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Shubham Zilpilwar
M. Tech, Department of Farm Machinery and Power Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India

Rajvir Yadav
Professor and Head, Department of Farm Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India

Dharmendra
M. Tech, Department of Farm Machinery and Power Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India

Correspondence
Shubham Zilpilwar
M. Tech, Department of Farm Machinery and Power Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India

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Study of garlic (*Allium sativum* L.) clove planters

Shubham Zilpilwar, Rajvir Yadav and Dharmendra

Abstract
Garlic (*Allium sativum* L.) is a species in "Alliaceae" family use for culinary and medicinal purpose. India is the second largest producer of garlic in the world after china. Garlic is the most ancient cultivated vegetables. It has been cultivated for thousands of years. From ancient time garlic is planting manually but it is more laborious operation. So, In India area under garlic cultivation is very less. To mechanize the garlic planting operation different researchers developed the garlic planter, but to overcomes the drawbacks of existing planter tractor operated garlic clove planter was developed having miss index, multiple index, quality of feed index, mechanical clove damage, effective field capacity and field efficiency is 3.64 %, 5.64 %, 90.72 %, 5.70 %, 0.32 ha/h and 79.02 %, respectively. Payback period and benefit cost ratio of developed garlic clove planter is 5.05 years and 1.98, respectively.

Keywords: garlic planter, spoon type metering, quality of feed index, mechanical seed damage, benefit cost ratio

1. Introduction
Garlic is one of the important bulb crop grown and commonly used as a spice or condiment throughout India. It was originated in the Yunnan province of China. Garlic is grown worldwide in 1.4 million hectares, with a total production and productivity of 24.54 million tons and an average productivity of 16.26 t/ha. China is the world leader in the area (0.8 million ha) as well as in production (21.197 million tons). India, although ranks second in area and production, the productivity is very low (5.76 t/ha) (Anon., 2016) [1]. The agricultural mechanization in India had large variations in terms of power availability varying from 0.60 kW/ha in Odisha to 3.5 kW/ha in Punjab. It is also noteworthy that efficient machinery helps in increasing productivity by about 30 % and saving in seeds by 20 %. It also improves farm productivity and farmer's earning to the tune of 5–22 % and 29–49 % respectively. Development and introduction of high capacity, precision, reliable and energy efficient equipment is the need of the hour for judicious use of inputs (Kulkarni, 2009) [7]. Precision planter provides desired plant population with uniform plant spacing and depth of operation, which results in uniform crop stand and hence the cost of cultivation is reduced due to the elimination of thinning operation as well as savings of seed and fertilizer (Pandey, 2009) [9]. The farmers are generally sowing garlic by manual method, which is highly labour intensive and time consuming. It requires about 60-82 man/days to sow one hectare of land by maintaining row to row spacing by 15 cm and plant to plant spacing by 5 cm for better plant population. The cost of garlic planting is also very high approximately Rs. 7200 per hectare, therefore farmers are taking this vegetable/medicinal crop in a very small area.
Garg and Dixit (2003) [4] developed and evaluated the performance of a single row manually operated planter for garlic planting. The machine was consisting of vertical discs with spoons type seed metering mechanism and hoe type furrow opener. The field capacity of the machine varied from 0.03 to 0.04 ha/h. The cost of planting using this machine is only 15 % of the cost of planting by the traditional method. Nare *et al.* (2014) [8] designed and developed a self-propelled garlic clove planter. The spoon type metering mechanism was used for metering the garlic clove and to maintain the precision during the planting operation. The miss index, multiple index, seed damage, actual field capacity and field efficiency of self-propelled garlic planter was 2.67 %, 8.0 %, 1.46 %, 0.065 ha/h and 79.84 %, respectively.

So, there was a need to develop a simple machine that can overcome the difficulty of garlic sowing and reduces the labour requirement and cost of sowing. Due to high intensive works and higher wage rate the garlic cultivation is discouraged by farmers day by day and hence, area also being reduced. To overcome such circumstances there is a necessity to mechanize the planting techniques for the farmers. Though manually operated machines are available, it is not so popular among the farmers due to low field capacity. Hence, to enhance productivity on Indian farms, there is a need to develop a tractor operated garlic (*Allium sativum* L.) clove planter which will be useful for garlic cultivation with higher field capacity, field efficiency and less human drudgery as compared to the manual planter.

2. Materials and Methods

A tractor operated garlic (*Allium sativum* L.) clove planter was designed and developed in workshop of Department of Farm Machinery and Power Engineering, JAU, Junagadh. The components of machine were developed on the principle of operation, available power source and soil condition, etc. Figure 1 shows the prototype of developed garlic (*Allium sativum* L.) clove planter. The different components of the garlic clove planter are seed and fertilizer hopper, delivery tubes, main frame, seed and fertilizer metering unit and frame, power transmission unit, furrow opener and bed former. The metering mechanism was tested soil bin under laboratory evaluation and prototype planter was tested in the field. The cost economics was carried out to check the economic feasibility for adoption by farmers. Comparative studies of different available garlic clove planters were carried on the basis of effective field capacity and cost of cultivation, etc.

Fig 1: Prototype of developed garlic (*Allium sativum* L.) clove planter

2.1 Calibration of Planter

Calibration was carried out for the determination of seed rate to be obtained from the planter at different settings and the variation in seed metering among furrow openers. Calibration was carried out by using standard method used by previous workers.

2.2 Performance Parameters

The performance parameters for the developed garlic clove planter were determined with the following methodology as per the test code for tractor operated equipment.

2.2.1 Miss index (MI)

Skips or misses are created when spoon fails to pick up and deliver seeds to the funnel with seed tubes. The missing percentages is presented by an index called miss index (MI) which is the percentage of spacing greater than 1.5 times the recommended spacing (10 cm for garlic). Smaller values of MI indicate better performance (Bakhtiari and Loghavi, 2009).

$$\mathbf{MI} = \frac{\mathbf{n_1}}{\mathbf{N}} \quad \textbf{(1)}$$

Where,

n_1 = Number of spacing in the region ≥ 1.5 times of recommended spacing,

N = Total no. of observations

2.2.2 Multiple index (DI)

Multiples are created when more than one seed is delivered by a spoon. The multiples percentage is represented by an index called multiple index (DI) which is the percentage of spacing that are less than or equal to half of the recommended spacing (10 cm for garlic). Smaller values of DI indicate better performance (Singh *et al.*, 2005).

$$\mathbf{DI} = \frac{\mathbf{n_2}}{\mathbf{N}} \quad \textbf{(2)}$$

Where,

$\mathbf{n_2}$ = Number of spacings in the region ≤ 0.5 times of recommended spacing,

N = Total no. of observations.

2.2.3 Quality of feed index (QFI)

In order to achieve the desired seed rate in precision planter, the number of seeds per hill recommended shall be one. Hence from the measured values of missing and multiple index, the Quality feed index was calculated by using following expression (Singh *et al.*, 2005) [10].

$$\mathbf{QFI} = \frac{\mathbf{n_3}}{\mathbf{N}} \quad \textbf{(3)}$$

Where,

$\mathbf{n_3}$ = Number of spacing in between 0.5 times of theoretical spacing and 1.5 times of the theoretical spacing,

N = Total no. of observations

2.2.4 Mechanical clove damage

One kilogram of seed sample was randomly selected. The 500 g seeds from the selected sample were filled in hopper and ground wheel rotated up to 15 revolutions. Seeds metered by seed metering spoon were collected from seed tube and checked for any visible mechanical damage of cloves including skin removal or crushing (Bakhtiari and Loghavi, 2009) [2]. The damaged clove percentage was calculated from collected seeds and the procedure was repeated thrice for each variety of seed samples.

$$\mathbf{SD} = \frac{\mathbf{W_{ds}}}{\mathbf{W_c}} \quad \textbf{(4)}$$

Where

W_{ds} = Weight of cloves damaged, g

W_c = Weight of cloves collected, g

2.3 Field capacity
The field capacities of the garlic clove planter were calculated with the help of following formulae (Kepner *et al*., 2005) [6].

2.4 Theoretical field capacity
Theoretical field capacity of planter was calculated by using the formula (Kepner *et al*., 2005) [6].

$$FC_t = \frac{W \times V_t}{10} \quad (5)$$

Where,
FC_t = Theoretical field capacity of planter, ha/h
W = Width of planter, m
V_t = Forward speed of tractor hitched with planter, km/h

2.5 Effective field capacity
The effective filed capacity of planter was calculated by using following formula.

$$FC_a = FE \times FC_t \quad (6)$$

Where,
FE= Field efficiency, %
FC_a = Actual field capacity of the planter, ha/h
FC_t = Theoretical field capacity of the planter, ha/h

2.6 Field efficiency
Field efficiency was calculated by using following formula (Kepner *et al*., 2005) [6].

$$FE = \frac{FC_a}{FC_t} \times 100 \quad (7)$$

Where,
FE = Field efficiency, %
FC_a= Effective field capacity, ha/h
FC_t = Theoretical field capacity, ha/h

2.7 Cost economics
Cost analysis was made for estimating the cost of different operations. The fixed and variable costs were taken into consideration to estimate the cost of operations. From the observations of field evaluation, the cost of operation of the tractor operated prototype planter was worked out. Straight line method of cost analysis (to find depreciation cost) was adopted (Hunt, 2001). The payback period and benefit cost ratio of developed planter was calculated as per given below.

(a) Payback period
Initial cost of the machine = 60000 Rs.

Custom hiring charges = (Cost of operation of machine per hour + 25 % over head charges) × 25 % profit over new cost
= (105.6 + 105.6 × 0.25) × 1.25
= 165 Rs./h

Average net annual benefit, Rs.= (Custom Hiring Fees, Rs./h – Total operating cost, Rs./h) ×
Annual utility
= (165 – 105.6) × 200
= 11880 Rs.

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Average net annual benefit}} \quad (8)$$

$$= \frac{60000}{11880}$$

= 5.05 years

(b) Benefit Cost ratio
Total benefit = Average net annual benefit (Rs.) × Life of machine (L) in year
= 11880 × 10
= 118800

$$\text{B: C ratio} = \frac{\text{Total benefit}}{\text{Total cost of investment}} \quad (9)$$

$$= \frac{118800}{60000}$$

= 1.98

2.8 Comparative study of developed garlic clove planter with existing planter
In India garlic cultivation is carried out on irrigated land. Prior to garlic planting bed formation is necessary for irrigation purpose. For garlic planting by manual garlic planter, self-propelled garlic planter and manual dibbling method bed formation is necessary before planting, because these planters not having arrangement of bed former with it. But in case of developed garlic clove planter the bed former attachment is available, so planting and bed formation is simultaneously done. Figure 2 shows the different types of garlic planters
For fertilizer application labour is required in manually operated planter and manual dibbling method, but fertilizer unit also provided in developed planter. Comparison of garlic planters was carried out on the basis of effective field capacity and cost of cultivation.

Manual Garlic Planting

Manually Operated Garlic Planter

Self-Propelled Garlic Planter

Tractor Operated Garlic Planter

Fig 2: Different types of garlic planters ([1&3]Nare *et al*., 2014, [2]Gajakos *et al*., 2015, [4]Zilpilwar, 2019)

3. Results and Discussions

It deals with the results obtained throughout the study of garlic (*Allium sativum* L.) clove planters. The study related to field testing of prototype planter was done to find out the performance of planter in field condition and its comparison with existing planters. Finally workout the economics of developed planter. Comparison of developed garlic planter was carried out with existing garlic clove planter. The results of the study were reported and discussed under the following contents.

3.1 Field Test of Developed Planter

The field evaluation was done as per the standard procedures. Results obtained were discussed below. The preliminary observations of the experimental field / plot recorded prior to the field testing. The 1152 m^2 flat area of field having medium black soil was selected for experiment. The moisture content and bulk density of soil was 16.63 % (d.b.) and 1.29 g/cc at the time of field testing of prototype. The Gujarat garlic varieties GG-5 was selected for planting. The Plant to plant and row to row spacing was 10 and 15 cm respectively as per the recommended crop parameters.

The developed garlic clove planter has working width 1.68 ± 0.08 meter. The average value of depth of clove placement was 4.21 ± 0.04 cm. It is quite difficult to maintain the appropriate forward speed in field condition. However, it was managed to keep the overall forward speed of 2.59 km/h. The fuel consumption of tractor during planting operation by garlic clove planter was determined as 3.04 ± 0.08 l/h, which is near about similar with fuel consumption for tractor operated seed drill. The seed rate of developed garlic clove planter is 443 kg/ha.

3.2 Performance parameter

The performance parameters of the garlic clove planter were determined with the described methodology. Table 1 shows the results obtained during field test of developed garlic (*Allium sativum* L.) clove planter.

- The observed miss index of developed garlic clove planter in field was 4.58%. It was observed that miss index is directly affected by increase in forward speed, because insufficient time to spoon for picking of clove and increase in vibration spoon dropped the clove randomly inside the seed metering box.
- Multiples are created when more than one seed is delivered by a spoon. The observed miss index in field for GG-5 garlic variety was 6.07 % at forward speed 2.59 km/h.
- Quality of feed index is the combine effect of miss and multiple index. The observed quality of feed index in field for GG-5 garlic variety was 89.34 % at forward speed 2.59 km/h.
- In mechanical planting of garlic, the clove damage is an important point of concern, because unacceptable level of clove damage can seriously affect yield, which in turn affects the farmers as economic loss. Due to peculiar shape of garlic cloves they are more prone to damage while handling mechanically. The observed mechanical clove damage was 5.70 % during field test of planter.

3.3 Field capacity

- The field capacities for the garlic clove planter are determined and discussed below.
- The theoretical field capacity of the developed garlic clove planter was found 0.41 ha/h. The theoretical field capacity depends on the width of coverage and speed of operation.
- The effective field capacity of garlic clove planter was worked out as 0.32 ha/h considering the time losses in the turning and riffling of seeds and fertilizer during the operation.
- The field efficiency of the garlic clove planter was found to be 79.02 %. Field efficiency could be increased by creating better operation condition and operator skill.

3.4 Cost Economic

The operation cost was analysed for the developed tractor operated garlic (*Allium sativum* L.) planter. Depreciation cost was calculated on the basis of straight line method. The developed planter was found to be operated at the cost of Rs. 553.63 per hour *i.e.* Rs. 1677.67 per hectare. Considering the custom hiring cost as 25 % more than the operation cost, the actual operation cost was found to be increased to Rs. 692.04 per hour *i.e.* Rs. 2097.09 per hectare. In case of providing custom hiring, the payback period of implement was found to be 2.27 years if implement works for 200 h/y with operation cost of Rs. 132 per hour.

Table 1: Results obtained during field evaluation of developed planter

Parameters	GG-5 Garlic
Miss index, %	4.21
Multiple index, %	6.20
Quality of feed index, %	89.59
Seed rate, kg/ha	443
Mechanical clove damage, %	5.70
Theoretical field capacity, ha/h	0.41
Effective field capacity, ha/h	0.32
Field efficiency, ha/h	79.02
Cost of operation, Rs./ha	1677.67

3.5 Comparative Study of Operation Cost of Different Methods for Garlic Planting

The cost of manual hand dibbling of garlic was Rs. 5200 per

hectare and garlic planting by manual garlic planter and self-propelled garlic planter was Rs. 3604 and 2321 per hectare. It was observed that cost of garlic planting by developed garlic clove planter is Rs. 1677.67 per hectare, which is 3 times less than manual planting, 2 times less than planting by manual garlic planter and approx. 1.5 times less than planting by self-propelled garlic clove planter. Comparison of different method of planting of garlic cloves is given in Table 2. Figure 3 & 4 shows the comparison of field capacity and cost of operation of different methods for garlic planting respectively.

Table 2: Comparison of operational cost of different methods of garlic planting

Method of Planting	AFC, ha/h	Labour required	Cost, Rs.	
			Per hour	Per ha
Tractor operated garlic planter	0.32	1	553.63	1677.67
[1]Self-propelled garlic planter	0.065	2	150.90	2321.00*
[2]Manual garlic planter	0.015	2 + 3	54.06	3604.00*
[1]Manual by hand dibbling	0.0019	65	10.00	5200.00*

*Excluding cost of bed formation (Nare *et. al*., 2014) [1]

The cost required for bed formation before planting was 522.43 Rs./h. In case of existing planters such as manual garlic planter, self-propelled planter, manual dibbling method the cost of bed formation also added with planting operation. But in case of developed planter the bed former is attached with itself, so bed formation and planting both operations could simultaneously done. It will result the reduction in cost of operation as compared to the other planters.

From figure 3 it is observed that the actual field capacity of developed tractor operated garlic planter is highest than other three planters and it is 0.32. From figure 4 it is observed that the cost operation of developed planter is least as compare to other planters and highest in case of manual dibbling due to more labour requirement for the planting operation.

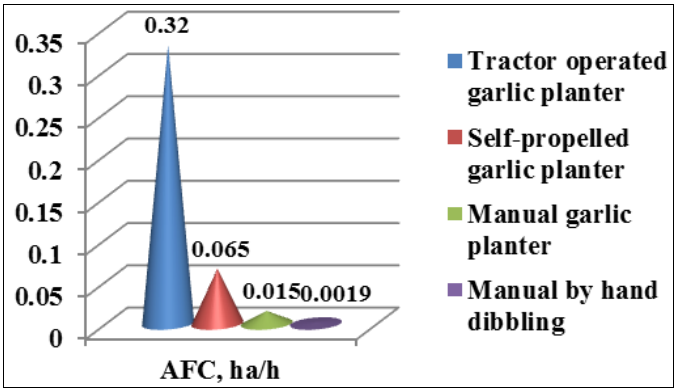

Fig 3: Actual field capacity for planting by different garlic planters

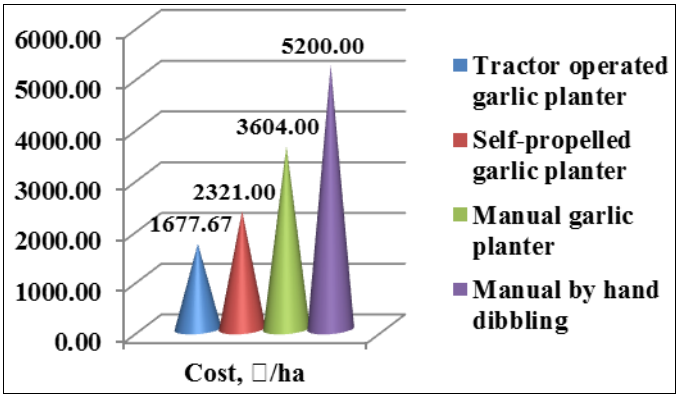

Fig 4: Cost of operation for planting by different garlic planters

4. Conclusion

The machine was tested in well prepared test plot and following conclusions were obtained. The quality of feed index was found 96.35 %. The effective field capacity of tractor operated garlic clove planter was 0.32 ha/h and it was about 4.92 times of self-propelled garlic planter, 21 times of manual planter and 168 times of manual dibbling methods. The field efficiency of developed garlic clove planter was 79.02 %. The cost of planting by developed prototype planter with operational cost of tractor was Rs. 1677.67 per hectare, which was 1.5, 2 and 3 times less as compared to self-propelled garlic planter Rs. 2321.00 per hectare, manually operated garlic planter Rs. 3604.00 per hectare and manual by hand dibbling Rs. 5200.00 per hectare respectively. The payback period and B:C ratio of developed garlic clove planter was 5.05 years and 1.98, respectively. The developed machine was minimizing the cost of cultivation due to multiple operations such as bed formation, planting and fertilizer application simultaneously with single machine. It was concluded that the developed tractor operated garlic (*Allium sat*ivum L.) clove planter for garlic planting shows better result with less miss and multiple index with high quality of feed index.

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