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Performance Evaluation of Tractor Operated Garlic (*Allium sativum* L.) Clove Planter

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ABSTRACT

Garlic (*Allium sativum* L.) is an important foreign exchange earner for India. The farmers generally plant garlic by manual method, which is labour intensive and time consuming. A tractor-operated garlic clove planter was developed and evaluated for its performance in the field. The average wheel slip, draft and average depth of seed placement by the developed planter were 6.93 %, 289.83 kg, and 42.1 mm, respectively. The average seed spacing, miss index, multiple index, quality of feed index, seed rate and seed metering efficiency for GG-4 and GG-5 garlic varieties were 99.4 mm, 6.12 %, 7.91 %, 85.96 %, 377 kg.ha^{-1}; and 96.35 % and 99.9 mm, 4.58 %, 6.07 %, 89.34 %, 443 kg.ha^{-1}, and 96.75 %, respectively during field tests. The effective field capacity and field efficiency of the developed planter were 0.33 ha.h^{-1} and 80.33; 0.32 ha.h^{-1} and 79.02 %, respectively, for GG-4 and GG-5 garlic seeds. The cost of planting by the developed planter with operational cost of tractor was ₹ 553.63 per hour (₹ 1677.67 per ha), and was less as compared to available planting machineries for garlic.

Indian agriculture continues to face the problem of labour shortage. In order to overcome such problem, adoption of appropriate technological interventions in existing agricultural practices are required. Appropriate technologies of farm mechanization with improvement in existing designs, newer materials and production techniques will cater the needs of farms (Manian *et al.,* 2002; Zilpilwar *et al*., 2020).

Garlic is an important bulb crop cultivating in India, and using as spice or condiment, culinary and medicinal purposes. India, although ranks second in area and production, the productivity is very low (5.76 t.ha^{-1}) (Anon, 2016). It is a frost-tolerant crop, and requires cool and moist climate during the growth period, and warm climate during maturity. It is usually cultivating in well-drained fertile loamy soil. The critical day length required for bulb formation is 12 hours. The main purpose of planting is to place the seed in soil at specified spacings at desired depth in the soil (Sahoo and Srivastva, 2000; Karay *et al.,* 2006; Hijam *et al*., 2014; Barik, 2014). Among the various farm operations, sowing and planting of seed is one of the crucial operations in crop production, but still farmers are using manual method of planting due to lack of mechanical interventions.

Rocha *et al.* (1991) designed and developed a manually operated garlic planter mounted on two bicycle wheels and equipped with a toothed belt distribution mechanism. The toothed rubber belt was equipped with sponge teeth 25 × 47 mm and 25 mm high. In field tests of the prototype, bulbs were spaced at 5 bulbs per meter. Garg and Dixit (2003) developed and evaluated the performance of a single row manually operated garlic planter. It could be operated by 2 persons and another helper for filling the hopper on the go. The field capacity of the machine varied from 0.03 - 0.04 ha.h^{-1}. It was labour-saving equipment requiring approximately 83 man-h.ha^{-1} in comparison to approximately 520 man-h.ha^{-1} in manual dibbling method.

Masoumi (2004) developed a roller-type metering device for a laboratory prototype of single row garlic planter consisting of a seed hopper, a vertical roller-type seed plate driven by an electric motor and a seed counter. Laboratory tests were conducted to investigate the effects of roller speed and size of seed cavities (cells) on the percentage of seed singulation and cell filling performance.

Singh *et al.* (2005) defined precision planting as the placement of single seeds in the soil at the desired plant spacing with the sowing devices equipped with single seed metering devices. Bakhtiari and Loghavi (2009) developed and evaluated an innovative garlic clove precision planter. The performance parameters as planting depth, seeding rate, seed spacing, miss index, multiple indexes, and clove damage were measured. Desirable plant spacing and density could be obtained by either increasing the number of seed holes around the metering drum or increasing the rotational speed of the metering drum relative to the ground wheel.

A tractor-operated garlic planter was developed under the AICRP Farm Implements and Machinery, at CTAE, MPUAT, Udaipur (Anon, 2013). It was provided with plastic roller with six blades (like an open impeller of centrifugal pump) seed and fertilizer metering mechanism. The two-row paired hopper and adjustable seed rate were the main features of the 15-row unit with minimum row spacing of 150 mm. The observed seed rate was 550-600 $kg.ha^{-1}$ with a local variety of garlic, and 850-900 $kg.ha^{-1}$ with a Coimbatore variety of garlic. The field capacity, field efficiency, and cost of planting were 0.51 $ha.h^{-1}$, 77 % and ₹ 1,000 per ha, respectively.

Nare *et al.* (2014) designed and developed a self-propelled garlic clove planter. Spoon- type metering mechanism was used for precision metering of garlic clove. The seed rate of garlic varied from 400-550 $kg.ha^{-1}$, and fertilizer rate was 150-200 $kg.ha^{-1}$ with 100 mm×150 mm spacing. The missing index, multiple index, seed damage, actual field capacity and field efficiency of the garlic planter were 2.67 %, 8.0 %, 1.46 %, 0.065 $ha.h^{-1}$, and 79.84 %, respectively. The operating cost of the machine was 151 $₹.h^{-1}$. Barik *et al*., (2016) developed a petrol engine (2.65 kW) garlic planter with cup-type and inclined plate type metering mechanism. The field capacity of the planter was 0.09 $ha.h^{-1}$ and field efficiency of 77.7 % at operational speed of 1.5 $km.h^{-1}$.

The farmers are generally sowing garlic by manual method, which is highly labour intensive and time-consuming, resulting in increased cost of cultivation. So, there was a need to develop a simple machine that can overcome the difficulty of garlic sowing and reduce the labour requirement, time and cost of planting. Due to intensive work and higher wage rate, the garlic cultivation is discouraged by farmers day by day, and hence, area also being reduced (Khamble *et al*., 2013; Borker *et al*., 2018). To overcome such circumstances, there was a necessity to mechanize the planting techniques for the farmers. Though manually operated, self-propelled machines are available, but they are not so popular among the farmers due to low field capacity. Hence, to minimize the cost of cultivation, a study was taken to develop a tractor-operated garlic clove planter that would be useful for garlic cultivation with higher field capacity, field efficiency and less human drudgery as compared to manual planter.

MATERIALS AND METHODS

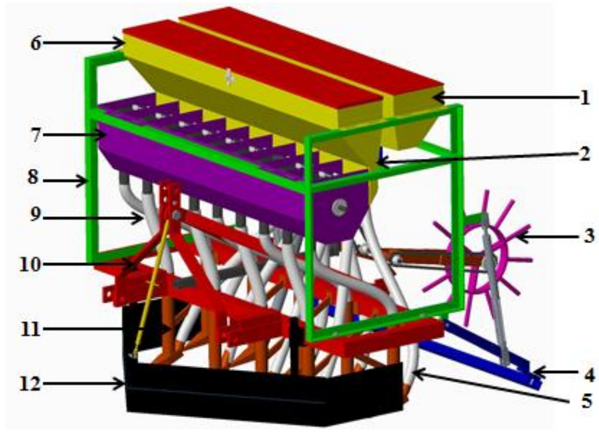
Tractor-operated Garlic Clove Planter

A tractor-operated garlic (*Allium sativum* L.) clove planter was fabricated in the workshop of the Department of Farm Machinery and Power Engineering, JAU, Junagadh. The design of machine components was based on the principle of operation, available power source, and soil condition. Figure 1 shows the isometric view of conceptual design of the garlic clove planter. Isometric views of metering roller and funnel are shown in Fig. 2. The different components of the prototype garlic clove planter consisted of a seed and fertilizer hopper, delivery tubes, main frame, seed and fertilizer metering unit and frame, power transmission unit, furrow opener, and bed former. Side view of the developed garlic planter is shown in Fig. 3. Technical specification of the developed garlic planter is given in Table 1.

Laboratory Evaluation

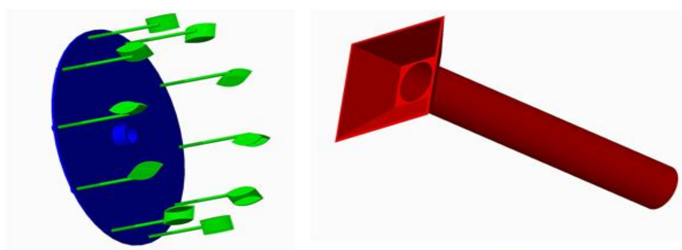
The metering mechanism was tested in a soil bin of rectangular size (16500 mm × 2000 mm × 1500 mm). The soil bin consisted of a tool carrier (1000 mm× 1000 mm × 1000 mm), and a rope drum unit of drum (diameter: 140 mm, length: 575 mm). The tool carrier was driven by 15 kW, 3 phase, variable speed electric motor.

The metering mechanism was tested in the laboratory with three different sizes of metering spoon (10 %, 20 %, 30 % more than maximum clove dimension of 26.27 mm×11.95 mm×10.24 mm), and at three levels of forward speeds (2.5 $km.h^{-1}$, 3.0 $km.h^{-1}$,



1. Fertilizer hopper
2. Fertilizer metering box
3. Ground wheel
4. Covering Device
5. Fertilizer tube
6. Seed hopper
7. Seed metering box
8. Frame
9. Seed tube
10. Three point linkage
11. Furrow opener
12. Bed former

Fig. 1: Isometric view of conceptual design of garlic clove planter



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1. Metering roller with spoon
2. Funnel

Fig. 2: Isometric view of seed metering roller and funnel

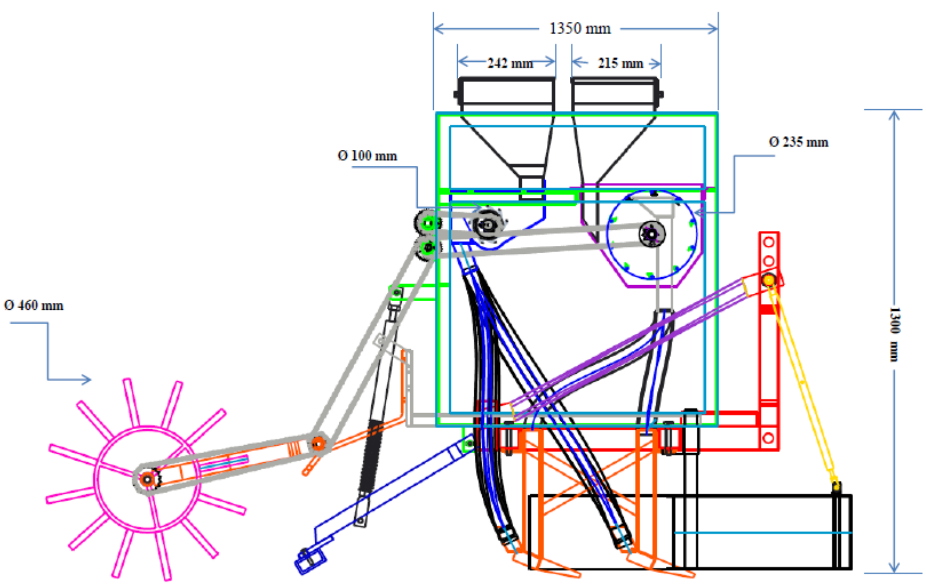


Fig. 3: Side view of developed garlic clove planter

Table 1: Technical specifications of developed garlic clove planter

Sl. No.	Particular	Specifications
1.	Power source	Tractor (26 kW)
2.	Overall dimensions	
	Length	1600 mm
	Width	1350 mm
	Height	1300 mm
3.	Hitch	
	System	Three-point hitch (Cat – II for 35 hp tractor); Extended out from main frame
	Material of fabrication	Hitch – MS flat (50 mm × 10 mm) Hitch base – MS square pipe (50 mm × 5 mm)
	Dimension	IS 4468 (Part 2) : 1993
4.	Hopper	
	Seed hopper	MS sheet (c/s 215 mm × 160 mm ×40 mm), length - 1350 mm
	Fertilizer hopper	MS sheet (c/s 242 mm × 128 mm × 65 mm), length - 1350 mm
5.	Frame	
	Frame for seed and fertilizer hopper	
	Material of fabrication	MS square pipe (50 mm×5 mm)
	Dimension(length × width × height)	1450 mm × 730 mm × 820 mm
	Frame for 3-point linkage	
	Material of fabrication	MS square pipe (50 mm×5 mm)
	Dimension (length × width)	1600 mm × 480 mm
6.	Seed metering unit	
	Mechanism	Spoon type metering mechanism
	No. of spoon	10
	Material of fabrication	MS sheet (16 gauge)for metering box and seed hopper box; MS flat for metering roller
	No. of units	9
	Overall length	1350 mm
	Overall width	320 mm
	Overall height	270 mm
	Metering roller	235 mm diameter; 3 mm thickness; 26 mm diameter and 4 mm thickness boss
	Spacing between rows	150 mm
7.	Fertilizer metering unit	
	Mechanism	Edge cell feed type metering rotor
	Material	Polyethylene
	No. of grooves	10
	Overall dimension	100 mm diameter, 26 mm thickness
8.	Power transmission unit	
	Transmission system	Ground wheel
	Transmission ratio	1.5 : 1
	Ground wheel	MS flat (45 mm × 5 mm); 460 mm overall diameter with pegs of 60 mm length; 12 pegs and 30 mm diameter hub
	Ground wheel shaft	16 mm round rod; 190 mm length
	Intermediate shaft	16 mm round rod; 320 mm length
	Main shaft	16 mm round rod; 560 mm length
	Seed metering shaft	16 mm round rod; 1500 mm length
	Fertilizer metering shaft	16 mm round rod; 620 mm length
	Ground wheel sprocket	18 teeth (Mount on intermediate shaft)
	Intermediate & main shaft sprocket	12 teeth sprocket
9.	Tines and furrow opener	
	Type	Shoe type
	Furrow opener	MS pipe (50 mm × 5 mm); length 387 mm; 70 mm × 54 mm × 34 mm rectangular cross section and 74 mm × 54 mm × 34 mm triangular cross section
	Boot	Hollow round pipe (38 mm × 3 mm)
	No. of furrow opener and boot	9
10.	Bed former	Mild steel sheet, 1500 mm × 790 mm × 195 mm
11.	Seed outlet and seed conveyer tube	
	Seed outlet (Funnel)	MS sheet (16 gauge)
	Conveyer tube	Polyethylene material: 40 mm × 3 mm
12.	Seed covering unit	
	Arms	MS flat (50 mm × 38 mm); length - 500 mm
	Spring (extension spring)	Spring steel; tension adjustable; free length - 250 mm; 200 mm active coil length
	Seed covering channel	MS channel: 80 mm × 40 mm; length - 1450 mm

3.5 km.h^{-1}). As per the results of laboratory test for different performance parameters (average seed spacing, miss index, multiple index, quality of feed index, seed rate) spoon size of 10 % more than maximum clove dimension was selected for developing the metering mechanism of the prototype planter. The spoons were fixed over the periphery of a vertical metering roller.

Design of Experiment

A complete randomize design was used at 5 % level of significance for statistical analysis in MS Excel for observed data of different performance parameters during field testing.

Field Evaluation

The planter was first calibrated in the laboratory for checking of variations in the amount of clove and fertilizer delivery among the nine furrow openers, and then evaluated for its performance in the field. A 26 kW tractor was used to operate the prototype planter during field testing. The planter was tested in the field as per methods given below. Figure 4 shows the field testing of the tractor-operated garlic clove planter.

Calibration of planter

Calibration was carried out for the determination of seed rate to be delivered by the planter, and the variations in seed metered among the furrow openers prior to field testing. The implement was kept on a levelled floor. An indication mark was made on the ground wheel for counting the ground wheel rotation. The ground wheel was fixed in such a way that it maintained some clearance from the ground. Polythene bags were tied to the boot of all nine furrow openers. Hoppers were filled with seeds and fertilizer, and then the ground wheel was rotated 15 times with an approximate forward speed. The seeds and fertilizer discharged from the tube were collected and weighed by digital weigh balance to determine the seed rate and fertilizer requirement.

Soil Parameters

Soil moisture content

Moisture contents of the soil samples were determined by standard oven dry method. An auger was used for taking soil sample at depth of 150 mm. The soil sample was kept in closed metallic box, and weighed using a digital weighing balance. The sample was kept at 105 ± 5 ^{0}C for 24 h in the oven, later the sample was removed from the oven and weight of dry soil sample was taken.

The average moisture content was determined on dry basis.

$$\text{Moisture content (d.b.)\%} = \frac{W_w - W_d}{W_d} \times 100 \quad \ldots(1)$$

Where,

W_w = Weight of wet soil, g, and

W_d = Weight of dry soil, g.

Soil bulk density of the soil

A metallic core cylinder of 54 mm diameter and 88 mm long was used to take sample from the field. The metallic core was pressed up to 150 mm depth.

Bulk density, ratio of dry weight of the soil to the volume, was determined as:

$$\text{Bulk density of soil (kg.m}^{-3}\text{)} = \frac{W - \left(\frac{W \times MC}{100}\right)}{V} \quad \ldots(2)$$

Fig. 4: Field test of garlic clove planter

Where,
W = Weight of moist soil collected, kg,
V = Volume of metallic core, m^3, and
MC = Moisture content of soil, %.

Operating Parameters

The following operating parameters of the planter were measured using the methods mention by Mehta *et al*. (1995).

Operating speed

Forward speed of the tractor with the planter was calculated by measuring the productive time (t_p) taken to travel 30 m length of plot.

$$V_t = \frac{d}{t_p} \quad \ldots(3)$$

Where,
V_t = Forward speed, $m.s^{-1}$,
D = Distance, m, and
t_p = Productive time, s.

Width of coverage

The width of coverage was determined by measuring the horizontal distance covered by the planter during planting operation using a measuring tape.

Depth of seed placement

The vertical depth of seed placement was measured with the help of measuring scale. Average of ten observations of depth of seed placement in furrows was considered.

Tractor wheel slip

Tractor wheel slip was measured by making a mark on the tractor drive wheel with coloured tape. The distances covered in 10 revolutions without load (D_1) and with load (D_2) were measured under same field condition.

Percentage slip was calculated by using the following equation:

$$\text{Wheel slip (\%)} = \frac{(D_1 - D_2)}{D_1} \times 100 \quad \ldots(4)$$

Where,
D_1 = Distance covered in 10 revolution of tractor drive wheel without load, m, and
D_2 = Distance covered in 10 revolution of tractor drive wheel with load, m.

Fuel consumption

Fuel consumption of the tractor operating the garlic clove planter was measured as per the standard prescribed method. A measuring cylinder was attached in between the fuel tank and the engine. The time of operation by the tractor in one litre of fuel was recorded. This process was repeated three times. Fuel consumption was determined by dividing the fuel consumed to the time of operation.

Draft of implement

A S–type load cell of standard full scale range (0-2000 kg) having nominal sensitivity of 2 mV/v, and made up of stainless steel, operating temperature (-)20 to 70 was attached in between two tractors. The load cell was connected to a data logger for recording the observations on load. The first tractor pulled the second tractor to which the garlic clove planter was attached. Planting operation was continued with the tractor to which the planter was attached in neutral condition. Draft of implement was measured during travel of 30 m distance. The draft (load) of the implement was recorded with data logger.

The planter was lifted off ground with 3-point linkage of the tractor in the same field, and the draft was recorded following the same procedure. The difference between the two values gave the draft required to operate the garlic clove planter under field condition.

Performance Parameters

The performance parameters of the planter were determined using the following methodologies as per the test codes for tractor operated equipment (ISO, 1984; BIS, 1993).

Selection of independent variables

The ultimate aim of planting was to maintain the singularity of seeds while placing them precisely at recommended spacing and depth without any missing or seed damage. The seed metering performance of the planter is dependent on forward speed of metering unit, speed of metering roller, size and number of spoon/cell and height of seed dropping (Hunt, 2001; Singh *et al.,* 2005; Findura *et al.,* 2008; Sharma and Kumar, 2014; Sahu and Verma, 2016). The selected variables (Table 2) were taken as testing parameters for precision seeding, because they play a comparatively more significant role in seed placement among the above mentioned.

Table 2. Levels of independent variables selected for laboratory evaluation

Sl. No.	Independent variable	Level	Value
1.	Forward speed (V)	3 levels	
		2.5 km.h^{-1}	V_1
		3.0 km.h^{-1}	V_2
		3.5 km.h^{-1}	V_3
2.	Size of spoon (S)	3 levels	
		10 % more than maximum seed dimension	I_1
		20 % more than maximum seed dimension	I_2
		30 % more than maximum seed dimension	I_3
3.	Replications (R)	3 levels	3
4.	Total number of treatments	V x I	9
5.	Total number of treatment combinations	V × I × R	27

Selection of Dependent Variables

The dependent variables chosen for the laboratory evaluation were average seed spacing, missing index, multiple index, quality of feed index, seed rate, and seed metering efficiency. These dependent variables were worked out for all treatment combinations of independent variables.

Average seed spacing

Average seed spacing (S) indicates the average value of spacing measured between two consecutive seeds in a row. It was measured using a standard measuring scale.

Average seed spacing was determined as:

$$S = \frac{\sum S_a}{N} \quad \ldots(5)$$

Where,
S_a = Actual spacing between two consecutive seeds in a row, mm, and
N = Total number of observations.

Miss index (MI)

Skips or misses are created when spoon fails to pick up and deliver seeds to the funnel with seed tubes. Missing percentages is presented by miss index (MI), which is the percentage of spacing greater than 1.5 times the recommended spacing (100 mm for garlic). Smaller values of MI indicate better performance (Bakhtiari and Loghavi, 2009).

Miss index (MI) is expressed as:

$$MI = \frac{n_1}{N} \quad \ldots(6)$$

Where,
n_1 = Number of spacing in the region times of recommended spacing, and
N = Total number of observations.

Multiple index (DI)

Multiples are created when more than one seed is delivered by a spoon. The multiples percentage is represented by multiple index (DI) which is the percentage of spacing that are less than or equal to half of the recommended spacing (100 mm for garlic). It is the ratio of number of spacing in the region times of recommended spacing in the single row to the total number of observations in that row. Smaller values of DI indicate better performance (Singh *et al.*, 2005).

Multiple index (DI) is expressed as:

$$DI = \frac{n_2}{N} \quad \ldots(7)$$

Where,
n_2 = Number of spacings in the region times of recommended spacing, and
N = Total number of observations.

Quality of feed index (QFI)

In order to achieve the desired seed rate in a 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 the following expression (Singh *et al.*, 2005):

$$\mathrm{QFI} = \frac{n_3}{N} \quad \ldots(8)$$

Where,

n_3 = Number of spacing in between 0.5 time of theoretical spacing and 1.5 time of the theoretical spacing, and

N = Total number of observations.

Seed rate

Seed rate indicates the actual sowing capacity of a metering mechanism. Seed rate of the metering unit was calculated by using the following formula:

$$\mathrm{SR} = \frac{N_C \times W}{l \times b} \times 10 \quad \ldots(9)$$

Where,

SR = Seed rate, kg.ha^{-1},

N_C = Number of seeds collected during a length of run,

W = Thousand seed weight, kg,

l = Length of run, m, and

b = Nominal row-to-row spacing of the crop, m.

Seed metering efficiency

Germination of selected garlic clove samples were carried out in the laboratory. The numbers of germinated cloves per unit area in the laboratory were considered as the expected number of seed to germinate per unit area (G_e) in the field for determination of seed metering efficiency. A 1000 mm × 1000 mm area was prepared for garlic plantation in the laboratory. Garlic clove samples were planted at a clove-to-clove spacings of 100 mm. Watering was carried out at required intervals, and daily observation of germination was noted.

Seed metering efficiency was calculated by using the following equation:

$$\eta_m = \frac{G_a}{G_e} \times 100 \quad \ldots(10)$$

Where,

η_m = Seed metering efficiency, %,

G_a = Actual number of seeds germinated per unit area in the field, and

G_e = Expected number of seeds to be germinated per unit area in the field.

Seed metering efficiency (η_m) of the planting system was calculated on the basis of actual percentage of germination in the field.

Field capacity

Theoretical field capacity is the rate of field coverage that would be achieved if the planter was operated continuously without interruption like turning at the ends and filling of hopper (Pabitra, 2014).

$$FC_t = \frac{W \times S}{10} \quad \ldots(11)$$

Where,

FC_t = Theoretical field capacity, ha.h^{-1},

W = Width of coverage, m, and

S = Speed of operation, km.h^{-1}.

Effective field capacity is the actual average rate of field coverage by the machine, based upon the total field time, and is given as:

$$FC_a = \frac{\text{Area of plot } (m^2) \times 0.36}{\text{Time taken } (s)} \quad \ldots(12)$$

Where,

FC_a = Effective field capacity, ha.h^{-1}.

Field efficiency

Field efficiency was calculated by using the following formula (Kepner *et al.*, 2005):

$$FE = \frac{FC_a}{FC_t} \times 100 \quad \ldots(13)$$

Where,

FE = Field efficiency, %,

FC_a = Effective field capacity, ha.h^{-1}, and

FC_t = Theoretical field capacity, ha.h^{-1}.

Field performance index

Field performance index of the planter was calculated by using the following formula (Lal and Datta, 2011):

$$\eta_f = \frac{T_e}{T_e + T_h + T_a} \times 100 \quad \ldots(14)$$

Where,

η_f = Field performance index, %,

T_e = Time required theoretically to cover one ha area, s,

T_h = Time lost due to interruption which is not proportional to area like time of filling, s, and
Ta = Time lost due to interruption which is proportional to area like time of turning, s.

Data Analysis

Statistical analysis of observed data of performance parameters during field testing of the planter were carried out at 5 % significance level.

Cost Economics

Cost analysis was made for estimating the cost of different operations such as soil preparation, bed formation, planting, fertilizer application, etc. for garlic cultivation. 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). Comparison of cost economics of planting operation by different planters and planting methods are given in Table 5. Manual garlic planter and manual garlic planting methods had been used by the farmers. Nowadays, self-propelled garlic planter developed by some researchers (Nare *et al.,* 2014) are in use, and were thus selected for comparison.

Facts and assumptions made for economic analysis:

Initial cost of planter, C	₹ 60,000
Life of tractor, L	10 years
Average annual use of tractor, H	200 h per year
Interest rate per year, i	12 %
Salvage value, S	10 % of C
Taxes, housing and Insurance per year, M	3 % of C
Repair and maintenance, R (Hunt, 2001)	10 % of C

RESULTS AND DISCUSSION

Field testing of the prototype garlic planter was done to find out the consequences of the effect of forward speed (V) on average seed spacing, miss index, multiple index, quality feed index and seed metering efficiency. The economics of developed planter was workout.

Field Evaluation of Developed Planter

The field evaluation was conducted during the month of February, 2019 in the research farm of the Department of Soil and Water Conservation Engineering, Junagadh Agricultural University, Junagadh.

Field parameter and crop details

A plot of 1,152 m^2 flat area of medium black soil was selected for the experiment. Three plots of size 30 m × 6.4 m were used for sowing each variety of seed. The moisture content and bulk density of soil was 16.63 % (d.b.) and 1290 kg m^{-3} at the time of field testing of the planter.

Two Gujarat garlic varieties (GG-4, GG-5) were selected for planting. Physical properties of the selected garlic varieties were determined prior to development of metering mechanism. The physical properties (L × W × T), sphericity, 1000-seed weight, angle of repose, and bulk density were 26.26 × 11.82 × 10.32 mm, 0.54, 0.544 kg, 38.16°, 497.82 kg.m^{-3}, respectively, for GG – 4 garlic variety; and 28.28 × 12.81 × 10.96 mm, 0.55, 0.667 kg, 37.19°, 529.71 kg.m^{-3} for GG-5 garlic variety, respectively (Zilpilwar *et al*., 2019).

The plant-to-plant and row-to-row spacing were maintained at 100 mm and 150 mm, respectively, as per the recommended cultivation practices (Nare *et al.*, 2014). Planting of garlic by others methods (manually operated garlic planter and manual dibbling method) were also carried out in the same test plot.

Operating parameters

The developed garlic clove planter had working width of 1.68 ± 0.08 m. The average value of depth of clove placement was 42.1 ± 0.4 mm. The average forward speed was maintained at 2.59 km.h^{-1}. Tractor wheel slip of the 2WD tractor was determined as 6.93 per cent. It was found that the rear wheel slip depended on the soil moisture content, and it was less when soil moisture content was less during field operation. The fuel consumption of the tractor during planting operation by the garlic clove planter was 3.04 ± 0.08 l.h^{-1}. The draft required to operate the garlic clove planter was 289.83 ± 6.93 kg. In comparison to other field operations such as ploughing and harrowing performed by the tractor, the draft for planting operation was less, which might be due to lesser depth of seed placement.

Performance parameter

The results of analysis of the performance parameter are given in Table 3, 4 for GG-4 and GG-5 garlic varieties, respectively. Figure 5 shows the germination of GG 4 and GG 5 garlic in field after 15 days of planting.

Average seed spacing

The forward speed showed significant effect on average seed spacing of both garlic varieties at 5 % significance level (Table 3, 4). Figure 6 shows that as the forward speed increased, the average seed spacing increased. The coefficients of variation were 1.43 % for GG 4 and 1.20 % for GG-5 garlic variety. The observed average seed spacing in field for GG-4 and GG-5 garlic variety were 994 mm and 999 mm, respectively, at forward speed of 2.5 km.h^{-1}.

Miss index

The forward speed of the tractor had significant effect on miss index of both garlic varieties at 5 % significance level (Table 3, 4). As the forward speed increased, miss index increased because of insufficient time available to a spoon for picking of clove from the hopper. Moreover, increase in forward speed increased machine vibration

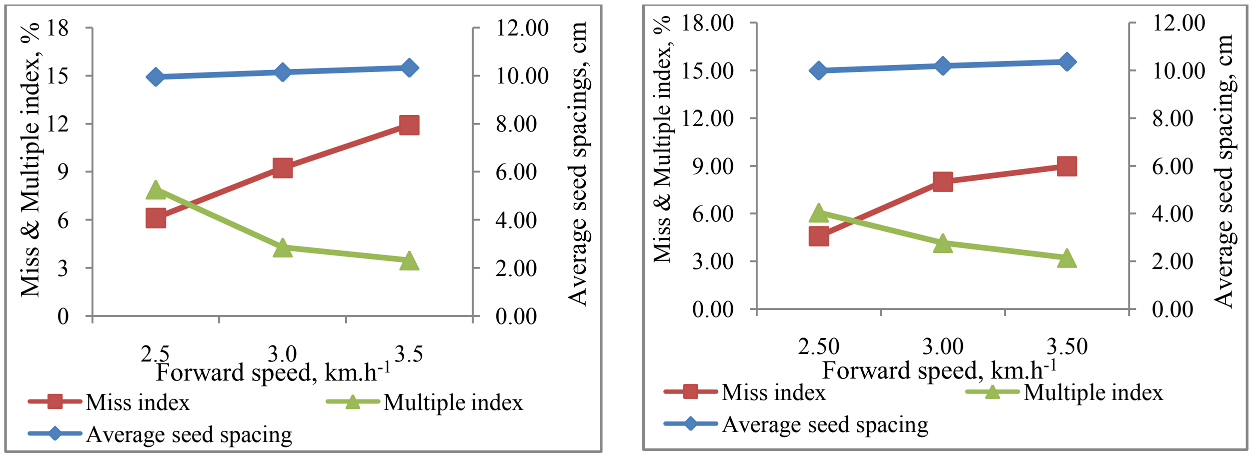
Table 3. Performance results of tractor-operated garlic clove planter using GG – 4 garlic variety

Sl. No.	Parameter	Mean	Range	SD, %	S.Em±	CD at 5 %	CV, %
1.	Average seed spacing, mm	101.4	99.4 – 103.3	0.193	0.084	0.290	1.433
2.	Miss index, %	9.09	6.12 – 11.62	2.896	0.103	0.356	1.961
3.	Multiple index, %	6.18	4.87 – 7.91	1.566	0.176	0.608	4.928
4.	Quality of feed index, %	84.73	83.22 – 85.96	1.393	0.157	0.542	0.320
5.	Seed rate, kg.ha^{-1}	360	341 - 377	17.947	5.182	17.932	2.491

Table 4. Performance results of tractor-operated garlic clove planter using GG – 5 garlic variety

Sl. No.	Parameter	Mean	Range	SD, %	S.Em±	CD at 5 %	CV, %
1.	Average seed spacing, mm	101.8	99.9 – 103.6	0.182	0.071	0.244	1.200
2.	Miss index, %	7.21	4.58 – 8.97	0.108	0.203	0.702	4.874
3.	Multiple index, %	4.49	3.22 – 6.07	1.454	0.113	0.392	4.368
4.	Quality of feed index, %	88.30	87.81 – 89.35	0.903	0.202	0.698	0.395
5.	Seed rate, kg.ha^{-1}	429	417 - 443	13.204	5.375	18.600	2.170

Fig. 5: Germination of GG 4 and GG 5 garlic under field condition



GG-4 GG-5

Fig. 6: Effect of forward speed on average seed spacing, miss index, and multiple index of garlic clove during field test of tractor operated garlic clove planter

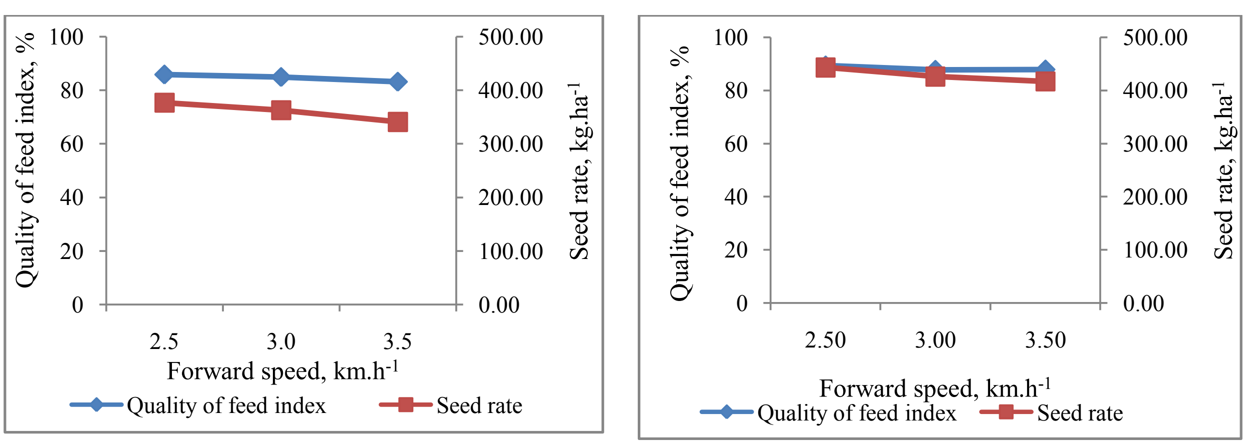
that caused random dropping of cloves inside the seed metering box from a metering spoon. The coefficients of variation were 1.96 % and 4.87 %, respectively, for GG-4 and GG-5 garlic variety. The observed miss index in field for GG-4 and GG-5 garlic variety were 6.12 % and 4.58 %, respectively, at forward speed 2.5 km.h^{-1}.

Multiple index

Multiples are created when more than one seed is delivered by a spoon. The forward speed of the planter showed significant effect on multiple index of both garlic varieties at 5 % significance level (Table 3, 4). It is also clear from Fig. 6 that as the forward speed increased, multiple index decreased. The coefficients of variation were 4.93 % and 4.37 %, respectively, for GG-4 and GG-5 garlic variety. The observed miss index in field for GG-4 was 7.91 % and 6.07 % for GG-5 garlic variety at forward speed 2.5 km.h^{-1}, and were similar to the results reported by Nare *et al*. (2014).

Quality of feed index

The forward speed of the planter showed significant effect on quality of feed index of both garlic varieties at 5 % significance level as given in Table 3, 4. Figure 7 shows that as the forward speed increased, the quality of feed index decreased as both miss index and multiple index had impact on the quality of feed index. The coefficients of variation were 0.32 % for GG 4 variety and 0.3954 % for GG-5 garlic variety. The observed quality of feed index in field for GG-4 and GG-5 garlic variety was 85.96 % and 89.34 %, respectively, at planter forward speed 2.5 km.h^{-1}; and were similar to the results reported by Nare *et al*. (2014).



GG-4 GG-5

Fig. 7: Effect of forward speed on quality of feed index and seed rate of garlic clove during field test of tractor operated garlic clove planter

Seed rate

Seed rate indicates the actual sowing capacity of a metering mechanism. The forward speed of the planter had significant effect on seed rate of both garlic varieties at 5 % significant level (Table 3, 4). It was observed from the Fig. 7 that as the forward speed increased, the seed rate decreased due to increase in miss index. The coefficients of variation were 2.49 % and 2.17 %, respectively, for GG-4 and GG-5 garlic variety. The average seed rates maintained by the planter were 360 $kg.ha^{-1}$ for GG-4 and 429 $kg.ha^{-1}$ for GG-5 garlic variety at forward speed of 2.5 $km.h^{-1}$, and were within 90-92 % of the recommended seed rate of 475-480 $kg.ha^{-1}$. The variation in seed rate was due to variation in clove weight of these two garlic varieties.

Seed metering efficiency

The seed metering efficiencies determined by comparing the germination percentage obtained from laboratory and field evaluation were 96.35 % and 96.75 % with respect to GG-4 and GG-5 garlic clove, respectively. The loss in germination was because of increment in mechanical damage and misplacement of seeds at inappropriate depth. This loss was observed in both laboratory and field testing.

Field capacity

The theoretical field capacity of the garlic clove planter was 0.41 $ha.h^{-1}$, similar to tractor operated garlic planter developed under the AICRP, FIM at CTAE, MPUAT Udaipur (Anon, 2013). The theoretical field capacity depends on the width of coverage and speed of operation.

The effective field capacity was 0.33 $ha.h^{-1}$ and 0.32 $ha.h^{-1}$ while planting GG-4 and GG-5 garlic variety, respectively. The field efficiency of the planter was found to be 80.33 % and 79.02 % for GG-4 and GG-5 garlic variety, respectively.

Field machine index

Field machine index was calculated by considering only productive time loss (turning loss, filling and refilling time loss). Field machine index of the developed planter was 82.22 % and 81.13 % for GG-4 and GG-5 garlic variety, respectively. It varied due to physical properties of the clove of the varieties.

Cost Economic

The cost of operation of the developed planter was ₹ 553.63 per hour (or ₹1677.67 per ha). Considering the custom hiring cost to be 25 % higher than the operation cost, the actual operational cost was estimated to be ₹ 692.04 per hour (or ₹ 2097.09 per ha). When used for providing custom hiring, the payback period of the implement was found to be 2.27 years with annual use of 200 h with operation cost of ₹ 132 per hour.

Comparative Study of Operation Cost of Different Methods for Garlic Planting

Bed formation is necessary in garlic cultivation for irrigation and for proper fulfilment of nutrient demands. Plating of garlic by self-propelled garlic planter, manual garlic planter and manual dibbling method required preparation of seed bed before planting. There is necessity of separate operation for fertilizer application. The developed garlic clove planter could simultaneously do bed formation, fertilizer application and planting operation by a single machine pass, which reduced the cost of cultivation (Zilpilwar, 2019).

The cost of manual hand dibbling of garlic was ₹ 5,200 per ha, and garlic planting by manual garlic planter and self-propelled garlic planter were ₹ 3,604 and ₹ 2,321 per ha, respectively (Table 5). It was observed that the cost of garlic planting by developed garlic clove planter was ₹ 1,678 per ha, which is 3 times less than manual planting, 2 times less than planting by manual garlic

Table 5. Comparison of operational cost of different methods of garlic planting

Sl. No.	Method of planting	AFC, $ha.h^{-1}$	Labour required	Cost	
				$₹.h^{-1}$	$₹.ha^{-1}$
1.	Tractor operated garlic planter	0.33	1	553.63	1677.67
2.	Self-propelled garlic planter	0.065	2	150.90	2321.00*
3.	Manual garlic planter	0.015	2 + 3	54.06	3604.00*
4.	Manual by hand dibbling	0.0019	65	10.00	5200.00*

*Note: AFC – Actual field capacity*Excluding cost of bed formation (Nare et al.,2014)* planter, and approximately 1.5 times less than planting by self-propelled garlic clove planter.

CONCLUSIONS

A tractor-operated nine-row garlic clove planter developed at the Department of Farm Machinery and Power Engineering, JAU, Junagadh was tested in a well-prepared test plot. The average tractor wheel slip during field testing of the planter was 6.93 % with draft and fuel consumption of 289.83 kg and 3.04 $l.h^{-1}$, respectively. The quality of feed index, seed rate, and seed metering efficiency were in the ranges of 85.96-96.35 %, 377-443 $kg.ha^{-1}$, and 96.35-96.75 %, respectively. The effective field capacity of the planter was 0.32-0.33 $ha.h^{-1}$, and was higher than some garlic clove planting methods. The field efficiency of the planter ranged between 80.33-82.22 per cent.

The cost of planting by the developed prototype planter was ₹ 1677.67 per ha, which was 1.5, 2 and 3 times less as compared to a self-propelled garlic planter (₹ 2,321per ha), manually operated garlic planter (₹ 3,604 per ha), and manual by hand dibbling (₹ 5,200 per ha), respectively. The developed planter could minimize the cost of operation by completing bed formation, planting and fertilizer application simultaneously in a single pass. It was concluded that, the developed tractor operated garlic clove planter showed better result in the ranges of 4.18 – 6.12 % miss index, and 6.07 – 7.91 % multiple index, with high quality of feed index.

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