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Performance Evaluation of a Push-Type Manually Operated Garlic Planter

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A B S T R A C T

Garlic is a spice crop grown throughout the world. It is used all over the world as a valuable condiment for foods. It is also known for remedy or medicine for various ailments and physiological disorders. India is second largest producer of garlic in the world. Garlic planting, as well as harvesting, is labour intensive operation. The labor requirement for planting is approximately, 520 man-h/ha. Most of the planting of garlic is done manually with the help of hand tools like khurpi. Commercially, it is sown by the Khera method. Garlic cultivation is limited due to excessive labor and time requirement as well as the high cost of planting. Therefore, low cost, lightweight, and precise garlic planter is the need of the hour. A push-type manually operated garlic planter was designed and developed. The developed planter was evaluated in the field conditions. The performance parameters like depth of planting, hill to hill spacing, number of seeds per hill, soil cover over the seed, missing hills, operating distance, operating time, operating speed, field capacity and seed rate were checked. The result of testing of the hill to hill spacing, depth of seed placement, number of seeds per hill, soil cover over the seed, missing hills, operating speed and field capacity were found 7.36 cm, 4.98 cm, 1.1, 4.98, 13.46%, 3.31 km/h, and 0.0367 ha/h respectively.

Introduction

Garlic belonging to the onion family, has long been recognized all over the world as a valuable condiment for foods. It is also popular for remedy or medicine for various ailments and physiological disorders. Besides, it has insecticidal, fungicidal and bactericidal properties too. Its regular use is known to lower the cholesterol and blood pressure in human body. Garlic has been cultivated for thousands of years; Central Asia is the prime place of its origin and the Mediterranean area is a secondary place. Its family is

*Amaryllidacea*e and botanical name is *Allum sativan Linn*. Fresh peeled garlic cloves (bulblets) have the following composition; moisture: 62.8%; protein: 6.3%; fat: 0.1%; mineral matter: 1.0%; fiber: 0.8%, carbohydrate: 29.0%; calcium: 0.03%; phosphorus: 0.31%; iron (Fe): 0.0001%; calorific value (food energy): 142 calories/100g; vit A: 0; nicotine acid:0.4 mg/100g: vit. C: 13 mg/100g (Pruthi, 2001). Garlic cannot withstand too hot or too cold weather; Short days are very favorable for the formation of bulbs. It can be grown well at an elevation of 1000-1500 m above the sea level. Time of planting for garlic in plane regions is September to November and in hilly regions from March to May (NIIR Board, 2004).

Garlic is grown commercially in over a dozen of states of India. The major garlic producing states in India are Madhya Pradesh, Gujarat, Uttar Pradesh and Rajasthan which produce about 80% of country's total output. In year 2014-15, the three major garlic growing states of India were Madhya Pradesh (60,000 ha), Rajasthan (45,000 ha) and Uttar Pradesh (37,200 ha). However, the highest productivity was shown by Punjab (12.16 t/ha), followed by West Bengal (11.94 t/ha) and Maharashtra (11.43 t/ha). The highest production was recorded for Madhya Pradesh (270,000 t), followed by Gujarat (250,000 t) and Rajasthan (218,400 t) (NHB, 2015; Malik *et al*., 2017).

In year 2015-16, the three major garlic growing states of India were Madhya Pradesh (80,000 ha), Rajasthan (69,100 ha) and Gujarat (40,600 ha). The highest production was recorded for Madhya Pradesh (450,000 t), followed by Rajasthan (377,490 t) and Gujarat (318,200 t) (NHB, 2016).

Traditionally, the garlic sowing is performed by khurpi or by dibbler. The seeds (cloves) are put in the holes made by khurpi and covered with a thin layer of soil. The garlic cloves are sown in well prepared soil at a depth of 5 cm with seed to seed spacing of 7.5 cm. Row-to-row spacing is kept at 10 to 15 cm.

In India, 140.3 million hectares is net sown area out this garlic is grown in 164860 hectares. In present situation, 62.96 percent farmers have less than four hectare plot. This implies that these farmers are unable to purchase costly power operated machinery and this is uneconomical too. Hence low cost and manual or animal operated machines have future scope (Mahajan and Gupta, 2011).

Garlic is sown on small scale with the help of khurpi and commercially sown by the khera (mala bansa) method. Man power requirement is very high for the garlic planting in traditional methods. It requires about 60-70 persons to sow one hectare in one day because row and plant spacing in garlic is very narrow, that is, 15 cm and 7.5 cm, respectively (Anonymous, 1998).

The sowing of garlic by traditional method is highly labor intensive. Due to requirement of high number of labor, crop sowing is delayed in most of the cases. The standard or required spacing between row-to-row and plant-to-plant and depth of planting is not uniform. In manual planting for larger areas, condition like soil moisture also change rapidly and it is not easy to hire the large number of labourers for the planting of garlic. Planting of garlic cloves in adverse condition will affect its germination which will ultimately affect the yield. Due to these reasons if the crop is delayed, the garlic will not fetch good price in the market.

A manually operated garlic planter has been developed by Garg and Dixit (2003). Two men are required one for pulling and another for supplying the seeds. This planter does not

have seed covering device, as such, the germination was not very good. It has also been reported that sowing depth is not uniform. The capacity of the seed hopper is only 3 kg due to which it requires frequent filling. On the same principle, Singh and Yadav (2000) also developed a manually operated garlic planter. During operation they found that the length of the machine was too much and it affected the stability of the machine. The main problem with this machine was that the seed metering mechanism did not meter the seed properly. The number of seed per hill varied from 0 to 6. The machine did not have row marker due to which there was too much variation in row to row spacing. Garlic is a cash crop which gives good profit to the farmers. To reduce the labour requirement for planting operation, it is necessary that the planters developed by Garg and Dixit (2003) as well as by Singh and Yadav (2000) be modified to make it acceptable to the farmers. With this view in mind, the planter was modified.

Materials and Methods

Considerations were made as a combined effect of seed morphology and machine operation. These factors are responsible for the performance of planter. The metering mechanism is depended on the morphology of the seed and seed germination depends on the quality of seed and mechanical damage during the plantation of seed. Therefore, the morphological properties were studied for the development of metering system. Five Kilograms of good quality garlic bulbs were purchased from the local market. The size of cloves can be defined as the maximum length, width and thickness. These measurements were made from a sample of 15 cloves and replicate fifty times. The measurement was done with the help of scale with an accuracy of ± 0.1 mm. The size, which is represented by length, width and thickness of garlic cloves, varies considerably.

Keeping in view the physical properties of garlic cloves, the components of garlic planter were designed and developed.

Seed box

The hopper should hold approximately 12 kg of the garlic cloves. This amount is assumed with view that the amount should not be too much to add excessive load on the operator or it should not be too small, which may require frequent filling.

The metering mechanism should be mounted inside the hopper towards the small side of partition created by baffle wall. The shape of hopper should be trapezoidal for proper installation of metering mechanism inside the hopper.

Hence, hopper bottom was selected to be of square shape having the sides of 20 cm. The angle of vertical side was kept at 75° for easy flow of cloves. The inclination is higher than the angle of repose of the garlic cloves (32°). A baffle wall was provided in side the hopper to create a partition at bottom in the ratio of 3:2. The smaller portion was used to install the occupied by metering mechanism and the larger portion for storing the garlic cloves.

Design of baffle wall was done according to space available in the hopper i.e. trapezoidal and dividing ratio for seed metering device and for storing garlic cloves. Baffle wall at the upper side was kept 32.8 cm long, inclined height 24.6 cm and at the bottom 10.0 cm. A hole was made of 35 cm diameter at the center of baffle wall. Design of seed metering covering sheet was also done according to space available inside seed box. The length of the sheet for covering the seed metering mechanism was selected as 38.0 cm and width 20.0 cm. The side view of the planter is shown in Fig. 1. The dimensions of seed box are also shown in Fig. 1.

Seed metering mechanism

For the designing of cup, the length of cup should be more than the maximum length of cloves. The width of cup should be more than the width of clove. The height of cup should be slightly less than the height of clove so that another clove cannot enter into the cup. As reported by Singh and Yadav (2000), the garlic cloves have length, width and thickness as 2.99 cm, 0.9 cm and 0.9 cm respectively. According to these dimensions of garlic cloves the size of the seed metering cups were selected. The length and width of cup was kept as 3.0 cm, and 1.0 cm respectively. The height of cup was selected as 0.5 cm (along the length) and 0.9 cm (along the width). The seed cup was fabricated with 1mm thick aluminum sheet. The CAD model of seed metering mechanism was prepared using AutoCAD and shown in Fig. 2.

The eight number cups were fixed over a disc at equal interval along the periphery. The disc of 20 cm diameter was fabricated with mild steel sheet of 4mm thickness.

Axle length (35 cm) and diameter (18 mm) were kept same as provided by Singh and Yadav (2000) as no problem was not reported about the axle. The diameter of hub for the seed-metering disk was kept 3.0 cm, which is same as earlier planter.

The seed box has been divided in two parts in the ratio of 3: 2 the smaller portion is used for mounting the seed-metering device.

A metal strip has been put with two sides of the seed box and baffle wall; It formed a trapezoidal shape that will work as funnel. In this manner the funnel was designed. The dimension of lower portion of the funnel is 4 cm x 4 cm to allow the garlic cloves to pass through it out any obstruction.

Seed tube

When a body falls freely downwards then the heavier part of the body tends to come down first and the lighter portion goes upward due to tube surface friction. Garlic cloves are thicker and heavier at base portion as compared to top portion. Instead of allowing the cloves to fall freely, if they slide along the tube, the chances would be better that they will fall upright in the furrow, which will help in early germination of the garlic cloves. For this reason, three strips of 0.5cm x 12cm x 0.5cm have been provided throughout the length of the tube. The length of seed tube was kept 15.5 cm, to take care of the ground clearance of the garlic planter, and the angle of inclination that is 30°. The strip has been provided for the reducing the kinetic energy, rolling force and to guide the garlic cloves. The width and thickness of the seed tube as 40 and 4 respectively.

Furrow openers

A shovel type of furrow opener was selected as by Singh and Yadav (2000) but slightly modified to reduce the friction forces, as it is cheap and simple in construction. The furrow opener mounted on the garlic planter should not make too narrow a furrow as it will hinder in the placement of the seed at proper depth. A wider furrow opener will require unnecessary more draft. Thus, width selected for this opener was reduced from 7.5 cm to 4.0 cm. The furrow opener was made in such a way that it could allow the seed to fall at 5 cm depth. It was made of tool steel having a carbon content of 0.7%. It was welded to a curved iron strip of 50 cm length, 2.5 cm width and 0.3 cm thickness. Ten holes were provided on the strip for depth adjustment as shown in Fig. 1. Another strip of same thickness and same number of holes was bolted at the top end of the first strip. In addition, other end of the second strip was

connected with the handle. To provide rigidity to the furrow opener, sank was connected with the hopper with a flat iron strip loop.

Power transmission system

To operate the metering mechanism power was taken from the rear wheels. For the transmission of power from the rear wheels to metering mechanism, two sprockets were provided and connected by means of a roller chain. It was assumed that the metering mechanism would have 8 cups, as more number of cups will create problem in proper filling. Accordingly, the speed ratio was calculated for 7 cm seed to seed spacing.

One front wheel and two rear wheels were provided in garlic planter. Rear wheels were provided to give stability to machine in stationary condition as well as for power transmission and to maintain uniform depth of furrow. Garlic planter is somewhat like a hand hoe. Diameters of front and rear wheels were selected to be 60 and 30 cm respectively. The size of front wheel was kept bigger than the rear wheels because the rolling resistance is lesser for large size wheels. Larger rear wheels, on which the seed hopper is mounted, will raise the height of the planter unnecessarily and it will create problem in the stability of the planter during operation.

Wheels were made up of flat iron strip of 2.5 cm width and 0.5 cm thickness. The length of iron strips for front and rear wheels was 188.5 cm and 94.25 cm respectively. Sixteen lugs of 2.5 cm length, 2.5 cm height and 0.3 cm thickness were welded on the periphery of every each rear wheel at an equal distance of 5.88 cm. This was done to make proper grip with the soil and to reduce the slippage. To strengthen the wheel, eight spokes welded at 11.77 and 23.56 cm on the inner side of rear and front wheels respectively. The other ends of the spokes were welded on the periphery of the hub. The mechanical clutch was provided for switching off or on the power supplied to seed metering device while turning in the field. The clutch lever is provided at right side of the handle and the clutch frog is mounted at the side of the seed box.

Frame and handle

A hollow steel pipe with an external diameter of 2.56 cm and 1 mm wall thickness was selected for making the handle. This pipe was selected, as it is easily available in the market, light in weight, cheaper in cost and strong enough to bear the load. One end of the handle was attached to the front wheel for proper guidance. In the middle, it was connected with an iron strip, which has five holes for adjustment of the handle to suit operators of different heights. At the other end of the handle a cross bar was mounted on both ends of which proper grips were provided to hold the planter. Two braces were provided for connecting hopper to the front wheel. Braces were made of iron strip having 2.5 cm width and 0.3 cm thickness.

Marker and covering device

Seed-covering device was provided for the covering garlic cloves with the soil at a certain depth. It was made of “Shisham” wood that was available in the workshop. The outer and mid diameter of the covering device was kept 50 mm and 30 mm respectively. A hole was provided of 20 mm diameter to mount it on a hallow pipe.

According to data available from the theoretical design, the drawing of all the parts was prepared with the help of AutoCAD 2006. CAD model and fabricated garlic planter is shown in Fig. 3. The developed planter was tested in laboratory as well as in field condition.

Idle running of the planter was done in the laboratory to check the working of all the parts. Once the working of the planter was found satisfactory in laboratory condition, it was operated in the field. In field trial it was observed that the garlic cloves were not flowing freely from the seed box to the seed metering mechanism. The hole provided for seed flow seemed to be too small. Its size was increased from 103cmx100cm to 150cmx100cm and an adjustable seed flow controlling metal sheet was also installed for controlling the flow of garlic cloves to the seed-metering device. This problem was not faced during the laboratory test. After enlarging the opening the planter was again checked in the field and was found that seed flow to the metering device was satisfactory.

A bed of sand measuring 3cmx10cmx10m was formed for allowing the cloves to fall on this belt. The cloves will remain in place after falling from the seed tube. The planter was operated after removing the furrow opener and covering device. The horizontal distance between two adjacent seeds was measured with the help of scale. This test was repeated several times to minimize the error.

The seedbed for the testing of the garlic planter was prepared with the help of spade and khurpi for field test. The field was divided in 5 equal size plots of 8mx3m. Type of soil in these plots was sandy loam and the moisture content of the soil at the time of testing was approximately 15%. For the performance evaluation of planter hill to hill spacing, depth of seed placement, number of seed per hill, soil cover over the seed, missing hills, time taken to plant the plots, row to row spacing and operating speed were measured.

Results and Discussion

The physical properties of the garlic cloves were determined for the design and selection of metering unit. It was observed that the variation in the length was from a minimum of 1.50 cm to a maximum of 3.30cm. The average length of the garlic cloves was 2.31 cm. It was also observed that 71.67% cloves were having a length between 1.9 and 2.9 cm. The range of garlic cloves width was 0.5cm to a maximum of 1.0 cm whereas, the mean width of garlic clove was 0.65cm. There was variation in thickness also which ranged from a minimum of 0.5cm to a maximum of 1.10 cm. The average thickness of the garlic clove was 0.67 cm. Hence it can be concluded that there is a considerable variation in length, width and thickness but considering the average value into account width and thickness were approximately the same. Thus, the size of garlic cloves was found to 2.31cmx0.65cmx0.67cm.

The developed garlic planter was tested in laboratory and field conditions. The data were statistically analyzed for hill to hill spacing, depth of planting, number of seeds per hill, soil cover over the seed, missing hills. The operating speed was also recorded.

The hill-to-hill distance varied from a minimum of 6.2 cm to a maximum of 8.20 cm. The average hill-to-hill spacing of each plot varied from a minimum of 7.00 cm to a maximum of 7.32 cm. The average hill-to-hill spacing was 7.36 cm as it is the average value of the mean of 450 readings. The variation in hill-to-hill spacing might have occurred due to the reason that the cloves can fall anywhere between the front and rear of the inner walls of the seed tube. As such, a maximum variation equal to the inner diameter of the seed tube can be a common feature another reason for variation in hill spacing could be due to variation in wheel slippage.

The depth of seed placement varied from a minimum of 3.9 cm to a maximum of 5.2 cm. The variation was in between ±10 percent

from the standard value of the depth of seed placement of 5.0 cm. It was seen that the maximum depth of seed placement was 5.2 cm as each individual data are the average of seven readings. The average depth of seed placement was 4.98 cm, which is very close to desired depth of 5 cm. It shows that depth of seed placement was highly satisfactory.

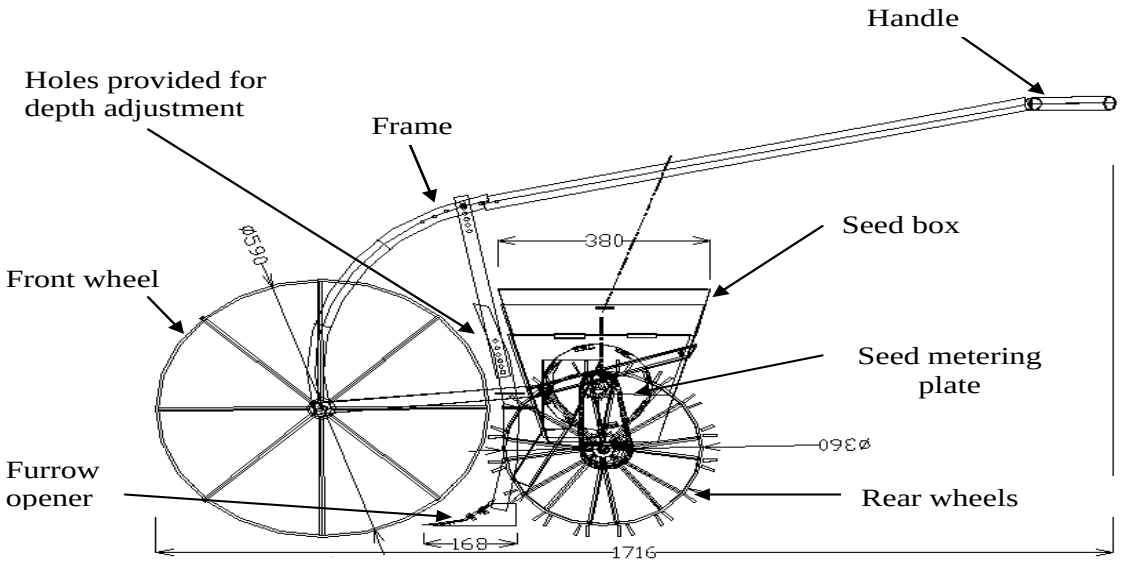
It was observed that the number of seeds varied from 0 to a maximum of 3. The number of seeds per hills, varied from a minimum of 0.98 to a maximum of 1.2. The average number of the seeds dropped per hill was 1.1. Naturally the number of seeds per hill can't be in fraction as the average value is a mean of a total of 450 readings; hence the result came in fraction. The variation in number of seeds per hill might have occurred due to varying size of seeds.

The soil cover over the seed varied from a minimum of 3.9 cm to a maximum of 5.2 cm. It was observed that the average soil cover over the seed of each plot varied from a minimum of 4.7 cm to a maximum of 4.9 cm. The average value of the soil cover over the seed was 4.75 cm. The variation in soil cover over the seed might have occurred due to irregular topography of the land. The amount of soil cover the seed seems to be satisfactory as it is quite close to the desired soil cover of 5 cm.

The missing hills varied from a minimum of 10 percent to a maximum of 15.85 percent. The average value of the missing hill was 13.86 percent missing hills might have occurred due to not proper lifting of seeds by the metering mechanism and improper fabrication of the seed cups. Row to row spacing varied from a minimum of 10 cm to a maximum of 17.5 cm. The average value of the row to row spacing in the plots was 15.05cm.

Garlic planter operating speed varied from a minimum of 3.16 km/h to a maximum of 3.47 Km/h. The average value of the operating speed in the plots was 3.31 km/h. Field capacity varied from a minimum of 0.034 ha/h to a maximum of 0.04 ha/h. The average value of the field capacity of all the plots was 0.0367 ha/h.

Fig.1 Side view of garlic planter



(Dimensions are in mm)

Fig.2 CAD model of seed metering mechanism prepared using AutoCAD

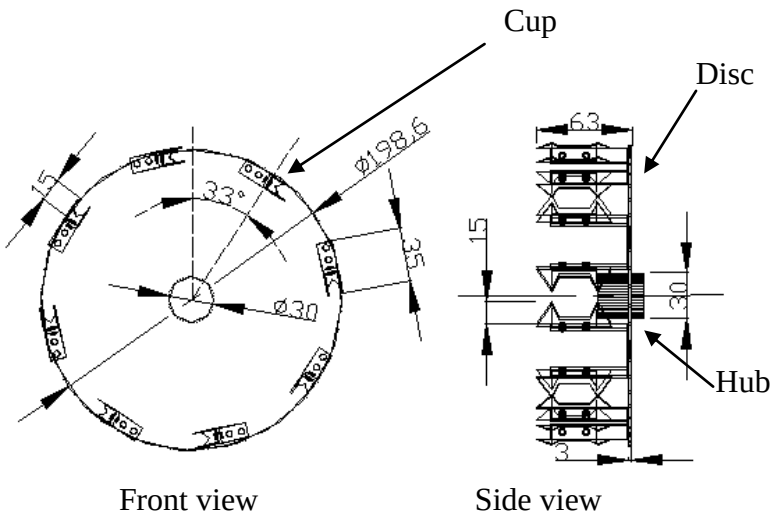
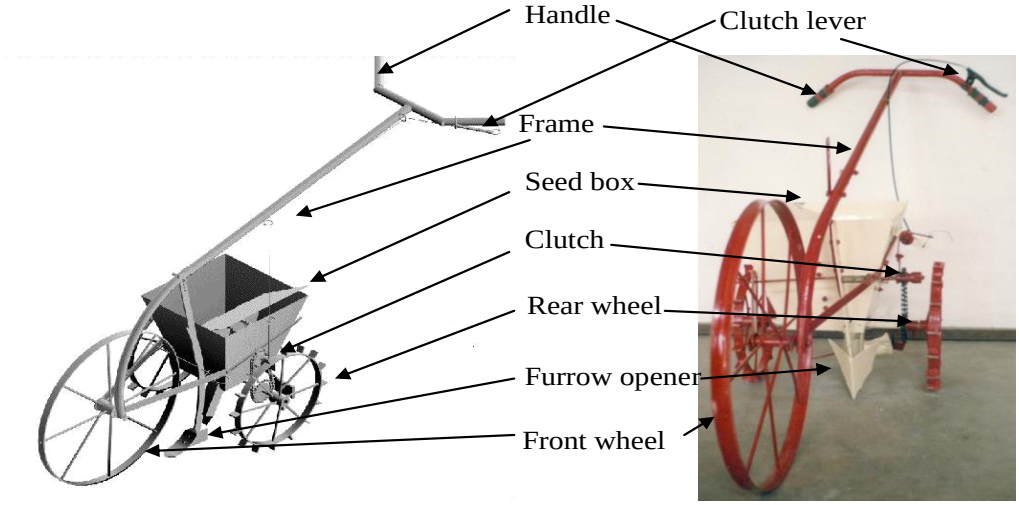


Fig.3 CAD model prepared using AutoCAD and fabricated garlic planter



(a) CAD model of the garlic planter (b) Fabricated garlic planter

In conclusions, the developed push type manually operated garlic planter was fabricated and evaluated in laboratory as well as field condition. With the improvement in the design of seed cups the garlic planter worked satisfactorily in the field. It has improved the seed placement significantly. For the easy turn of the garlic planter on the field the one wheel is freed and which increases the performance of planter during turning. Average number of seeds per hill was 1.11 and average hill to hill spacing 7.11 cm.

Hill to hill spacing was with in ±10% which seems to be satisfactory. Average depth of seed placement was 4.75 cm and depth of soil cover over the seed was 4.75 cm, both were very near to the requirement of the garlic cultivation. Average operating speed of the garlic planter 3.31 km/h and operator can walk easily behind it. Average row-to-row spacing maintained by the garlic planter was 15.05 cm, which is close to standard requirement of row-to-row spacing. Field capacity of 0.0367 ha/h seems to be satisfactory as one hectare of garlic can be planted in 26.59 h.

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