1.18 C	1.21 B	1.27 A	

Actual Field Capacity (ha/hr)

The mean values of actual field capacity (Table 5) for different shape of blade and (25, 45 & 60) days after sowing were recorded as (0.1455, 0.1062 & 0.1042ha/hr). Actual field capacity was maximum (0.1455ha/hr) at 25 DAS because the soil has required moisture for tillage operation as compared to other days (45 & 60). For different shape of blades (C, J, L & R) values of actual field capacity were recorded as (0.1536, 0.0969, 0.1171 & 0.1069ha/hr). The actual field capacity of J-shape blade was minimum (0.0969ha/hr) as compare to other shapes of blades because the J-shape blade was operated for the first time and due to its shape and the actual field capacity of L-shape blade was recorded maximum (0.1536ha/hr) because it was more pulverized the soil due its shape. Mean value of treatment for actual field capacity shows that C, J, L and R shape blades are non-significant with each other. However, actual field capacity in the three experiment (25, 45 & 60) DAS was non-significant with each other at 5% level of probability. Research results of site-B are in line with the Tewari *et al.*, 2014 who found actual field capacity of self-propelled rotary power weeder and observed 0.092, 0.08, 0.096ha/hr at forward speed of 2.3, 2.0 and 2.4km/hr in tomato, yard long bean and okra crops, respectively.

Table 5. Effect of different shapes of blades with different time interval after sowing on actual field capacity (ha/hr).

Shape of Blades	25 DAS	45 DAS	60 DAS	Mean
C	0.2554 A	0.1038 B	0.1016 B	0.1171 A
J	0.0992 B	0.0974 B	0.0942 B	0.0969 A
L	0.1186 B	0.1170 B	0.1158 B	0.1536 A
R	0.1088 B	0.1066 B	0.1052 B	0.1069 A
Mean	0.1455 A	0.1062 A	0.1042 A	

Field Efficiency (%)

Mean values of field efficiency (Table 6) of different shape of blades and days after sowing on field efficiency of cotton field. Days after sowing (25, 45 & 60) the data of field efficiency was collected from the field (86.25, 83.90 & 82.30%) during operation of interculture implement. The field efficiency was maximum (86.25%) at 25 DAS because first time implement have to work in less hard surface of soil as compared to other days at second time field efficiency decreases (83.90%) at 45 DAS likewise field efficiency minimum (82.30%) at 60 DAS. For different shapes of blades (C, J, L & R) values of field efficiency were recorded in field (81.80, 76.53, 92.66 & 84.26%). The weeding efficiency of J-shape blade was minimum (76%) as compare to other shape of blade. The value of field efficiency increases of L-shape blade was recorded (92.66%) such as R–shape blade was recorded (84.26%). The effect different shape of blades on mean value of field efficiency was observed (C & R) are non-significant with each other while J and L are significant with each other at 5% level of probability. However, field efficiency in the three experiments (25, 45 & 60) DAS was significantly differs with each other at 5% level of probability. Research results are not inline at site B with the finding of G. Kishore Kumar *et al.*, 2018 who find the field efficiency of power weeder 83%.

Table 6. Effect of different shape of blades with different time interval after sowing on field efficiency (%).

Shape of Blades	25 DAS	45 DAS	60 DAS	Mean
C	85.20 CD	82 DE	80.20 EF	81.80 C
J	78.20 FG	76.80 GH	74.60 H	76.53 D
L	95.35 A	92.60 AB	91.40 B	92.66 A
R	87.60 C	84.20 CD	83.25 DE	84.26 C
Mean	86.25 A	83.90 B	82.30 C	

Operational Cost (Rs/ha)

The effect of different shape of blade and days after sowing on operational cost of interculture implement in cotton field was represented in (Table 7). Days after sowing (25, 45 & 60) was calculated as (2193, 2287 & 2435Rs/ha). The operational cost was minimum (2193Rs/ha) at 25 DAS because the time required for weeding and fuel consumption was less as compared to other days 45 and 60. The operational cost was increased (2287Rs/ha) at 45 DAS, similarly value of operational cost was increase (2435Rs/ha) at 60 DAS. For different shape of blades (C, J, L & R) operational cost was recorded as (2269, 2376, 2244 & 2221Rs/ha). The operational cost of L-shape blade was minimum (2244Rs/ha). While the maximum operational cost was observed in J-shape blade (2376Rs/ha). Operational cost of C-shape blade was recorded (2269Rs/ha). While the value of operational cost was recorded of R-shape blade (2321Rs/ha). The effect of different shape of blades on mean value of operational cost was observed C, J, L and R shape blades were found non-significant with each other. However the effect of days after sowing (25, 45 & 60) on operational cost has significantly differed with each other. Research results at site B are contradictory with Majunatha *et al.,* 2016 who found the operational cost Rs 1469 per ha, which was 41.25% less as related to manual weeding of Rs 2500 per ha^{-1}.

Table 7. Effect of different shape of blades with different time intervals after sowing on operational cost (Rs/ha).

Shape of Blades	25 DAS	45 DAS	60 DAS	Mean
C	2166 D	2247 C	2395 B	2269 C
J	2232 CD	2386 B	2514 A	2376 A
L	2163 D	2223 CD	2495 B	2244 C
R	2237 CD	2297 C	2430 B	2321 A
Mean	2193 C	2287 B	2435 A	

Conclusion

It was concluded from the study that the maximum weeding efficiency, depth of operation, theoretical field capacity, actual field capacity, field efficiency, fuel consumption and minimum plant damage and operational cost was obtained in L-shaped blade.

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