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DESIGN DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED GARLIC PLANTER

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In Pakistan average productivity of garlic is about 9t/ha that is far behind the other garlic producing countries. In Pakistan conventional method for the sowing of garlic involves the placement of cloves at proper depth with 4 inch inter clove distance. In this method, sowing of garlic is performed by human labor which is costly, time consuming, labor intensive and causing hand metering fatigue. This traditional method of planting takes about 60-65 man-days/ha with average cost Rs. 36270/ha. Keeping in view above constraints, single row manually operated garlic planter has been designed and developed at Agriculture Mechanization Research Institute, division Faisalabad and its field performance was evaluated at Machinery Demonstration Unit (MDU) Farm of Agriculture Engineering Research Division Faisalabad during Rabi season of 2017. The planter was equipped with main frame, bucket chain conveyor, ground wheel, power transmission and seed hopper. Seed bucket having size of 27 mm dia. provided for clove transfer from seed hopper to seed tube. Solid rubber tire having dia. 460 mm, pulled over the metallic rim, was provided with sprocket at its hub, to transmit power to drive shaft through chain No. 428. A set of sprockets of teeth 30, 12 40 30 have been arranged to synchronize the forward speed and bucket conveyor speed for placement of cloves at inter distance of 102 mm. A seed hopper fabricated with MS sheet with capacity of 2 kg was provided to feed the seed bucket conveyor. During field test, effective field capacity (EFC), field efficiency and capacity of garlic planter was found to be 0.042 ha/hr, 81.02 percent and 0.336 ha/man/day respectively. The planter dropped seed @ 200 kg/acre at 9.8% missing during field test and average plant population of 165000 per acre was observed after 2 week of germination with total operating cost of Rs. 2003/ha with the net saving of Rs.32593/ha (Rs. 13190/acre) which is an attractive amount with minimal labor force. Although during field testing, planter performed efficiently but some modifications have been recommended to make it two rows for better stability of planter during operation.

Keywords: Garlic; Planter; performance evaluation; field efficiency; operating cost.

INTRODUCTION

Garlic (Allium sativum, Linn.) is actually a perennial herb belonging to the family Alliaceae and it is also second most widely used condiment after onion. Many researches confirmed the presence of certain antioxidants, minerals and vitamins in garlic hence it can be used to reduce cholesterol, blood pressure level and help to protect against heart disease and cancer. (Hussain *et al.,* 2012; Kumar *et al*., 2010;Mengesha and Azene, 2015).In addition to this, garlic is a significant crop in terms of high yield potential, high return and suitability for small land holding farmers. On Worldwide scale garlic is cultivated on an average of 2.5 million acres with approximate total production of 25 million tones. China is the leading garlic producing region which contributes 80 percent of the total world production (FAO, 2014).In Pakistan, it is grown on small scale and consumed by majority of peoples but due to lack of self-sufficiency in garlic production most of garlic is imported. In Pakistan during the fiscal year 2014-15 the area of production under garlic was 7973 hectare with production of 73 thousand ton and the contribution in Punjab in terms of area under cultivation and production was 39% and 34% respectively. It was clear from the above statistics that this much production was unable to meet the total demand. (Ahmad 2010). Hence 40.30 thousand ton of garlic was imported from India, China, Christmas islands and Chili to meet domestic consumption (Condiments, Vegetables and Fruit Statistics of Pakistan 2014-15). The statics shows that Pakistan has to produce her own resources of garlic production. In Pakistan the production of garlic per acre is usually low as compared to other rising countries due to unavailability of appropriate disease free seeds (Cloves) and inappropriate agronomic practices of garlic (Javed *et al.,*2008; Mengesha and Azene, 2015).

Cultivation of garlic is possible in different sort of soil but usually well drained fertile loamy soil having pH range from 6 to 7 is most appropriate for good yield. Garlic is propagated by clove so clove's size, seed rate, seed depth and proper time of seed plantation are important parameters for ensuring healthy and desired plant population (Gajakos *et al.,* 2015). The cloves having 2-3 cm size should be used for planting (Lallan *et al.,* 1992) and The most recommended plant spacing for garlic crop is 10 cm between plants and 30 cm between the rows (Alam *et al.,* 2010).In Pakistan conventional method for the sowing of garlic involved the manual placement of cloves at proper depth that is time

consuming, labor-intensive, causing backache and fatigue due to longer hours of careful vertical placement of seed and hand metering to avoid crowding and bunching. Conventional method of garlic planting is very expensive as about 60-65 man-day/ha (Gajakos *et. al.,* 2015) costs for Rs 36270/ha that contributes 17.3% of total cost of production. Gajakos *et. al.,* 2015, developed a walk-behind Garlic planter in 2015 and found 84.79% field efficiency with 28.33% missing efficiency during field testing. The planter was provided seed metering system with cups attached at periphery of disc. During the rotation of seed metering disc, cups were not able to change its orientation by keeping the seed safe but dropped the seed while tilting the cup and this was the reason of high missing percentage.

Keeping in view above said constraints, a research study was conducted in 2017 at Agricultural Engineering Research Workshop Faisalabad, with the following objectives:

1. Design and development of Walk- behind single row garlic planter.
2. Laboratory testing and performance evaluation of Walk- behind single row garlic planter.
3. Economic analysis of the planter

In order to meet above said objective various research article related to garlic planter were reviewed. Rocha *et al.(1991)* designed and developed a manually operated garlic planter for bulbs and its field performance was evaluated at 5 bulb per meter spacing. Lallan *et al.* (1992) proposed that size of garlic clove is important for better germination/yield for better payback. To address the issue of excessive payment for conventional method of planting of garlic, *Jiraporn et. al. started* development of garlic planter in1999. After collection of data about conventional method of planting and effect of planting methods to yield, it was concluded by Jiraporn in 2002, in research study that drilling method was best suited for fabricate garlic planter. Jarudchai *et al.* (2002) designed and developed 3 types of garlic planter in Thailand by employing three different metering mechanism viz. (1) Inclined metering plate (2) vertical metering plate (3) spring plate. In this study, 2 model of garlic planter by using two type of metering system i.e the vertical metering Plate with triangular grooves, bucket type metering system and uniformity of both metering system was evaluated. Garlic Planter with bucket type metering system has shown the most impressive results with broken percentage of about 0.23 percent. Gajakos *et. al*. (2015) conducted a research study for performance evaluation of manually operated garlic planter on actual field condition and economic analysis. This planter was consisted of disc type metering mechanism having spoon on its face. (Benjaphragairat *et al.*, 2010). The spoon start to picks up the clove in the seed box as disc start to rotate in the seed box. Field efficiency and saving in cost of operation was found to be 84.79 % and 84.35 percent respectively with 33.28% missing and even then high yield return than manual sowing (Bakhtiari *et al.*, 2009). But the planter developed by AMRI (Research) Faisalabad consist of chain type metering system having buckets on it with the lower percentage of missing as compared to planter in the study of Gajakos *et al*., 2017.

MATERIALS AND METHODS

***Design and Development*:** To meet the objectives, a walk-behind single row planter (Bucket type) was designed with following are main parts:

1. Main frame
2. Drive wheel
3. Bucket conveyor
4. Seed Tube
5. Seed hopper
6. Furrow opener.

***Main Frame*:** Main frame was fabricated with MS pipe having dia. 25.4 mm just to make it light weight. All the other components were mounted on this main frame. Main frame was extended to use it as handle for its operator to control the planter and the handle was oriented at an angle of 35º to exert power at furrow opener through main frame for ease of operation.

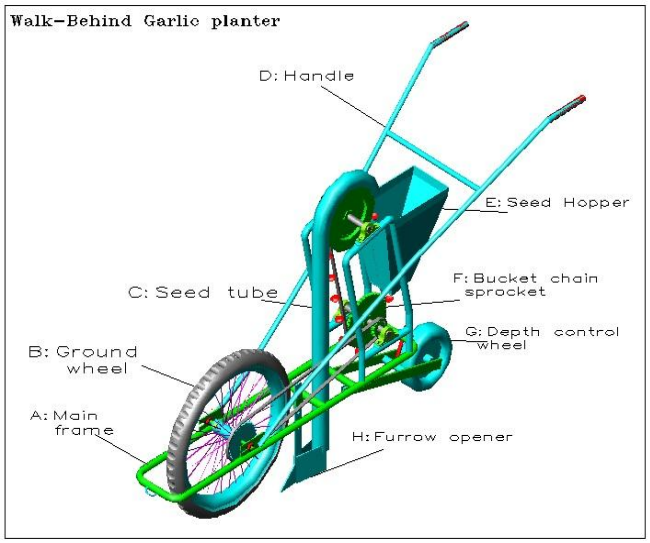

Figure 1. Manually operated Walk behind Garlic Planter

***Drive Wheel*:** A ground wheel having dia. of 460 mm has been provided to drive the bucket conveyor. It is equipped with solid rubber tire to minimize the wheel slippage during operation. A sprocket having 26 teeth has been provided at hub of the drive wheel to transmit power from ground wheel to sprocket on main shaft for operation of bucket conveyor as shown below in a schematic view of the planter.

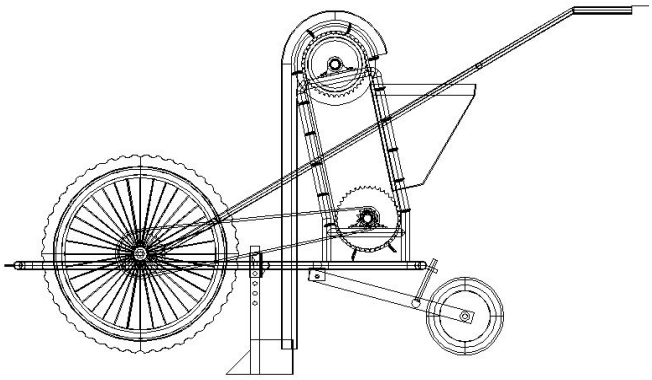

Figure 2. Schematic view of Walk –Behind Garlic Planter

***Bucket Conveyor*:** A set of 18 buckets having dia. 27 mm have been fastened to the chain No. 428, to elevate the clove of garlic from the seed hoper to the seed tube for its free fall to the soil. Buckets were so arranged on the chain to provide inter clove distance of 102 mm.

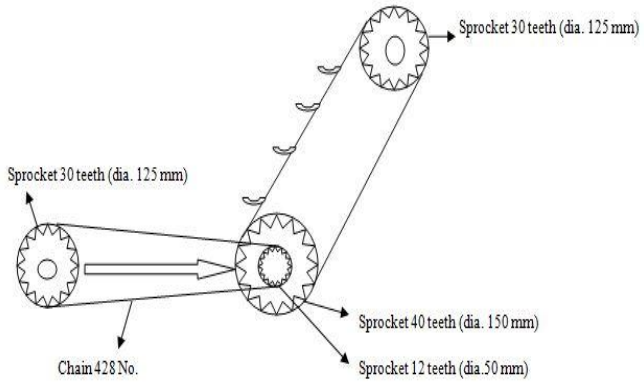

Figure 3. Power transmission of Manual operated Walk-behind Garlic Planter

Dia. of ground wheel = 460 mm
Distance travelled in one revolution (π DN)
$= \frac{22}{7} \times 460 \times 1 = 1446$ mm
Sprocket ratio (Dr/Dv) = 30/12 = 2.5
Revolution of main shaft/revolution of ground wheel = 2.5
Dia. of sprocket at main shaft = 150 mm
Circumference of sprocket at main shaft (π DN)
$= \frac{22}{7} \times 150 \times 1 = 471.43$ mm
Chain length in one revolution of ground wheel
$= 471.43 \times 2.5 = 1178.58$ mm
Inter bucket distance at chain
= 76.2 mm
No. of cloves dropped/revolution of ground wheel
= 15
P-P distance = 1446/15 = 96.4 mm
= 96.4/25.4 = 3.8 inch

***Seed tube*:** The discharge spout having elliptical shape, made of MS sheet SWG 24 has been provided to rout the cloves from delivery point to furrow opener. Generally, all the cloves are discharged under free fall condition, however under gravitational fall; possibility is there to strike along the side of the seed tube. The seed tube is actually linked with a short cylindrical pipe that is dropped into the furrow.

***Seed Hopper*:** MS sheet SWG 22 was used for the manufacturing of seed hopper. Mild steel must have an elliptical cross section with the design capacity of 4500 cm^3.The dimension of hopper is 30cm x 10cm x 15cm. The seed hopper is shaped to focus its center of gravity falls on the axis of buckets line. By this arrangement, last clove in the seed box tends to make ride on the bucket for delivery to the furrow opener.

***Laboratory Test*:** Laboratory testing of garlic planter was conducted at workshop AMRI Research Division Faisalabad in order to study the following parameters.

1. Seed rate (kg/ha)
2. Missing % age (at different hopper filling level)

Figure 4. View of Missing bucket during laboratory testing

First of all circumference of ground wheel was measured and seed box was filled with garlic cloves. Garlic planter was hanged on a stand made for the purpose. Mark was put on ground wheel in order to count revolution and ground wheel was made free to rotate.

Figure-5. Clove size measurement during laboratory testing

Cloves dropped by the planter were counted and weight was measured for the known revolutions of ground wheel. Area covered by fixed number of revolution and seed rate was determined by using following formulas (Gajakos *et al.*, 2015).

$$Area\ Covered = (\pi DN) \times W \quad \text{(Eq.1)}$$

Where, D=Diameter of ground Wheel.
N=No. of revolution
W=Width of operation

$$Seed\ Rate(\frac{kg}{ha}) = \frac{weight\ of\ cloves\ collected(kg)}{Area\ Covered(ha)} \quad \text{(Eq.2)}$$

***Theoretical Seed rate*:** The theoretical Nos. of seed per hectare was calculated by using the following mathematical relationship (Nier *et al.*, 2014).

$$Theoretical\ seed\ rate\ (seed/ha) = \frac{10^8}{(W \times Xs)} \quad \text{(Eq.3)}$$

Where, $W = Row\ width\ (cm) Xs = Seed\ spacing\ along\ row\ (cm)$

***Field Performance Test*:** The field testing of planter was carried out at Machinery Demonstration Unit of Agriculture Engineering Research Division Faisalabad, in order to evaluate its overall performance by following research conducted by Gajakos *et al.*, 2014. Two plots having an area of 0.5 acre were selected to conduct the test. Field test was conducted to determine evenness of seed spacing, average depth of seed placement, effective field capacity and field efficiency of garlic planter. During field test; field efficiency, field capacity and timing of every activity involved was continuously observed by three different persons. One person operate planter on prepared field while others person observed and recorded the field data. Stop watch was used to record productive (time during which garlic planter was actually performed the intended operation) and non productive time (time used for filling of seed box, turning of planter at the end of field, removal of clogs and adjustment). The methodology and experiment technique adopted in studying performance evaluation of machine is discussed as below.

***Uniformity Index*:** Uniformity index is useful parameter to evaluate the precision of metering unit of planter. Observation of seed were randomly selected in the field and firstly theoretical seed spacing was calculated, then actual seed spacing in field was measured to estimate uniformity index by using following formula.

$$Uniformity\ Index = (1 - \frac{\sum\ (A-A1)}{NA1}) \times 100 \quad \text{(Eq. 4)}$$

Where
A = Actual spacing between two consecutive cloves
A = Theoretical Clove spacing
N= Number of seed

***Seed Missing*:** The accuracy of metering unit of garlic planter was checked with the help of missing percentage by taking observations of number of buckets passed across the reference point at three different speeds. In this method firstly number of buckets worked out in given row length at each working speed and then actual number of cloves dropped were observed for same row length and speed. The missing %age was determined by counting buckets and cloves dropped. The Missing hill percentage was calculated by the following formula:

$$M = \frac{Nt - Na}{Nt} \times 100 \quad (Eq.5)$$

Where
M = % age of Missing
Nt= No. of buckets passed across the reference point for given wheel revolutions (theoretically).
Na= Actual number of cloves observed in given wheel revolutions.

The accuracy of metering unit of garlic planter was checked with the help of missing % by taking observations of number of plants in arbitrarily chosen five rows after three week of planting. Initially in this strategy, hypothetical number of plants that ought to be available in given line length was worked out and afterward actual number of plants in each line for same line length were checked and recorded. Missing percentage was ascertained by using the following formula:

$$M = \frac{Nt-Na}{Nt} \times 100 \quad \text{(Eq.6)}$$

Where,
M = % of Missing
Nt= No. of cloves to be present in a row for given row length, (theoretically).
Na= Actual number of cloves observed in a row.

***Seed Depth*:** In order to measure average depth of seed placement, the loose soil on observed hill drop randomly selected in row, was removed till garlic clove were visible in furrow and depth of cloves was measured with measuring tape.

***Effective Field Capacity*:** Effective field capacity of garlic planter was measured by taking both productive and nonproductive time into consideration and area covered in

that specified time period was calculated by measuring length and width of experimental plot. Mathematically effective field capacity of garlic planter is expressed as below.

$$Effective\ Field\ Capacity(\frac{ha}{hr}) = \frac{Area\ Covered}{Total\ Operational\ Time} \quad \text{(Eq.7)}$$

$$Total\ Operational\ Time(hr.) = Productive\ Time + Non\ Productiv\ Time \quad \text{(Eq---8)}$$

***Theoretical Field Capacity*:** Theoretical field capacity of machine was calculated with the help of speed of operation during field test of garlic planter by measuring time required to cover 18, 24 and 30 meter length by using stop watch. The speed of operation and theoretical field capacity were calculated by using following mathematical relations.

$$Speed\ of\ Operational(\frac{km}{hr}) = \frac{Distance\ Covered\ (km)}{Time\ (hr.)} \quad \text{(Eq.9)}$$

$$Theoretical\ Field\ Capacity(\frac{ha}{hr}) = \frac{Speed(\frac{km}{hr}) \times Width\ of\ implement(m)}{10} \quad \text{(Eq.10)}$$

***Field Efficiency*:** Field efficiency of garlic planter was estimated by calculating ratio between Effective field capacity and theoretical field capacity as expressed below.

$$Field\ Efficiency\ (\%) = \frac{EFC}{TFC} \quad \text{(Eq. 11)}$$

Where,

$EFC = Effective\ Field\ Capacity$

$TFC = Theoretical\ Field\ Capacity$

***Economic Analysis*:** Cost of operation of garlic planter was worked out using RNAM test Code.

RESULTS AND DISCUSSION

***Laboratory Test*:** Garlic cloves were used for laboratory testing of garlic planter in order to estimate the seed rate, missing and damage percentage of garlic Planter. During laboratory testing **of** manually operated garlic planter, the planter was hanged on a stand to make its wheel free for rotation. A sign was marked on tire and the wheel was rotated at normal speed. A reference point was also marked at main frame to count buckets passing the reference point. For known Nos. of drive wheel revolutions, Nos. of buckets passing the reference point were counted. During the operation, a uniform speed of the wheel was ensured and found 7% missing with zero damage. Nos. of buckets on chain conveyor and inter distance of bucket on chain conveyor were important parameters in order to maintain inter clove distance that was estimated to 100-150 mm. It was also observed that seed missing is directly proportional to seed quantity in the hopper. As level of seed in hopper lowers down, the chances of seed missing was increased. At 50 % and 25 % filled seed hopper seed missing/ empty bucket was found 12 % and 28% respectively. Hence in order to ensure evenness of seed, the hopper should be filled frequently.

Field Performance Test

***Missing %age/plant population*:** Walk- behind garlic planter was tested at MDU farm Faisalabad, to evaluate its performance. Soil was fully prepared for sowing of garlic. The planter was operated at average speed of 2.5 km/hr by keeping in view the walking speed of an ordinary man. An area of 0.1 ha (40m × 25m) was selected that was divided into 3 sub plots. Garlic planter was tested separately in each sub plot to determine the missing % age at each seed filling level of seed hopper.

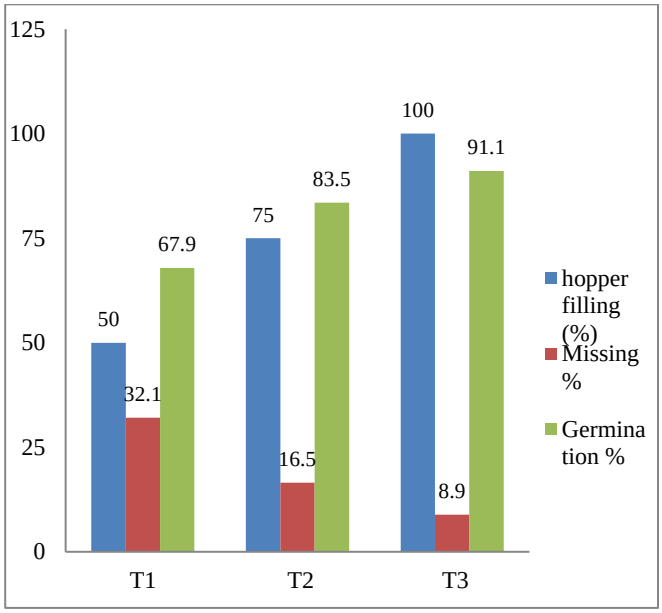

Figure 5. Effect of Hopper filling on Plant population T1: hopper filling 50 percent, T2: hopper filling 75 percent, T3 hopper filling 100 percent,

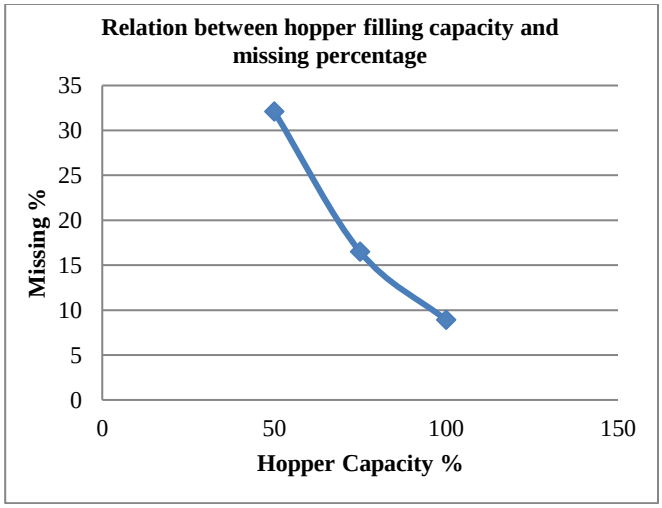

Figure 6. Effect of hopper on Missing percentage

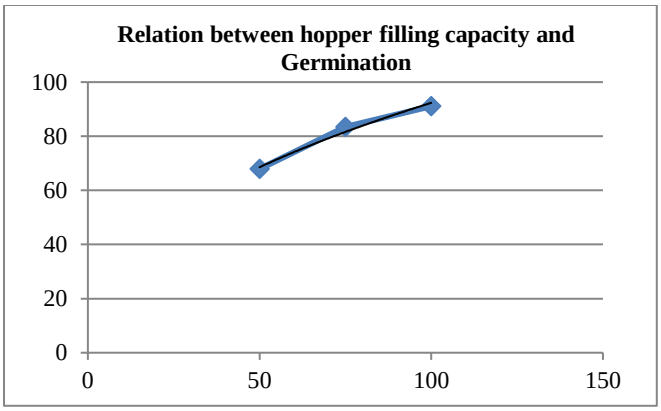

Figure 7. Effect of hopper on Germination

The planter was tested at three hopper fillings i.e. 50% filling, 75% and 100 % hopper filling for missing percentage determination. At different fillings, missing %age was observed to work out its working efficiency. At 100% hopper filling, missing was 8.9% and average plant population of 165000 per acre was observed after 2 week of germination that was far better as compared to missing percentage of 28.33% found in manually operated garlic planter developed by Gajacos. *et al*., 2015. The improvement was probably due to change in design of seed metering system as bucket conveyor elevated and dropped the seed gently as compared to disc type seed metering system provided in manual planter developed by Gajakos. *et al*., 2015. While with 50% and 75% hopper seed filling resulted 32.1 and 16.5% plant missing. Graphical presentation (as shown in fig. 5, fig. 6 and fig. 7) have revealed that at average man walking speed, seed level in seed hopper is a major factor for better results.

***Field Capacity and field efficiency*:** During field test, planter was operated manually by walking behind at an average operating speed of 2.5 km/h. The planter was adjusted to drop the clove at depth of 20-25 mm with 5-10 mm soil cover. According to data collected during field test average operational time, turning time, filling time and adjustment time required to cover an area of one acre was worked out 465, 53, 40 and 15 minutes respectively. Effective field capacity (EFC), field efficiency and capacity of garlic planter was found to be 0.042 ha/hr, 81.02 percent and 0.336 ha/man/day respectively.

It was also observed that garlic planting done in wetter condition exhibited far better germination and growth as compared to plantation done in dry soil. It was probably due to alkaline soil, lower organic matter in soil and hard soil cover over the seed after 1st irrigation. Working capacity of walk behind garlic planter was found 21-23 times higher than manual planting method with 81% and 91.1% field efficiency and working efficiency respectively. The results were in line with the study already conducted by Jarudchai y. *et al*., 2002.

Table 1. Cost analysis of manually operated garlic planter.

Description	**Units.**		
Name of Machine:	Manually Operated Garlic Planter		
Initial Cost of Machine (Rs.)	12000.00		
Life in years (year)	8.00		
operating hours per year (hr./Year)	235.20		
Total life (hr.)	1881.60		
Salvage Value (@ 10% of initial cost) (Rs.)	1200.00		
Test Data			
Field Capacity (ha/hr)	0.04		
Labor required			
Unskilled (man-hr/ha)	23.63		
unskilled (man-day/ha)	2.95		
Wages (Rs. /day)	558.00		
Wages (Rs. /hr)	69.75		
Fixed cost of Garlic Planter	**Rs./Year**	**Rs./hr**	**Rs./ha.**
Depreciation	1350	5.74	135.61
Interest (12 % of ave. investment)	792	3.37	79.56
Insurance (2 % of ave. investment)	132	0.56	13.26
Tax (4.5 % of purchase price)	540	2.30	54.24
Housing (1% of purchase price)	120	0.51	12.05
Repairs and Maintenance	600	2.55	60.27
Fixed cost of Garlic Planter (A)	**3534**	**15.03**	**355.00**
Variable cost of Garlic Planter			
Labor cost	16405.20	69.75	1647.94
Variable cost of Garlic Planter (B)	16405.20	69.75	1647.94
Total operating cost of Garlic Planter (A+B)	**19939.20**	**84.78**	**2002.94**

However slight variations in results of laboratory testing and field testing were probably due to variation in man forward speed, skill of operator, ungraded garlic seed and unconsciously slight tilt of planter.

***Cost Analysis*:** The total cost of operation of the garlic planter was worked out by considering the fixed and operational cost of machine that was based on prevailing market rate during season.

Gajakos *et. al.,* 2015 described that manual sowing of garlic requires about 60-65 man-day/ha (0.016 ha/day/man to 0.015 ha/day/man). Whereas walk-behind planter is capable of planting 0.34 ha/day/man that is 21-23 times higher than manual planting. Walk-behind planter cost for Rs. 3677/ha as compared to cost of manual planting Rs.36270/ha with the net saving of Rs.32593/ha that is an attractive amount with minimal labor force.

Table 2. Cost effective comparison of Manual VS Mechanized Garlic Planting.

Description	Manual Planting of Garlic Cloves/ha	Mechanical Planting of Garlic/ha
Labor	520 man-hrs (65 man-days)	24 man-hrs (3 man-days)
Wages	Rs.36270	Rs.1674
Operational cost	Nil	Rs.2003
Total planting cost	Rs.36270	Rs.3677
Net saving/ha	Rs. 32593	
Net saving/acre	Rs. 13190	

***Conclusions and Recommendations*:** In Pakistan mostly sowing of garlic is generally done by human labor that is costly, time consuming, labor intensive and causing fatigue due to hand metering. This traditional method takes about 60-65 man-day/ha with average cost of planting Rs.36270/ha while planter takes 3 man-days/ha that costs Rs. 3677/ha. Hence net saving in cost of planting was Rs. 32593/ha by using one row manually operated garlic planter. The field efficiency of garlic planter was found 81 % with working capacity of 3 man-days/ha, missing 8.9% and uniformity index was found to 88.7% respectively. However overall field performance of Garlic planter was satisfactory. Following recommendations are being suggested for future to improve efficiency.

- A marker should be provided to demarcate the next row at desired distance.
- Graded seed be used for planting.
- Operator should be trained for smooth operation without minor tilt.
- The Planter should be modified to multi row planter (at least two rows) for better stability of planter during operation.
- Multi row planter should be equipped with power source (engine) to attain uniform speed.
- Garlic planting with planter be done in wetter condition and avoid to irrigate the field after the dry planting.

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