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Development and testing of power operated Interculture implements for poor and small farmers of Pakistan

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Abstract

In Pakistan Cotton (Gossypium) is planted during “summer” season from April to June, mainly in two provinces with Punjab 75% and Sindh 25% of the total area. It is an essential oil seed and fabric cash crop, lifeline for textile and palm-oil industry of the country. However, Grapevine (Vitis) is a major fruit and in Pakistan its 70% cultivated area is in Baluchistan, Khyber Pakhtunkhwa and Pothwar region of North Punjab. Heavy weed infestation is the major cause of low productivity in cotton and grapevine. To improve yield effective weed control is vital, as weeds are the most efficient users of space, sunlight, water and nutrients due to their fast growth habits. Excessive use of pre and post emergence herbicides degrading air, water, soil environment and quality of produce. To protect environment power operated intercultural-implements with different shape of blade were developed at Malik Engineering Workshop Dhudial-Chakwal with collaboration with Faculty of Agricultural Engineering & Technology, PMAS-Arid Agriculture University Rawalpindi during 2018-19. Machine performance was tested under local condition of Punjab at two sites. For grapevine at Site-A: University Research Farm Koont-Chakwal PMAS-AAUR and for cotton at Site-B: Maher-Rab-Nawaz-Sial Agriculture Farm, Mukhiana tehsil and district Jhang. The intercultural machine was tested for weeding efficiency, plant damage, speed, depth, theoretical field capacity, effective field capacity, field efficiency, fuel consumption and operational cost. Performance of the indigenously fabricated machine blades were compared with the available rotary weeder. The data collected to experimentation was statistically analyzed at 5% level of Probability.

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Introduction

In Pakistan, 70% of grapes are cultivated generally in the province of Baluchistan and some districts of Khyber Pakhtunkhwa with an annual production of 122,000 tons with an average yield of 19tons ha^{-1} compared to 25tons ha^{-1}. It indicates that there is a significant amount of biodiversity present in the grape germplasm for use in genetic enhancement and description for productive grape production in the northern areas of Pakistan, Khyber Pakhtunkhwan and Baluchistan. Germplasm is important because it includes the genotypes variety needed to grow new and improved lines (GOD, 2015).

Grape (Vitis) is one of the most important fruits in the world and its history is very long. Within "The Holy Quran," it was also praised. It is assumed that the European grapevine originated in the region between the Black and Caspian Seas, where it continues to grow wild. It is believed to have been introduced / spreader through Europe and later to all continents by explorers (Mukhtar, Ndiaye, Philippe, & Ahmad, 2011).

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).

Pakistan is a key player in the cotton markets around the world. As the 3rd largest yarn producer and 2nd largest exporter in the world, the 7th largest fabric producer and 3rd largest exporter (ICAC, USA). Cotton and cotton products from Pakistan account for nearly 60% of its overseas earnings. Cotton crop production accounts for less than 10% of agricultural value-added and about 2% of Pakistan's GDP, a large portion of Pakistan's economy is dependent upon cotton and its products (Sial *et al.*, 2014).

Karnkal (2013) studied the weeding operations and told off that intercultural operation controls unwanted plants between the rows which consume more fertilizers and reduce the crop yield. In weeding operation, recently power weeders are introduced with rotary tillage equipment having 3.75-5kW capacity and engine weight of 300-400kg. These implements are not become popular due to blockage of weeds in between tines and separating cleaning is required when used in higher moisture content. Present pattern of row cropping concept widely adopted by Pakistan 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 maneuverability in the small land holdings.

Rajashekar *et al.* (2014) stated that 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.

Chavan *et al.* (2015) explained that 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.

The goal of the current study was to investigate the non-target effects on soil biota and grapevine nutrition of chemical and mechanical weed control. Since earthworms mycorrhizal fungi and soil microorganisms have been shown to be influenced by chemical herbicides, it was hypothesized that alterations caused by herbicides would be apparent by changes in both crop and soil (Aristilde *et al.* 2017).

Majunatha *et al.* (2016) investigated the field performance of rotary weeder and observed that field operating speed 2.5kmh^{-1} with rotor speed 210rpm were found to be optimum for L-type blade compared to other types. The maximum weeding efficiency was 92.5% with a field capacity 0.42hahr^{-1} and fuel consumption for operation is 5.2lha^{-1}. The lowest plant destruction was as low 3.15%. The cost of weeding with this tractor operated rotary weeder in red gram was found to be Rs 1469 per ha, which was 41.25% less as related to manual weeding of Rs 2500 per ha.

Subrata & Bhattacharya (2013) and his team work on blade interaction with soil during interculture operation. For study of soil blade interaction they generate soil bin. In soil bin all soil parameters like (density, type of soil, moisture contain and hardness) these are manually controlled.

Feld rotary tiller cum inter-row weeder quality to establish appropriate mechanical control practices in soybean fields. Build tangential thrust force with negligible slippage to drive the system forward (Dhruwe, 2018).

Weeds are likely to be the most ever-present plant pest category and are responsible for major crop yield losses. Weeds have a significant share (30 percent) of the total losses incurred by pests. They can crop yield and deteriorate product quality, thus increasing production market value. Weed management in all agro-ecosystems is therefore crucial in preserving our plant productivity and ensuring food safety (Rana, M. C.*et al.*, 2016).

Materials and methods

This study was focused on development and testing the performance of power operated intercultural-implements. During experimentation, the performance was tested for available rotary weeder and locally developed small scale new intercultural-implements with three different shapes of blades (L, C & J). The interculture-implement was tested for following parameter in cotton and grapevine field.

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.

The weeding efficiency of the weeder was calculated by the following equation (Remesan *et al.,* 2007);

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

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 grapevine destroyed after weeding operation in a unit area to the number of grapevine 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 grapevine per unit area before the weeding operation.

q = Total number of grapevine 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.

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

Where;

d = Depth (mm),

Forward speed of implement

Marked 75 m distance in the grapevine 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).

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) =$\frac{\mathrm{W}\times V_f \times 3600}{10000}$

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.

$a= \frac{A}{(\mathrm{Tp} + Tc)}$ (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 expressed in per cent and calculated using by following question (Hunt, 1995):

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

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 grapevine 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

The sum of fixed cost and variable cost is known as "operational cost". Variable cost was calculated by considering repair and maintenance 50% of initial cost, fuel cost per hour, lubrication cost 15% of fuel cost and operator wages for interculture implement during its working. Fixed cost was calculated by considering the depreciation, interest on capital, insurance and housing 2-3% of initial cost (Kepner, Bainer, & Barger, 2005).

Depreciation 5 year life and 10% salvage value = $\frac{Purchase\ value - Salvage\ value}{machine\ life}$

Investment for calculating interest at 6% $= \frac{cost\ of\ new\ machine + salvage\ value}{2}$

Results and discussion

Present experiment was conducted for development and testing of different intercultural-implements for comparative study. Data was recorded for different parameters; weeding efficiency, plant damage, actual field capacity, theoretical field capacity, depth of operation, forward speed of implement, field efficiency, fuel consumption and operational cost and analyzed statistically 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 at site-A and B. Soil texture of samples were measured before weeding operation. The soil texture for site-A was loam with electrical conductivity is 0.81dsm^{-1}, pH 7.27, organic matter 0.53(%), available phosphorus 5.8 (mg kg^{-1}), available potassium 120 (mg kg^{-1}) and saturation 39 (%) and for site-B soil was loam with electrical conductivity 1.68dsm^{-1}, pH 7.30, organic matter (0.59%), Available phosphorus 4.4 (mg kg^{-1}), available potassium 120 (mg kg^{-1}) and saturation (39%) respectively.

Moisture content

The soil samples were collected before weeding operation and moisture content measured with help of gravimetric method. Three samples were collected from Site-A and B. The moisture content of those samples was measured. The average moisture content was found from Site-A (9.85%) and Site-B (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

Soil samples were taken before weeding operational and bulk density was measured according to oven dry method. Samples were collected from three different places from field Site-A and B. The bulk density was calculated from Site-A 2.5291 (g/cm^3) and Site-B 1.775 (g/cm^3). Research result are not in line with Goel *et al.*, 2008 who found of range (1.25 to 1.40g/cm^3), respectively.

Forward speed of implement

The forward speed of small scale interculture-implement was calculated for both of sites 0.375 and 0.416m/s respectively. The forward speed of operation was measured by the following equation (Islam, 2017).

Forward speed (m/sec)= $\frac{Distance}{time}$

Weeding Efficiency (%)

Effect of different shapes of blades and experimental sites on weeding efficiency is shown in Table 1. Weeding efficiency was better at site-B (83.5%) in cotton field as compare to site-A with grapevine. Cotton is a seasonal crop with rotation and continuous tillage before it sowing. However, grapevine field are usually remains productive for decades result in more weed infestation. On the other side weeding efficiency was slightly low (81.15%) at site-A due to hard and weedy field condition. Mean weeding efficiency of interculture-implement with different shape of blades C, J, L and R was 81.4, 76.6. 91.70 and 81.1% respectively. Weeding efficiency of L-shape blade was maximum (91.70%) as compared to other shapes of blade as L-shape blade pulverizes soil in better way. However, weeding efficiency of J-shape blade was minimum (76.6%), which result in less pulverization of soil that's why it is not recommended. Mean value of treatment for weeding efficiency shows that C and R shape blades are non-significant while J and L shape blades are significantly differ with each other at 5% level of probability. However mean weeding efficiency for both the sites were significantly differ with each other at 5% level of probability. The results of both sites are in line with the G. Kishore Kumar *et al.*, 2018 who found weeding efficiency 78% of power weeder.

Table 1. Shape of blades and weeding efficiency (%).

Shapes of Blades	Site-A	Site-B	Mean
C	79 D	83.80 D	81.4 B
J	74 E	79.20 D	76.6 C
L	89 B	94.40 A	91.70 A
R	79 D	83.20 C	81.1 B
Mean	80.25 B	85.15 A	

Plant Damage (%)

Plant damage (Table 2) was at site-B (11.3%) were higher as compare to site-A because weeds height in cotton field was equal to plant height and number of plant in 1m^2 was eights as compared to grapevine with one plant in area of 1m^2. At site A there was no plant damage due to more height and mature plant. For different shape of blades C, J, L & R plant damage was found 5.7, 8.5. 3.8 & 4.6% respectively. Plant damage of J-shape blade was maximum (8.5%) as compared to other shape of blades because the J-shape blade less pulverize. However, plant damage of L-shape was minimum (3.8%) result in more pulverization of soil and maximum weeds residues mix with the soil. 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, plant damage in the both sites were significant with 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. Shape of blades and plant damage (%).

Shapes of Blades	Site-A	Site-B	Mean
C	0.0 E	11.4 B	5.7 B
J	0.0 E	17.0 A	8.5 A
L	0.0 E	7.6 D	3.8 C
R	0.0 E	9.2 C	4.6 C
Mean	0.00 B	11.3 A	

Depth of Operation (mm)

Depth of operation (Table 3) was more at site-B (51.20) as compare to site-A because of more tillage, seasonal sowing of cotton. At site-A depth of operation was comparatively less (47.70) because soil surface was hard with minimum tillage operation. For blades C, J, L & R-shape of mean depth of operation was 49.50, 42.60, 55.60 & 50.60mm. Operational depth of L-shape blade was maximum (55.6) as compared to other blade shape as it pulverize the soil in better way and maximum weeds residues mix with the soil. However, depth of operation of J-shape was minimum (42.60) results, less pulverize the soil and it was mostly use for disturbed the soil surface. 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, depth of operation in the both sites were significantly differ with each other at 5% level of probability. 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. Shape of blades and depth of operation (mm).

Shapes of Blades	Site-A	Site-B	Mean
C	48.40 C	50.60 BC	49.50 B
J	40.20 E	45. 00 D	42.60 C
L	52.60 B	58.60 A	55.60 A
R	49.60 C	50.60 BC	50.60 A
Mean	47.70 B	51.20 A	

Fuel Consumption (liter/hr)

Comparatively more fuel consumption (Table 4) was observed at site-A (1.23liter/hr) as compare to site-B due to hard field condition prevailing in the field. At site-B fuel consumption was minimum (1.21liter/hr) because of continuous tillage operation. Fuel consumption was recorded for C, J, L & R-shape blades and found 1.20, 1.25, 1.20 & 1.24liter/hr respectively. Fuel consumption of J-shape blade was maximum (1.25liter/hr) as compared to other shape of blades because the J-shape blade less pulverize the soil surface and minimum weeds residues mix with the soil just disturbed the soil surface due to shape and cutting angle. However, fuel consumption of L-shape blade was minimum (1.20liter/hr) results, more pulverize the soil and it was mostly use for mix crop residue with soil surface. Mean value of treatment for fuel consumption shows that C and L shape blades are non-significantly differ while J and R shape blades are significant with each other at 5% level of probability. However, fuel consumption in the both sites were non-significant differ with each other at 5% level of probability. These 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)

Actual Field Capacity (ha/hr)

Actual field capacity (Table 5) site-A & B was observed 0.1012, 0.1186ha/hr. However, for different shape of blades C, J, L & R actual field capacity was calculated as 0.1290, 0.0955, 0.1190 & 0.1084ha/hr respectively. Its maximum value (0.1290ha/hr) was observed. Due to shape and cutting angle of C-shape blade it less pulverize soil, result in minimum weeds residues mix with the soil. However, actual field capacity of J-shape was minimum (0.095ha/hr) as a results, it just use to slightly disturb the field conditions. Mean value of treatment for actual field capacity shows that C, J, L and R shape blades are non-significant with each other at 5% level of probability. However, actual field capacity in the both sites were non-significant with each other at 5% level of probability. Research results 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 4. Shape of blades and fuel consumption (Liter/hr).

Shapes of Blades	Site-A	Site-B	Mean
C	1.21	1.19	1.20 B
J	1.24	1.25	1.25 A
L	1.22	1.18	1.20 B
R	1.23	1.21	1.24 A
Mean	1.23 A	1.21 A	

Table 5. Shape of blades and actual field capacity (ha/hr).

Shapes of Blades	Site-A	Site-B	Mean
C	0.1043 AB	0.1536 A	0.1290 A
J	0.0939 B	0.0970 B	0.0955 A
L	0.1165 AB	0.1168AB	0.1190 A
R	0.1101 AB	0.1068 AB	0.1084 A
Mean	0.1062 A	0.1186 A	

Field Efficiency (%)

Mean field efficiency of interculture-implement (Table 6) at site-A & B was 83.90, 83.90%. Field efficiency for different shape of blades C, J, L and R was 84.20, 75.50, 92.60 and 85.60% respectively. Maximum field efficiency (92.60%) was observed in L-shape blade due to its shape and cutting angle, result in more pulverization and maximum weeds residues mix with the soil. However, field efficiency of interculture-implement with J-shape blade was minimum (75.50%) which result in minimum disturbance of the soil. Mean value of treatment for actual field capacity shows that C, J, L and R shape blades are significant with each other at 5% level of probability. However, field efficiency at the both sites was non-significant 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. Shape of blades and field efficiency (%).

Shapes of Blades	Site-A	Site-B	Mean
C	82.00 C	82.80 C	84.20 C
J	76.40 D	74.60 D	75.50 D
L	92.80 A	92.40 A	92.60 A
R	84.40 BC	86.80 B	85.60 B
Mean	83.90 A	84.15 A	

Operational Cost (Rs/ha)

Operational cost (Table 7) at site-A and B was observed 2308 and 2397Rs/ha respectively. Operational cost for different shape of interculture-implement blade C, J, L & R was recorded in the field 2423, 2422, 2306 & 2350Rs/ha respectively. Maximum operational cost (2350Rs/ha) was observed in C-shape while minimum operational cost (2306Rs/ha) was recorded in L-shape. Research results are contradictory with Majunatha *et al.,* 2016 who found the operational cost Rs 1469per ha, which was 41.25% less as related to manual weeding of Rs 2500per ha^{-1}.

Table 7. Shape of blades and operational cost (Rs/ha).

Shapes of Blades	Site-A	Site-B	Mean
C	2392 B	2269 D	2423 BC
J	2468 A	2377 BC	2422 A
L	2348 BC	2264 D	2306 C
R	2379 BC	2321 CD	2350 B
Mean	2397 A	2308 B	

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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