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# Review on Mechanized Cabbage Harvesting Systems and Its Present Status in India

**Shinde Om Shankarrao[1], Dr sanwal Singh Meena[2], Dr. Sachin wandkar[3]**

[1]MTech student ctae, mpuat ,Udaipur
[2]HOD FMPE department ctae, mpuat ,Udaipur
[3]asst professor fmpe ctae ,mpuat, Udaipur

**Abstract**

Cabbage (*Brassica oleracea* var. *capitata*) is one of the most important vegetable crops cultivated worldwide, with India being the second-largest producer. Despite its significance, cabbage harvesting in India is predominantly performed manually, which is labour-intensive, time-consuming, and associated with health risks such as musculoskeletal disorders, fatigue, and exposure to adverse environmental conditions. This review examines the development and present status of mechanized cabbage harvesting systems, with particular emphasis on their applicability in Indian agriculture. The study discusses the harvesting stages, cultural practices affecting mechanization, and the physical and mechanical properties of cabbage that influence harvester design. Various harvesting subsystems, including lifting and cutting mechanisms, conveying units, and leaf removal systems, are reviewed along with their operational principles and performance. Commercial cabbage harvesters developed in Europe, North America, Japan, and China are also analyzed. The review highlights that most existing harvesters are designed for large-scale farming, require high power inputs, and involve multiple operators, making them unsuitable for the small and fragmented landholdings common in India. The paper identifies the need for a compact, low-cost, low-power, and single-row self-propelled cabbage harvester specifically tailored to Indian farming conditions. Further research on the physical characteristics of Indian cabbage varieties, optimization of operating parameters, and development of efficient harvesting mechanisms is essential to enhance mechanization, reduce labor dependency, and improve harvesting efficiency in India.

## 1. Introduction

Cabbage is a dense, leafy vegetable that belongs to the *Brassica oleracea* species, which also includes broccoli and kale. Its scientific name is *Brassica oleracea* var. capitata. It is well-known for being low in calories but high in fibre, antioxidants, and vitamins C and K, all of which promote immune and digestive health. It can be eaten raw and it can also be consumed processed. When the head is firm, tight, and has stopped growing usually 90–120 days after planting, though some varieties may be ready as early as 60 days cabbage is ready for harvesting [1]. Since cabbage grows best in cool, humid climates, winter (October to February) is the primary season for harvesting cabbage in India, particularly in the plains.

The harvest season, however, varies by region; hills have a slightly earlier sowing period with harvests in January or February, while plains harvest from August to November [1]. To harvest cabbage, cut the head from the stem slightly above the soil line using a sharp knife or pruners. For storage and protection, leave two to four outer leaves on the head. You can cut the stem just below the head for a continuous harvest, leaving the stump in the ground to promote the growth of smaller cabbages [2].

The design of the cabbage harvester and the quality of harvesting are significantly influenced by the spacing between and within rows. Cool, humid climates are ideal for cabbage growth. The optimal temperature range for germination is 20 to 25°C.The optimal temperature range for growth and head formation is between 15 and 20°C, according to Hara and Sonoda (1982). Plant density has a major impact on both maximum yield and uniform plant maturity (Tegen and Jembere, 2022). Because of their weight and competition for scarce resources, long plants with high plant densities are more likely to lodge. Plants become stuck in the spaces between rows as a result, making mechanical harvesting more difficult.These heads are easily crushed or damaged by mechanisation. The optimal plant density can only be attained with the proper intra-row and inter-row spacing [2].

After China, India is the world's second-largest producer of cabbage. In China, cabbage is one of the most widely grown vegetables. While Uttar Pradesh, Odisha, Bihar, and West Bengal are India's top producers of cabbage, Rajasthan's output is less consistent. In 2024 and 2025, Rajasthan produced 9.739 thousand tonnes of cabbage, which was significantly less than its 2017 high of 19.66 thousand tonnes but higher than its all-time low of 4.20 thousand tonnes in 2014.

In Europe, the US, Japan, and China, the automated method of harvesting cabbage has advanced to a greater degree. However, compared to those, very little research has been done in India. A prime mover that runs on conventional fuel powers the majority of cabbage harvesters in other nations. To operate it, multiple operators are also needed. However, a small, low-power cabbage harvester would be ideal for Indian conditions, taking into account the cost of Indian cabbage as well as the size of landholdings [4] claim that while the single-point clamping method may successfully lessen the cutting force of the cabbage root, it may also raise the possibility of cabbage stem splitting failure. They investigated the connections between chemical composition and cutting forces and optimised the cutting position for a Chinese cabbage harvester. The most significant factor influencing cutting force was determined to be fibre content. The least amount of cutting force was found when the cabbage stem's diameter was between 30mm and 35 mm then cutting force was 110N-130N, investigated how the physical characteristics of Chinese cabbages affected the harvesting procedure[5]. Indian cabbage varieties are spherical or teardrop-shaped, while Chinese cabbage is oblong. According to reports, cutting force changed as stem diameter and plant height changed, and this was a crucial consideration when designing the conveying system [6].

One of the most significant winter vegetables in India is cabbage (Brassica oleracea L. var. capitata). Depending on the climate and soil conditions, cabbage seedlings are transplanted in furrows, ridges, or flat areas. After 90 to 120 days of planting, cabbage is ready for harvesting. Cabbage is harvested by hand in India. In order to harvest the head, it is bent to one side and then cut with a knife [7] .High energy is needed in this process [4].This conventional harvesting technique used by rural farmers has numerous disadvantages. Agricultural workers' musculoskeletal disorders are caused by stooping posture, which causes biomechanical stresses in the back, neck, upper, and lower limbs [8].

When harvesting, using bare hands all the time can result in hand bruises that can become infected. When harvesting by hand, they are also exposed to pesticides and fertilisers [9]. Working all day in the sun exposes agricultural workers to a variety of heat-related illnesses, including heat exhaustion, nausea, dizziness, heat stroke, dehydration, and even death [10]. A comparatively stable mechanised agricultural system for harvesting cabbage has already been established in Europe, the USA, and other developed nations [11]. China and Japan are at the forefront of research in Asia, primarily concentrating on small self-propelled harvesters [4]. However, small and marginal farmers with less than two hectares of land make up 86.2% of all farmers in India [12].It is challenging to conduct field operations correctly due to the small land sizes and irregular field shapes. This is one of the reasons why mechanisation in India has mostly been restricted to haulage and stationary farm operations.

The purpose of this study is to examine the technologies currently in use for harvesting cabbage. Three subsystems in cabbage harvesting cutting mechanisms, conveying systems, and leaf separating units are the primary focus of this article. First, the stage of harvesting and cultural customs that influence the mechanical harvesting of cabbages were briefly reviewed. A thorough examination of the mechanical and physical characteristics of cabbage, which are crucial for creating a cabbage harvester, comes next. After that, a variety of lifting and cutting mechanisms were covered. After discussing methods for transporting and trimming cabbages, some commercial cabbage harvesters and their shortcomings were described.

## 2. Stage of Harvesting of Cabbages

The developmental stage at which a fruit or vegetable meets the requirements for consumer use is known as harvesting maturity [13]. Before it reaches full physiological maturity, cabbage is harvested during the growing stage [14].

When the heads are mature and firm, they must be harvested. Split heads can occur if harvesting is delayed a few days past maturity, especially in wet weather. When harvesting cabbage, its size and firmness serve as the primary indicators of maturity. Some cabbages are harvested with a diameter of 10 cm, while others have a diameter of 15 to 25 cm. A mature head can be slightly compressed with moderate hand pressure because it is firm or compact. It is not appropriate to harvest a very loose head since it is immature. The arrangement of the wrapper leaves can also be used to determine harvest maturity; when the head is exposed and the leaves are spread, the plant is typically mature. Indian cabbage varieties are categorised as early-maturing (harvested within 60 to 65 days after transplanting) or late-maturing (harvested within 100 to 105 days after transplanting) based on how long they take to mature. The early-maturing variety includes Golden Acre, Pride of India, and Early Drum Head. Conversely, late-maturing varieties include Copenhagen Market, September Early, and Late Large Drum Head [7]

## 3. Important Cultural Practices for Mechanical Harvesting

The maximum yield and equal maturity of plants depend on plant density [2].When plant density is high, competition between individual plants for basic requirements leads to long plants that are prone to lodging due to weight and lack of vegetation space. As a result, inter-row spaces become covered with the lodged plants and cause problems in mechanical harvesting [15].These heads are easily damaged or crushed by mechanisation [16] .experimented on cabbage yield with two different spacing (60 x 40 cm and 60 x 45 cm) For the late cabbage variety [15] suggested a plant density of 28,600 plants per hectare and a spacing of 70 x 50 cm. It permits healthy plant growth, the development of large-leafed leaf rosettes, the formation of compact heads with appropriate head weight, and it is suitable for mechanical harvesting.

### 4. The manual Method of Harvesting

Harvesting cabbage involves bending the head to one side and using a sickle or sharp knife to cut it. To minimise cutting energy and harvesting effort, the cutting tools need to be regularly sharpened [7]. To prevent damage, cut the cabbage with two or four leaves, and cut the stalk very flat closer to the head. Remove wrapper leaves that are yellowed, damaged, or diseased. Heads with serious insect damage and other flaws ought to be discarded. This traditional harvesting method used by rural farmers has many disadvantages. In agricultural workers, stooping posture causes musculoskeletal disorders and biomechanical stresses in the upper and lower limbs, neck, and back [8]. Du et discovered that 230 N was the maximum cutting force needed to cut the cabbage stalks. This indicates that this process requires a lot of cutting energy.[4]

### 5. Physical and Mechanical Properties of Cabbage

When designing a harvester, it is crucial to take into account the geometrical dimensions of the plant, such as the head size, stem length, and root diameter. Once more, determining the mechanical characteristics of cabbages is crucial for determining the optimal cutting position and combination [17]. The vertical and horizontal forces required to uproot the cabbage were measured by Hamdy [18] and ranged from 155.68 to 418.2 N and 186.88 to 498.35 N, respectively. Three distinct cabbage varieties (Glory, Emerald Cross, and Market Price) were weighed by Stout et al [19]. The average percentage of the weight of the head, roots, and leaves of the three cabbage varieties was found to be between 52.5 and 71, 8.8 and 20. and 4.3 to 9, respectively.

Parsons and Rehkugler [20] also measured these parameters for Glory 61, Marion Market, and Robson Lord Large Glory cabbage varieties. The maximum force for pulling a cab bage horizontally from the ground on sandy loam soil was found to be 792.65 N. It was discovered that the results fell between 65.1 and 72.2, 23.9 and 34.5, and 3.5 and 4.9, respectively. Eight physical characteristics (plant diameter, plant height, head diameter, head height, stem diameter, length of the leaf stem, length of the stem, and the height of the center of gravity of cabbages) were measured for eight Chinese cabbage varieties by Kanamitsu and Yama Moto [21]. It was discovered that the average plant height and head height were 281.1 mm and 106.85 mm, respectively. Plant diameter, head diameter, plant weight, and head weight averaged 389.05 mm, 128.05 mm, 1.75 kg, and 1.41 kg, respectively, while stem diameter, leaf stem length, and stem length averaged 27.5 mm, 58.35 mm, and 44.7 mm, respectively. The morphological dimensions and shape of three Indian cabbage varieties—Pusa Mukta, Pusa Drumhead, and Septem ber Early—were examined by Pandey and Singh [22]. The shapes were divided into spherical, elliptical, teardrop, and inverted teardrop categories using Gilbert's[23] equation.

The length of the leaf stem was found to vary from 12 to 33 mm, suggesting that the heads' bottoms were extremely near to the ground. The cabbages were lifted using a screw auger, and the impact of the screw auger pitch on the accuracy of the cutting was examined for three distinct Chinese cabbage varieties. The 120 mm pitch screw auger caused less damage than the 80 mm pitch screw auger, according to the results. Hokuyo and Ryutoku cabbage varieties were found to have pulling forces of 162 and 259 N, respectively. Compared to Indian varieties, Chinese cabbages are more oval. Before creating a single-row cabbage harvester, Kumar [24] investigated the biometric characteristics of the cabbage (variety was not mentioned) .[25]revealed that as cutting speed increased, Chinese cabbage rootstalk shearing force changed. The shearing forces showed a negative correlation with the degree of knife edge smoothness and a positive correlation with knife edge thickness. Cutting positions on the cabbage root had the biggest effects on the cutting force, according to Li et al. [26] At a distance of 40 mm from the upper leaves, the least amount of cutting force was found. Higher cutting speed and the use of a serrated blade decreased the cutting force significantly in their test. The optimal cutting position and cutting combination for cabbage root were examined by Du et al. [17] As root diameters increased, the cutting force decreased and reached its lowest point in the range of 30 to 35 mm, which was thought to be the ideal cutting position. To reduce splitting failure levels, Du et al. [27] recommended sliding angle, cutting speed, and cutting diameter of 40, 300 mm/min, and 35 mm, respectively. Before creating a self-propelled cabbage harvester, Du et al. [4] measured six physical characteristics of Chinese cabbage: plant height, extension diameter, ball diameter, root height, leaf height, and plant weight.

The root height in the experiment ranged from 54 ± 7.2 mm to 126 ± 11.6 mm. The range of plant height and ball diameter was 150 ± 14.5 mm to 330 ± 30.4 mm and 125 ± 12.5 mm to 212 ± 20.1 mm, respectively. A cabbage pull-out testbed with two screw poles, a capping belt, a double-disc cutter, and a drive mechanism was created by Zhou et al. [28] When the angle between the screw pole and the ground, the distance between two screw poles, and the screw pole's rotational speed were 15 ˚, 50 to 70 mm, and 180 rpm, respectively, the highest pulling out percentages were achieved. The reviewed literature makes it evident that different varieties of cabbage have different mechanical and physical characteristics.

When designing a harvester, this needs to be taken into account. The target variety must be taken into consideration when choosing the dimensions of a cabbage harvester's various components and operating parameters. Alternatively, it can be configured so that the harvester can cover multiple types of cabbage in a specific area [19] For instance, Pandey and Singh [22] measured the physical characteristics of three Indian varieties: September early, Pusa Mukta, and Pusa Drumhead. A mechanical harvester was required to accommodate a maximum feeder leaf diameter of 0.9652 m (Pusa Drumhead). The maximum value recorded for the stump diameter, a parameter that all cutting techniques must consider, was 0.0510 m (September Early).

Varieties, soil types, and soil conditions all affected the amount of force needed to extract the plant from the soil. The Pusa Drumhead variety's maximum and minimum horizontal pulling force values were 178 N and 40 N, respectively, while the September Early variety's values were 140 N and 45 N, respectively. For the September Early variety, the vertical pulling force ranged from 45 N to 220 N. Conversely, feeder leaf angle ranges from 0 to 60 ˚, and stump length varied from 0.1080 to 0.0127 m with a mean of 0.0511 m. The cabbage's weight varied from 1.069 kg to 3.461 kg.

## 6. Lifting and Cutting Mechanisms for Cabbage Harvesting

including the weight of the head, outer leaf, and stump. The head height of a conveyor must be between 0.2320 and 0.1143 meters. These factors need to be considered because they vary from variety to variety. The cabbage harvester invented by Hamdy[18] and Boyer[29] was designed to lift the cabbage before cutting its roots. Lifter shoes were made to lift the head off the ground, align it with the lifter's V-belts, and keep it there until it was lifted and grasped. The V-belts kept the plant secure, from the lifter shoes to the trimming disc knives. Hamdy [18]employed two disc blades as a cutting element, whereas Boyer [29]only used one.

To raise the cabbages, Stout et al.[19] fastened steel fingers to the two lower sheaves of the V-belts. The cabbage plants were placed in front of two disc knives, one of which had a serrated edge. Wright and Splinter[18] employed a system that included a bandsaw blade, a head-sup porting device, and a set of discs. To make it easier for the plant to pass through the supporting device, the discs were positioned at the front to remove the lower leaves. The head was supported for the cutting operation by a set of hydraulically driven, spring-loaded V-belts on either side of the head. Fluck et al.[30] used a hydraulic cylinder to change the cutting height.

The cutter was a circular crosscut saw blade with a diameter of 45.72 cm that was powered by a hydraulic motor via a gear belt drive at roughly 2400 rpm. Kanamitsu and Yamamoto [21] cut the wrapper leaves and the leaf stem using a rotating disc cutter with a peripheral speed of 6 m/s. In the case of a tractor-mounted cabbage harvester, a height control system was used to regulate the harvesting apparatus's relative position from the ridge surface. A mechanism that used two belts to pull cabbages up with the stalk was introduced by Chagnon et al. [31]The stalks were cleanly cut by a revolving steel blade. It was determined that 37 m/min and 600 rpm were appropriate belt and blade speeds. As a stalk cutting tool, Bolhuis et al. [32]employed two contra-rotating cutter discs. To help with the cutting action on the stalks, scallops were formed in the cutting edge of one of the discs. Dobson [33] straightened the stems to a roughly vertical position using two forward plant alignment wheels. A toothed cutting disc-shaped rotary cutter was utilised. Du et al. [4]presented new dual discs with a diameter of 200 mm that were partially overlapped and staggered up and down. It was discovered that a rotational speed of 400 rpm was appropriate for chopping cabbage roots. Albarran et al. [34] employed a mechanical harvester with a stationary decorating device for cabbage, romaine lettuce, and iceberg lettuce.

In front of the decorating device, a positioning device was attached to the chassis. Willem [35] harvested vegetables, primarily broccoli and cabbage, using a cutter and stripper. The leaves were removed from the stem using the stripper. Together, the stripper and cutter moved vertically. It was made up of multiple blades or an anvil. In a single-row Egyptian cabbage harvester, El Didamony and El Shal [36] employed dual cutter discs. They employed four cutter disc speeds (400, 500, 700, and 900 rpm), four cutter disc angles (0 ˚, 15 ˚, 35 ˚, and 50 ˚), and two distinct cutter discs (smooth edge and serrated edge). They reported a cutter disc angle of 35 ˚ and a serrated edge-type disc operating at 900 rpm.produced optimum result.

## 7. Conveying and Trimming Unit

Hamdy [18] transported cabbages to the root cutting disc using a lifter V-belt. The trimmed heads and loose leaves were pushed to the cleaning belt at the back of the machine by an overhead belt that moved at 1.15 times the speed of the lifter V-belts. In order to separate the stems from the cabbages, Boyer [29] installed two parallel conveyors that moved the plants upward and backward on the frame into the path of a revolving blade. The same kind of conveying unit was also created by Stout et al. [19] A lifting V-belt raised the cabbage plants to a pair of disc knives.

A different method for cutting loose leaves was introduced by Wright and Splinter[18]. A PTO (power take-off)-driven elevation system received the cut heads after they were transferred to the conveyor. The separator unit received it after that. A flight roller was positioned above a flat belt in this unit at a 30-degree clockwise angle to the heads' direction of travel. Fluck et al. [30]raised the heads backward using an intermediary conveyor. The tractor's back was equipped with a loading conveyor. Each conveyor was driven by a separate hydraulic motor via roller chain drives. To lift Chinese cabbages in walking-type and tractor-mounted cabbage harvesters, Kanamitsu and Yamamoto[21] combined a set of biaxial screw augers under a set of feed belts.

Bolhuis et al. [32]transported the cabbages to the cutter discs using a fork-shaped guide, with the cabbages' heads above the guide and their stalks extending between the guide's limbs. After the stalks were cut, the cab bages were guided to be inverted and transferred from the cutting station to a lower receiving end of the rear conveyor arrangement thanks to the arrangement's geometry. Dobson [33]developed a brassica harvester with an endless conveyor. It was made up of two opposing rows of curved fingers that could be carefully rotated between an inner, closed position and an outer, open position.

The plant head moved to a closed position inside the conveyor after entering through the open side with the fingers. The cam tracks at the harvester's back end caused the fingers to open once more, allowing the cut plant heads to be released from the harvester onto a transverse conveyor belt. Du et al.[33] transported the cabbage plants from the picking mechanisms to the leaf separators using two transverse belts moving at the same speed. The flexible circular grooves on the surface of these two rubber belts, which measured 2 m in length, 20 cm in width, and 25 ° in inclination, carried cabbages. Albarran and associates.

did not include a conveying or trimming unit with a decorating mechanism in their mechanised harvester. The clogging issue between the lift and cutting zone was discovered by Toncheva et al[37]. Installing a transporter with an eccentric shaft, active tray, and blade clamp effectively resolved the issue. The goal of the optimisation was to shorten the heads' residence time in the shear apparatus. Important parameters included the platform's forward speed, the angular velocity of the eccentric shaft, and the space between the active tray and the blade clamping conveyor. Among these, the platform's speed was determined to be negligible, and the ideal shaft speed and clearance values were found to be 0.105 rad/s and 60 to 70 mm, respectively.

A model for the ideal number of workers involved in sorting cabbage heads under adaptive technology of a combine harvester was created by Alatyrev et al. [38] The shipping and stacking of cabbage heads in containers was regarded as a delay queuing system, while cabbage head correction was regarded as a multichannel queuing system (QS) with refusals. It was determined that two and three people, respectively, were the ideal number of operating personnel needed for correcting and stacking the heads in containers. To lessen damage to cabbage, Ali et al. [39] conducted kinematic analysis and simulation of the transportation component of a single-row Chinese cabbage harvester. width of transportation, link

In the analysis and simulation, length and feeding velocity were considered the key variables. Analysis of the links' position, velocity, and acceleration revealed that a link length of 190 to 200 mm was best for transporting cabbage. The simulation led to the selection of 500 to 600 mm for the transport width and 0.2 m/s for the cabbage transfer speed. For Chinese cabbage, Song et al. [40] created a semi-automatic pallet unloading and piling system that only needed one worker. To prevent major damage, the operator could slightly adjust the cabbage's position to ensure piling. The semi-automated piling mechanism with retractable bellows was equipped with a sensor to check incoming cabbages.

The suggested system's piling capacity was approximately 95.6% that of manual piling. A mass-based and volume-based real-time yield monitoring system was implemented in the transport section of a small cabbage harvester by Chowdhury et al. [41] Two CCD (charge-coupled device) cameras were used for the top and side images of the volume-based yield monitoring system. An impact plate made with load cells was utilised for mass-based yield monitoring. Both methods demonstrated a strong correlation with the measured weight of the cabbage, but the mass-based yield monitoring method performed better (coefficient of determination = 0.97) than the volume or image-based yield monitoring method (coefficient of determination = 0.94).

## 8. Leaf Removal Unit

Leaf Removal Unit Before the cabbage was sent to the conveyors, some researchers created a leaf separator unit to remove the wrapper leaves. The cabbage heads are shielded from mechanical harm during transit by the additional wrapper leaves. However, this would force vendors or vendors to physically separate wrapping leaves before selling. Wright and Splinter [18]employed a leaf separator unit made up of a flat belt with a flight roller positioned 3.5 inches above the belt at a 30-degree angle to the direction of head travel. While the heads rolled off the side into the last conveyor, the loose leaves and some immature heads went under the flight roller. [18]

introduced an adjustable cutting height arrangement but did not supply a leaf separator unit. In order to minimise the number of heads that needed to be trimmed, the header height was changed. The operator could most easily ascertain this by watching the heads on the intermediate con veyor roll while travelling backward. An inclined conveyor was first used as a leaf separation device by Chagnon et al. [31] However, the cabbages colliding with one another resulted in excessive bruising. The leaf separating unit was subsequently taken out. A leaf removal device with a rubber belt and conveyor belt was created by Du et al. [5] On the conveyor, the rubber roller had an inclination angle of 40 to 60.

The conveyor speed was found to be between 0.5 and 2 m/s, and the ideal rubber roller speed was determined to be between 300 and 400 rpm. For all of these leaf removal devices to function, a sizable area is required. The size of har vesters is increased by this extra space. Therefore, adding a leaf separating unit may cause a turning issue and raise the harvester's power requirements under Indian landholding conditions.

## 9. Performance of Cabbage Harvesters

At the Michigan State University Agricultural Engineering Laboratory, Hamdy [19] created a mechanical cabbage harvester based on a beetroot harvester. The cabbage heads were lifted and moved using a belt and inverted lifter shoes. Lifting, root removal, head trimming, and loose-leaf dropping presented some challenges for him. Most of the time, the lifter shoes and lifter belts broke the roots at the throat between the belts, pushed the plants forward, and gathered a lot of dirt and trash. A sliding runner, a positive feeding device (paddle and fingers), and a gathering element (steel fingers on sheaves) were used to solve this issue. These components are also required for improved cabbage harvester field performance, according to Stout et al. [19]

The cabbage harvesting machine's speed ranged from 1.28 to 1.77 km/h. The lifting and root cleaning mechanisms were unable to handle the volume of material at speeds greater than 1.77 km/h. Emerald

Cross and Market's mechanical harvesting capability The price variations were determined to be 10.20 and 9.30 t/h, respectively. Wright and Splinter [18] assessed the machine's performance based on the quantity of wrapper leaves remaining around the head, the source of damage, and head damage. Larger head weights were found to cause more damage. The percentages of marketable heads, machine damage, and unacceptable size were found to be between 36 and 73.2, 4.6 and 48.1, and 4.4 and 28.1, respectively. [18]

claimed that compared to the manual harvesting method, the cabbage harvester decreased bruising. After conducting a cost analysis of the cabbage harvester, it was found that providing three receiving vehicles would improve the harvester's productivity and reduce costs when unloading takes longer than thirty minutes. Kanamitsu and Yamamoto's tractor-mounted cabbage harvester [21] needed two operators and had a work speed of roughly 2.5 seconds per head. However, because it took a long time to remove the heads from the field and move them to the trucks, the fieldwork efficiency was only 41%. Chagnon and associates.

conducted an economic analysis of the mechanical cabbage harvester and found that workers were more productive when machines were used. Hachiya et al.'s trailer-supported harvesting system [42] was more than 50% faster than manual harvesting. One percent of the harvested heads in the field test were thrown away because the machine had cut them very deeply, which was regarded as cutting loss. The harvester's ideal forward speed was determined to be 10 cm/s, and its field efficiency surpassed 80% because it didn't need to stop in order to unload. According to Du et al. [42]in order to achieve superior harvesting quality of cabbages by machinery, the planting mode and certain uncontrollable factors, such as the uniformity of cabbages, were crucial.

The entire experiment was conducted in both the traditional field and the experimental field (planting standards were adhered to). The highest accurate cutting and picking rates in the experimental field were determined to be 75% and 93.3%, respectively. In the traditional field, the corresponding percentages were 57.8% and 95.8%. This demonstrated how planting mode affected the mechanical cabbage harvesting system's performance. In a push-type single row cabbage harvester that required a pushing force of 44 N on the road and 88 N on the field, Kumar [24]found that the average cutting efficiency, conveying efficiency, and head damage were 94.24%, 90.16%, and 9.84%, respectively.

At a forward speed of 0.14 km/h, the developed cabbage harvester's effective field capacity and field efficiency were 0.0058 ha/h and 82.85%, respectively. However, the harvester lacked a suitable mechanism for adjusting cutting height. Nevertheless, no research was done to maximise power usage. A single-row Egyptian cabbage's productivity, power needs, cabbage damage, and specific energy requirements were found to be 12.56 t/h, 2.28 kW, 3.8%, and 0.18 kW h/t, respectively [35] However, this harvester lacked a conveying and storage unit, so the operator had to manually gather the cabbages after cutting, which increased the labour requirement even more.

**Available Commercial Cabbage Harvesters**

ASA-LIFT cabbage harvester: Based in Sorø, Denmark, ASA-LIFT is a well-known producer of vegetable harvesting equipment. A tractor was needed as the primary mover. The cabbages were guided by cone-shaped rotating torpedoes, and saw blades severed the stem as it rose off the ground. It was then carried upward after being securely tucked between two rubber belts. Although there was a leaf trimming unit, two workers performed the final touch by hand. After carefully inserting the cabbages into the boxes, the boxes were set on a tipping platform to allow for a 90-degree tilt. This harvester's cutting height could also be changed. This device can harvest cabbages weighing one to eight kilograms. A minimum requirement of spacing of cabbage crop for quality harvesting was reported as 60 cm for harvesting speed of 3 km/h [43]

The Venhoucke single-row cabbage harvester was created by the Belgian business Vanhoucke Machine Engineering. It works well for harvesting various kinds of cabbages. The cabbages were raised to the front of the clip bindings by two propelled torpe does, which are long and conical in shape. A drum with stainless steel bars around its edge served as the clip binding. It pulled the cabbage from the ground and held it in place. Beneath the clip bindings was a propelled steel blade that could be adjusted in height to cut the roots. The leftover excess leaves were cleaned by two counter-rotating conveyors. The cabbage was then transported to a container or straight into a trailer by lift. Two operators, including a driver, were needed. The damage percentage was reported to be between 15 and 20 percent, and the power requirement was high—85 horsepower [43]. Univerco cabbage puller: Univerco, a Canadian company that manufactures equipment for horticultural culture mechanisation, created a cabbage harvester. This harvester used a picker (350 cm long and 88 cm wide) to pull the cabbages at an angle of 25. The cabbages were then lifted by inclined conveyor belts at a speed of 29 m/min to a revolving blade that cleanly cut the stalks. The cabbages were then transported from the picker's rear to the front of the tractor via a horizontal sorting conveyor. Before placing them in a storage bin, the workers were hired to pick and sort them. This harvester needed two tractors and four workers, including two drivers, despite having a lower damage percentage. In addition to not being affordable for India's rural farmers, this machine will not be appropriate for the land sizes used for cabbage cultivation in India [31]

**Worldwide Advancement of Cabbage Harvesting Technology and Present Condition of India**

In the early 1930s, Russia created the first cabbage harvester[4] Before creating a cabbage harvester, a number of researchers thoroughly examined the mechanical and physical characteristics of cabbage plants [18][19][20] To enhance working performance, parallel-twin screws [44] counter-rotating lifter belts [45] and raking reels [46] were introduced in the ensuing decades. Commercial varieties of cabbage harvesters mounted on large tractors were created by Hortech (Padova, Italy), ASA-LIFT (Sorø, Denmark), and Univerco Hydraulique (Napierville, Canada) [31] However, these harvesters are best suited for large fields rather than small ones.

In the 1990s, the Bio-oriented Technology Research Advancement Institution (BRAIN) of Agriculture Machinery in Japan began developing both walking and tractor-mounted cabbage harvesters [21] In order to cut labour costs and boost productivity, BRAIN later created a new automated system for harvesting cabbage, which was put on the market in 2001 [42]A basic cabbage harvester mounted on a tractor was produced in China, and field tests revealed that it performed well. To meet commercial demand, this harvester hasn't been promoted yet [4] However, there isn't a cabbage harvester on the commercial market in India.

Few studies [24][22] have measured some of the mechanical and physical characteristics of Indian cabbage varieties that are crucial for creating a mechanical harvester. Due to their size, cabbage harvesters from other nations cannot be utilised in Indian fields. Due to the small potential market, Indian farm machinery manufacturers are reluctant to start a development program for a cabbage harvester. However, in order to lessen their labour, cabbage growers require a cabbage harvester.

**10. Conclusions**

The literature on cabbage (dimensions and varieties), different cabbage harvester subsystems, and their performance was reviewed. Mature cabbages are typically cut by hand in India using a sickle or knife, which takes a long time. When harvesting cabbage, workers adopt a stooped posture that results in labour drudgery and decreases productivity. Research on cabbage harvesters has been done at a higher level in Europe, the US, Japan, and China, but only a small amount of research has been done in India, despite the country being the world's second-largest producer of cabbage.

The harvesters that are available in other countries run on conventional fuel and require multiple operators to operate with a larger prime mover. The cabbage harvester should be designed with low power consumption and comparatively smaller size (preferably single-row) for better handling in smaller fields and minimal damage to cabbages during cutting and conveying, taking into account the type of landholdings and the financial situation of Indian farmers. The only cabbage harvester created in India is a manual push model that uses a battery to power mechanical cutting. The cutting height cannot be changed to suit the various types of cabbages.

In-depth research on the mechanical and physical characteristics of various Indian cabbage varieties is required to provide such an arrangement. To save space and power, a separate unit can be attached in place of a separate leaf. A few researchers' kinematic analysis is limited to tractor-drawn harvesters, which might not be suitable for Indian conditions. For the smaller fields, a walk-behind self-propelled cabbage harvester is therefore necessary. Few studies have used optimisation to determine the ideal workforce size for a cabbage harvester. However, optimisation is required for Indian cabbage harvesters in order to lower power consumption while taking into account different operational parameters such as conveyor speed, cutting height, cutting speed, and forward speed.

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