# Mechanization of garlic (*Allium sativum*) cultivation in India: An overview

M. KUMAR[1], B. B. GAIKWAD[2] and R.K. SAHNI[1]

*[1]ICAR-Central Institute of Agricultural Engineering, Bhopal-462038 (Madhya Pradesh) and [2]ICAR-National Institute of Abiotic Stress Management, Baramati– 413115 (Maharashtra)*

**ABSTRACT:** Mechanization of agriculture having being the only way to address shortage of agricultural labour, has been adopted in few cultivation operations of garlic, one of the most important crop spices in India. Attempts to mechanize planting and harvesting operation in garlic have led to the development of farm machinery prototypes in different parts of India. This paper aims to present an overview of the present status and avenues of further mechanizing the cultivation of garlic in India.

**Key words:** Garlic mechanization, garlic planter, garlic harvester

India is the second largest producer of garlic in the world after China. It is grown and used as a spice or condiment throughout India. According to the National Horticultural Research and Development Foundation (NHRDF) India's garlic area, production and productivity were 3.16 lakh ha, 1.61 MT and 5.08 t/ha in 2017–18 (NHRDF, 2020). As per Directorate of Onion and Garlic Research (DOGR) there is need to increase garlic production to 1.79 million tons and productivity to 7.31 t/ha by 2050 **(**DOGR**,** 2013). Varietal improvements and mechanized cultivation would be crucial to achieve higher productivity of garlic in India. The major garlic producing states in India are Rajasthan (36%), Madhya Pradesh (25%), UP (11.7%) and Gujarat (9.4 %) in the year 2017–18. The average productivity of garlic for different states varies widely and in major garlic producing states, it varies from 4.38 to 7.91 t/ha in the year 2017–18 (NHRDF, 2020). The average global garlic productivity of nearly 16.71 t/ha in 2011 (DOGR, 2013).Thus, there stands ample scope to further increase productivity through varietal improvement amenable to its mechanized cultivation. There are avenues of mechanized cultivation available with present agronomic practices and few would need changes in the current agronomic practices to facilitate mechanization in order to realize the goals of maximum productivity of garlic in India.

The farm productivity is positively correlated with the availability of farm power coupled with efficient farm implements and their judicious utilization. The overall mechanization level in India is only 40–45% even though 90% of the total farm power is contributed by mechanical and electrical power sources. The farm power availability has grown from 0.28 kW/ha in 1960–61 to 2.10 kW/ha in 2013–14 (Kale *et al*., 2016). However, further increase to the minimum of 2.5 kW/ha by 2020 is required to assure timeliness and quality in field operations. Farm mechanization is increasing in every crop grown in India due to the shortage of farm labour and garlic is not an exception. Mainly mechanization of planting and harvesting operations which are specific to garlic crop characteristics has got focus in recent times. Other unit operations from field preparation to irrigation (expect intercultural operation) were carried out by using general crop machinery. However, mechanizing the intercultural operation which is one of the major labour intensive operations is challenging and general crop intercultural equipment cannot be used due to closer row spacing of garlic crop. This paper summarizes the agricultural machinery developed in National Agricultural Research System, public sector in India and abroad with potential for adoption in present cultivation practices in India.

## Mechanization of Pre Harvest Operation in Garlic Cultivation

The machinery for field preparation, seed bed preparation, fertilizer application and spraying is available for garlic cultivation as for these operations available machinery can be used. For planting, weeding and harvesting operations the special crop specific machinery need to be used because of garlic crop characteristics. The details for planting weeder and harvesting machinery for garlic cultivation have been given below:

### Planting

Garlic is cultivated by planting single clove vertically with the shoot in the upright position at 20mm below the soil surface with plant to plant spacing of 100mm and rows to row spacing of 150mm**.** However, farmers have adopted different spacing such as 100×100mm,75× 125mm, 75 × 150mm. Big cloves (>1.5g) are selected for planting at the seed rate of 400–500 kg/ha to ensure higher germination rate. Planting is very cumbersome and labour intensive operation. It requires about 520 man-h/ha.

Several prototypes of seed drills/planters for garlic have been developed in India and have been discussed below.

**Garlic bulb breaker**

A manually operated garlic bulb breaker with capacity 50 kg/h was developed at CTAE, Udaipur (Prasad, 2013) consists of a hollow cylinder with cushioned battens, a concave, an aspirator and a prime mover (Fig.1). The cloves are separated because of the beating action of battens and friction between bulb and concave. Aspirator separates the light paper skin, root and middle stem of bulb. Clean cloves are collected along the chute below the concave. Its capacity has been reported to be 800 kg/h with 0.5 hp single phase motor. In addition of that different capacity garlic bulb breaker are also available in Indian market.

**Fig. 1: Garlic bulb breaker**

**Manual planter**

Manual planters have been developed by State Agricultural Universities (SAU's) of areas cultivating garlic for the farmers with marginal land holdings. Punjab Agricultural University (PAU), Ludhiana developed a manual planter (Fig. 2) with the metering mechanism of spoons placed on the periphery of the vertical plate (*ICAR Annual Report, 2004*). It is light in weight (12 kg), requires two persons for operation and having field capacity of 0.038–0.05 ha/h. This machine helped to reduce labour requirement to 83 man-h/ha for planting garlic in comparison to 520 man-h/ha by the traditional method.

Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola, developed a manual planter comprising of mainframe seed box, metering mechanism, ground wheel with lugs, adjustable furrow opener and seed tube, covering bracket and marker (Gajakos *et al*., 2015). This equipment operated by two persons, could maintain depth of clove placement to 40–50mm with field efficiency and missing hill of 84.35% and 28.33%, respectively.

**Animal drawn planter**

The animal drawn planter still holds relevance in several garlic growing areas having draught animals as the source of power for agricultural operations. ICAR-Central Institute of Agricultural Engineering (CIAE), Bhopal developed a three-row animal-drawn garlic planter (Fig. 3) consisting of cup type metering mechanism and fertilizer drilling attachment for simultaneous planting and fertilizer placement in the single pass at a depth of 25–40mm (Kumar *et al.,* 2014). The average draught requirement, field capacity, saving in time, seed spacing, miss index, multiple index, seed damages and labour requirement were reported to be 450 N, 0.06 to 0.08 ha/h, 90%, 108.7±40.1mm, 10.23, 7.45, 4% and 13 man-h/ha, respectively. The height of hopper can be adjusted with the help of lifting rod handle to regulate the number of cloves in the metering section.

**Tractor operated automatic garlic seed/planter**

Higher planting rates relevant for large land holdings are achievable using tractor operated garlic planters. Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur developed a 12-row garlic planter (Fig. 4a) consisting of the star wheel type seed and fertilizer metering mechanism to plant 500 to 700 kg/ha of garlic in rows spaced 150 mm apart with 0.35

**Fig. 2: Manual garlic planter**

**Fig. 3: Animal drawn garlic planter**

ha/h field capacity (*ICAR Annual Report, 2007*). The spacing of garlic cloves and field efficiency were reported to be 50 to 100 mm, and 70%, respectively. Another 13/15 row garlic planter developed by MPUAT, Udaipur in collaboration with M/s R.K Agro Industries, Rajkot has plastic roller with 6 blades mechanism for seed metering(Singh, 2010). The clove spacing, row to row spacing, hopper capacity, field capacity, furrow opener of standard NS clove spacing was reported to be 80–100 mm, 150 mm, 250–300 kg, 0.4–0.5 ha/h, 50 mm seed tube for local and 75 mm for Ooty variety of garlic, respectively.

ICAR-Indian Agricultural Research Institute (IARI), New Delhi developed 9-rows garlic planter (Fig. 4b) with the vertical cup type metering system (IARI Annual Report, 2014). The row to row spacing, plant to plant spacing, feed index, miss index and multiple index were reported 150 mm, 75 mm, 88%, 2% and 10%,respectively. No visible clove damage was recorded in the laboratory testing. The actual field capacity and field efficiency of the planter was 0.2 ha/h and 74%, respectively, at the working speed of 2 km/h.

Punjab Agricultural University (PAU), Ludhiana developed 6–row tractor operated garlic planter (Fig. 4e) having spoon size of 23 mm in diameter and 2.5 mm in depth of operation and row to row spacing of 150 mm (Mehta, 2015).This machine was evaluated for showing of Punjab garlic1 variety on 1 m wide beds and the field capacity of machine was reported 0.18–0.21 ha/h at the speed of 2–2.5 km/h. The average percentage of missing and multiples were 9.13 and 26.70%, respectively.

**Self-propelled garlic planter**

IARI, New Delhi designed self-propelled garlic planter (IARI Annual Report, 2015a) having a 2.65 kW petrol engine as a prime mover (Fig.5a). In this machine inclined plate metering mechanism was used. Average seed spacing, miss index, multiple index, quality of feed index, precision and seed damage were reported 94.2mm, 6.8%, 12.72%, 80.48%, 22.67% and 8.26%, respectively. Field capacity of the planter was found to be 0.09 ha/h with a field efficiency of 77.7% while operated at a speed of 1.5 km/h. The average depth of placement was 26mm.

Another self-propelled garlic planter (Nare *et al*., 2014) capable of planting three rows of garlic cloves at a spacing of 100×150mm was developed at Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur (Fig.5b). A vertical plate cup or spoon type picking device was employed as a

(a) 12-row planter (b) 9-rows planter (c) 6-row planter

**Fig. 4: Different tractor drawn garlic planter**

**Fig. 5: Self-propelled garlic planter developed at (a) IARI, New Delhi and (b) JNKVV, Jabalpur**

**Fig. 6: Garlic seeder/planter made by Private manufacturer**

metering mechanism in the planter. The actual field capacity was found to be 0.065 ha/h with the field efficiency of 79.84%.

It was observed that the placement of garlic cloves was at uniform depth in the range 42 to 52 mm with a minimum SD and CV of 3.3 mm and 6.92%, respectively. The miss index, multiple index and seed damage was found to be only 2.67, 8.0 and 1.46% respectively.

Tractor operated garlic seed drill/planters were also made by different manufacturers in MP, Rajasthan and Gujarat (Fig. 6).These garlic seeders/planters generally use plastic/PVC roller with groves type metering mechanism. These types of metering mechanism do not maintain clove to clove spacing. The details and performance of garlic planters developed in India are summarized in Table 1.

Manual planting of the garlic cloves is preferred by farmers to assure the upright position of planting by pressing the wider part of the clove downward in soil by finger pinch. This helps in straight emergence of shoot, out of the soil at the earliest. However, planters used in India drop garlic cloves through seed tubes, cloves fall freely due to gravity. This results in the random positioning of cloves on contact with soil surface and thus do not ensure upright planting. The metering mechanisms used in Indian garlic planters are spoon type, cup type, star wheel type, plastic roller type have higher miss and multiple index around 10% (Table 1). The use of developed garlic planters though helps in timely planting operation and reduced labour requirement, results in non-uniform planting as compared to manual planting further leading to less yield and low quality of produce (non-uniform bulb size) due to miss and multiple planting.

The major garlic producing states have vertisols/ black cotton soil, which tend to remain cloddy even after harrowing. This causes excessive jerks to the planter while in operation resulting in bouncing off the picked clove off the spoon and thus miss planting. A finely prepared seedbed can help reduce the jerks to the planter and lower the bouncing of picked clove off the spoon, and thus lower miss planting.

**Table 1: Performance parameter of garlic planters**

| Parameters | Power source | | | |
|---|---|---|---|---|
| | **Manual** | **Animal Drawn** | **Tractor operated** | **Self-propelled** |
| No. of rows | 1 | 3 | 6–15 | 3–4 |
| Row spacing, mm | 157 | - | 150 | 150 |
| No. of labour required for operation | 2–3 | 1 | 1 | 1–2 |
| Labour requirement man-h/ha | 83 | 13 | NA | NA |
| Field capacity ha/h | 0.018–0.05 | 0.06–0.08 | 0.2–0.5 | 0.09 |
| Metering mechanism | Spoon/cup type | Cup type | Spoon type, Star wheel, 6 blade roller, vertical cup | Inclined plate, vertical plate cup or spoon type |
| Depth of clove placement, mm | 40–50 | 25–40 | - | 42–52 |
| Plant spacing, mm | 74.6 | 108.7 | 50–100 | 94.2–100 |
| Miss index % | 11–28.33 | 10.23 | 2–5.13 | 2.67–6.8 |
| Multiple index % | NA | 7.45 | 10–16.14 | 8.0–12.72 |

A garlic planter developed in South Korea (Choi *et al*., 2003) has a mechanical metering system that ensures upright planting of garlic clove. Pneumatic type and spoon type metering mechanism have been used in the planters developed in other countries. However, these machines are capable of sowing garlic at 30.5–152 mm clove to clove spacing and 275–495 mm row to row spacing (Broch, 2018a, ERME, 2012a). In these machines, row to row spacing is higher which is not suitable to the Indian conditions. Indigenous development of these proven metering mechanisms with customization to suit local needs can improve the performance of garlic planters. This would not only ensure uniform planting, reduces post planting labour, but also higher productivity and quality of product.

**Weed management**

Control of weeds at the initial growth stages is essential for getting high quality bulb yield. Generally, two manual or chemical weeding is done within the first month after planting of garlic. The manual weeding is highly labour intensive and drudgerous due to clove to clove distance. Development of a mechanical weeder catering to the present agronomic cultivation practices of garlic in India would greatly aid the weeding operation. A tractor operated mechanical weeder for garlic crop sown on broad beds was developed at ICAR-CIAE, Bhopal which may be a potential solution for tedious weeding operation in garlic (ICAR-CIAE, 2018–Newsletter).However, optimization of planting geometry to suit available weeders without significantly affecting plant population could be another possible solution to address weeding in garlic. For pest and disease management hand-operated knapsack sprayer, self-propelled sprayer, self-propelled intra-canopy sprayer etc. are available and can be adopted for use in garlic crop.

**Harvesting**

Garlic is recommended for harvesting after 50–75% drying of leaves on maturity. Harvesting should be done by pulling the plants along with the bulbs. Garlic bulbs along with top may be cured/ dried in the field for two to three days after harvesting to increase storage life by minimizing microbial and fungal infection and water loss. The harvesting time of Rabi garlic crop generally varies from March to April across India expect hilly regions where longer duration varieties are harvested in the month of May. The Kharif garlic harvesting is carried out during October to November. Manual garlic harvesting is a labour intensive and time consuming operation. Several prototypes of digger/harvester have been developed in research institutes and SAUs of India and are summarized below.

**Fig. 7: Animal drawn garlic digger**

**Animal drawn garlic digger**

An animal-drawn garlic digger (Fig.7) developed at ICAR-CIAE Bhopal having blades of 550 mm of radius of curvature and 700 mm wide curved with radius of curvature 700 mm had 86% efficiency. Field capacity and average garlic damage was reported to be 0.12 ha/h and 3.62%, respectively. The animal drawn garlic digger saved 75% cost and 44.8% energy as compared to the traditional method of manual digging (Kumar *et al.,* 2017).

**Tractor drawn digger/harvester**

Tractor drawn diggers were developed at IARI, New Delhi and MPUAT, Udaipur. Two prototypes were developed at IARI, New Delhi in which one is 4-row tractor operated garlic harvester (IARI Annual Report, 2014) shown in Fig.8a and another is oscillating soil separator type garlic harvester for (IARI Annual Report, 2015b) garlic shown in Fig.8b. In former garlic digger, the working width, power requirement, mature garlic harvesting percentage, bulb damage percentage, soil separation index and field capacity of the machine were reported 0.6 m, 4.54 kW, 96.12%, 5.94%, 0.26 and0.24 ha/h, respectively. The operational cost of the machine was found to be 55% lower than that of manual harvesting. Whereas, in later garlic harvester for which amplitude, revolution, length, width of soil separator, rod spacing and minimum depth of operation were kept as 10 mm, 540±10 rpm, 1000 mm, 900mm, 50mm and 120mm, respectively. The average harvesting efficiency, bulb damage, soil separation index for garlic harvester were reported 94.76%, 4.81% and 0.23, respectively. The optimum power requirement of the harvester was 5.74 kW for soil moisture content of 12.88±0.35 %. The garlic harvester had a breakeven point at 125.36 h/year with a payback period of 2.6 years.

(a) 4-row garlic harvester (b) Oscillating soil separator for garlic

(c) Garlic Harvester-cum-windrower (d) Peanut and garlic harvester

**Fig. 8:Tractor operated garlic digger/harvester**

A tractor operated garlic harvester-cum-windrower was developed at MPUAT, Udaipur (ICAR annual report, 2015) is shown in Fig.8c. The power is given by tractor power take off (PTO) to gearbox with a ratio of 1: 1. The field capacity of the harvester is 0.26 ha/h at a forward speed of 2.4 km/h.

Several manufacturers are also making diggers which are used for different crops along with garlic. One such unit of peanut and garlic harvester shown in Fig.8d. Different garlic digger/harvester with digging blade and stationary MS rods combination or digging blade and oscillating type separating mechanism developed in India. The performance parameters of these machines are presented in Table 2.

**Table 2: Performance parameter of garlic digger/harvester**

| Parameters | Power source | |
|---|---|---|
| | Animal Drawn | Tractor operated |
| Operating width, mm | 440 | 600–900 |
| Field capacity ha/h | 0.08–0.10 | 0.24–0.26 |
| Garlic harvesting percentage,% | 86 | 94.8–96 |
| Damage to garlic, % | 5–8 | 4.8–5.9 |
| soil separation index, % | - | 0.23–0.26 |

However, in abroad garlic harvester binders and garlic harvester detoppersvare being used. In garlic harvester detopper, two operations i.e. harvesting and detopping are performed simultaneously. The harvested garlic is either sold in the market or used for processed food. In garlic harvester-cum-binder, two operations i.e. harvesting and binding are performed simultaneously and harvested garlic is stored, which is prevalent practice in India. The garlic harvester detopper or harvester binder designed for higher row spacing (400–650 mm) and power requirement is ranging from 70–110 hp (ERME, 2012b and Broch, 2018b). However, a one row garlic harvester of JJ Broch company is required 35 hp and suitable for 400 mm row to row width. Garlic harvester-detopper and harvester-binder of developed countries are costly and use of these machines is very limited in Indian condition due to less row to row spacing. There is a need for indigenous development of the garlic harvester binder according to soil and agronomic practices.

**Table 3: Status of farm mechanization in garlic cultivation and future remarks**

| S. No. | Operation | Available equipment | Remark on mechanization status |
|---|---|---|---|
| 1. | Field preparation | MB Plough, disc plough, cultivator, leveler, rotavator, disc harrow, chisel plough, etc. | This operation is mechanized and common for most of the crops. |
| 2. | Bulb breaker | Garlic bulb breaker (Prasad R., 2013 ) | This operation is mechanized. |
| 3. | Sowing/ planting | Manual : PAU, Ludhiana (IARI Annual Report, 2007)<br>PDKV, Akola (Gajakos *et al.*, 2015)<br>Animal drawn:CIAE, Bhopal (Manish Kumar *et al.*, 2014)<br>Tractor drawn:<br>MPUAT, Udaipur (Singh, 2010).<br>IARI, New Delhi (ICAR Annual Report, 2007)<br>PAU, Ludhiana (Mehta, 2015)<br>Broch, 2018bERME, 2012b<br>Self-propelled:<br>IARI, New Delhi (IARI Annual Report, 2015a)<br>JNKVV, Jabalpur (Nar *et al.*, 2014) | Scope for development of planter with better performance and higher field capacity. |
| 4. | Fertilizer application | Planter-cum-fertilizer applicator, Fertilizer broadcaster, Sprayers | This operation is mechanized and common for most of the crops. |
| 5. | Weed control | Manual weeding | A weeder need to be developed to suit cultivation practices of garlic |
| 6. | Plant protection | Hand-operated knapsack sprayer, self-propelled sprayer, self-propelled intra-canopy sprayer | This operation is mechanized and common for most of the crops. |
| 7. | Harvesting | Animal drawn:<br>ICAR–CIAE Bhopal (Kumar *et al.*, 2017)<br>Tractor drawn :<br>IARI, New Delhi (IARI Annual Report, 2014 & 2015b)<br>MPUAT, Udaipur (ICAR annual report, 2015)<br>Broch, 2018b<br>ERME, 2012b | Harvesting-cum-binding equipment for garlic need to be developed to support garlic growers. |

On the basis of machinery available in India and abroad, the status of farm mechanization in garlic cultivation and future scope is presented in Table 3.

## CONCLUSION

In India, garlic planters with vertical rollers metering mechanism are mostly used, in which seed to seed spacing is not maintained. For mechanization of weeding operation a weeder was developed at ICAR, CIAE, Bhopal. Garlic diggers are available but no garlic harvester-cum-binders available in India. The planters and harvester-cum-binders developed outside India are not suitable for Indian condition due to different agronomical practices and its higher cost. For increasing mechanization in garlic cultivation, different garlic planters, weeders diggers developed at research institutes and SAUs need to conduct adoptive trial at farmer's field and further modification shall be needed based on trials feedback. The garlic planters and harvester-cum-binders developed outside India, required to be modified to suit the local agronomical practices with low cost solution to the farmers.

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