Complete mechanization of oil seed crop cultivation for enhancement to augment the potentiality of yellow revolution in India-Review

ABSTRACT

This study explores how mechanization could support oil seed production in India in line with the self-sufficiency objectives of the yellow revolution. The text highlights the limitations, such as low yields and reliance on imports, and highlights how mechanization can increase productivity, profitability, and resource usage. Particular mechanized techniques for different stages such as field preparation, sowing, weed management, and harvesting are explored with an emphasis on groundnut, Castor, Sunflower, Rapeseed, Soybean and sesame cultivation. This review paper promotes broader adoption of mechanization as a crucial tactic to accomplish sustainable growth in oil seed production and reduce dependence on imports.

KEYWORDS Mechanization, yellow revolution, Precision farming, combine harvester, oil seeds, Productivity.

1. INTRODUCTION

Globally, the oil seeds is produced about 361 Lakh during 2020-21 followed by 332.192 lakh tones during 2019-20 where in India, it is produced about 41.5 million metric tons during 2022-23. In India, the oil seeds cultivated in 42.5mha during 2023-24 with production of 41.5 MT Data source: OAA New Delhi historical data series (2022-23) estimates. The oil seed crops include sesame (*Sesamum indicum L*.), sunflower (*Helianthus annus.L*), Rapeseed (*Brassica napus var*), groundnut (*Archasis hypogaea L*.), soybean (*Glycine max*), Castor (*Ricinus communis L*.). The country's edible oil demand is estimated to be 25.0 million tonnes, while domestic production only amounts to 11.2 million tonnes (The Hindu, March 17, 2022). The supply and demand for edible oils differ by 56.0%, in which filled by imports (estimated imports of 13.65 million tonnes in 2022–2023 compared to 13.84 million tonnes in 2021-22). (Dorab Mistry, September 23, 2022) in the Hindu. Although, the production of oil seeds were very low worldwide, the benefits such as high nutrition, high economic value, it must be covered for production over larger areas. Here with, mechanization would reduce consumption of time, labour could be managed efficiently and also it might profitable. Manual labour using bullock drawn implements is used for all fields operations consumes lot of time. So, used for Mechanization reduces labour and time requirements by 20-30%, saves seeds and fertilizers by 15-20% and increasing productivity by 10-15% Srinivas et al. 2009.The yellow revolution during the period of 1986-87 aimed at the production of oil seeds for self-reliance and the production increased from 12 million tonnes to 24 million tonnes. The father of yellow revolution is Sam Pitro and the revolution targets sesame, sunflower, soybean, castor, groundnut and rapeseed. In this review considering the importance of oil seeds from seed to seed discussed with critical analysis.However, the farming systems identify potential resource constraints of mechanization and this review primary objective is to clarify the benefits and profitability of mechanization in oil seeds.

2 .SESAME

According to Abou et al.2017Sesame (*Sesamum indicum)* is a Pedaliaceae family. The sesame is one of the world most important and oldest known oil seed crops. Sesame is also referred to as "Til" or "Gingelly" and is one of the oldest crops that yields oil. Sesame is known for its adaptability as a flavouring agent in a variety of Indian dishes even when it has an oil content of 40 to 50% Gojiya et al. 2022.Sesame is rich in calcium, phosphorus and protein is therefore a valuable source of nutrition its agricultural importance is expanding globally Gojiya et al. 2023.Sesame seeds contain fat, protein, minerals, vitamins and dietary fiber. Sesame oil, derived from traditional oil production methods is high in unsaturated fatty acids, fat-soluble vitamins, amino acids etc. furthermore, studies sesame seeds contain 21.9% protein, 61.7% fat and are rich in minerals like Fe and Ca Rout et al. 2018.

2.1 FIELD PREPARATION

A tractor or a traditional/country plough used to plough the ground. Then, it should be repeatedly harrowed or tilled using a rotary tiller. Considering that sesame seeds are tiny, this procedure aids in breaking up the soil, establishing a fine tilth, and getting rid of weeds to promote rapid germination Bandhiya et al. 2023.

2.2 SOWING

Manual planters also known as mechanically operated seeders are similar to hand-pushed or pulled seed drills, hand-operated seeders, tractor-operated seed drills, precision planters and pneumatic sesame row planters Fig.1. Some of the parts that will become more complex include hand-pushed seed drills, seed metering devices, and furrow openers for planting sesame seeds. Therefore, even though they have limited capabilities, farmers who use hand hoes to prepare their land frequently rely on manual planters Sharaby et al. 2019.

Pneumatic Precision Planter - seed sowing

Fig.1. Different type of Sowing in Sesame

2.3 POWER TILLER-MOUNTED AIR-ASSISTED SEED DRILL

A power tiller operated air assisted seed drill has been developed by TNAU, Coimbatore specifically for sowing small seeds like sorghum, cumbu and sesame. You can change the distance between rows from 300 mm (for four rows) to 600 mm (for two rows). The device can efficiently plant seeds in that region in the allotted time. By raising the tool bar, the metering shaft's power can be turned off. The machine has a field capacity of 0.15 to 0.2 hectares per hour. Which means that during an hour of use, it can cover an area of that size Bandhiya et al. 2016.

2.4 WEED MANAGEMENT

Weeding was done using a self-propelled power weeder 35 days after sowing Divya et al.2015. For row-seeded sesame crops, use blade harrowing for inter-cultivationBandhiya et al.2023

2.5 HARVEST

Sesame seed harvesting can commence when the plant's lower leaves start to shed and its leaves, stems and capsules turn yellow in colour. Delaying till the crop reaches full maturity may result in seed shedding, so it is important to act quickly. Ripe sesame plants should be chopped at ground level for

harvesting Fig.2. Once the plants have been harvested, stack them in the sun for a week or ten. In doing the plants are able to dry and become ready for the threshing procedure. The diesel single-cylinder engine of the reaper-binder has a 12.2 horsepower output. Four forward gears and one reverse gear are available in its mechanical drive system. A gear drive that is controlled by a lever allows the power take-off (PTO) to be engaged.

The cutting bar, which has a 140 cm cutting width, has continuously moving forks that effectively move the cut crop in the direction of the binder. When the sheaf is ready, the binder itself ensures accurate twine cutting and binding of the cut crop. With the use of a special spring, the sheaf diameter can be changed in four different ways to provide flexibility according to different needs. Using a pedal, the reaper-binder's lifting and lowering operations are hydraulically drivenGojiya et al. 2022.

Reaper Binder-Harvester

Fig. 2.Sesame Reaper Binder Harvesters

3. GROUNDNUT

One of the most important food and oilseed crops in the world is groundnut, or peanut (*Arachis hypogaea L.*; 2n = 4x = 40). One of India's main oilseed crops, groundnuts account for 25% of the nation's total oilseed production. Groundnuts are grown on 27.66 million hectares worldwide, and their total yearly production is 43.98 million tons (FAOSTAT 2022).

3.1 FIELD PREPARATION

A good seed bed is prepared for the sowing process using secondary tillage equipment such as rotavator and disc harrow following the primary tillage operation Fig.3. shahid et al. 2010. A tractor – drawn rotavator is used to prepare the land after a disc harrow Arivazhagan et al. 2023.

Rotavator

Fig.3. Different type of Field preparation

3.2 SOWING

According to Hari sudanet al.2020mechanizing groundnut cultivation through scientific intervention could potentially achieve the dual goals of increased productivity and energy efficiency. Groundnut seeds were used in the mechanized sowing process using an IAC Runner, with 0.9 m row spacing. Twenty meters in length and twelve meters in width, each plot measured 240 square meters. The tractor-digger-inverterFig.4.set'sdisplacement speed stabilization and maneuverability were represented by a 15-meter-long plot among the longitudinal plots Zerbato et al. 2014.

Mutlicrop seeder

Fig.4. Different sowing methods of mechanization for Groundnut.

3.3 WEED MANAGEMENT

Crop production is greatly influenced by weed control, which also determines the crop's success. Today, the most popular techniques for getting rid of weeds are hand weeding and applying herbicides. Weeding with a nail weeder days 25 and 45 utilizing a power weeder through 25 and 45 DASArivazhagan et al. 2023Fig. 5.A large area will be weeded in a short amount of time using a tractor-drawn weeder that can cover four to five hectares per day According to Yadav et al. 2007. Mechanical weed control not only removes weeds from between crop rows but also maintains a loose soil surface, which improves soil aeration and water intake capacity.According to Chivinge et al. 1990Mechanical weed control is a less labour-intensive and faster method than hand weeding. Cash crops inter rows, such as cotton, tapioca, and grape, can benefit from weeding in between with a power weeder.

Nail weeder

Power weeder

Fig.5. Weeding for different mechanization in Groundnut

3.4 INTERCULTURAL OPERATION

The growth of weeds poses a significant obstacle to crop productivity and production, and weed control is crucial to crop yield. Nowadays, it's common practice to remove weeds by hand weeding and applying herbicides. Mechanized weeding stretches the soil to create an environment that is conducive to peg penetration. A large area will be weeded in a limited amount of time using a tractor-drawn weeder that covers five to five hectares per day Govindaraj et al. 2011.

3.5 DECORTICATING EQUIPMENT

The process of removing groundnut kernels from their dried pods is known as decortication; the decorticator can handle 250–300 kg of groundnuts per hectare. In a brief amount of time, huge quantities of groundnut pods are shelved Madhusudhana et al. 2019.

3.6 HARVEST AND THRESHING

Reported that Negrete et al. 2015 groundnut combine harvester operation yield savings of 39% and 96% in terms of money and time, respectively, in comparison to the traditional manual digging and stripping method. Harvesting groundnuts is a significant operation that requires a large workforce and high cultivation costs. According to Madhusudhana et al.2019 groundnut strippers are highly helpful, and a combined harvester will make the post-harvesting process easier to complete. To improve the quality of the mechanized digging process, it is therefore imperative that the operation be suitable for each scenario that arises and that all potential causes of loss are minimized. A 4X2 FWD tractor with a 110 kW (150 hp) engine was used to pull a 2x1 digger, which formed a plot of two lines, at a speed of 7 km/h. The tractor was designed for mechanized peanut digging in sandy, medium, and loamy soils Fig. 6. Digging was done in the loamy soil with a 4x2 digger (four lines forming two plots) pulled by a 4x2 FWD tractor with an engine that produced 139.7 kW (190 hp) at nominal speed, or 7.3 km/h^{-1}.

Mechanical harvest

Fig. 6. Mechanical Harvest for Groundnut

4. CASTOR

Castor (*Ricinus communisL.)* is a significant non edible oilseed. All India castor production in 2022-23 is at 18.82 lakh tonnes as against 16.19 lakh tonnes in 2021-22. *Ricinuscommunis L*. has 2n = 20 Chromosomes and is a member of the Euphorbiaceous family. The species known as Castor bean (*Ricinus communis L.)* is indigenous to Ethiopia in Africa. The Indian agricultural sector is gradually transitioning from relying on human labour and draft animal power (DAP) to using mechanical power, as the upkeep of DAP and manual labour is getting more expensive in addition to limited supply of food and fodder for animals.As a result, mechanical power has become more affordable and necessary to achieve goals of timeliness and effective use of input use and natural resources Srinivasarao et al. 2013.

4.1 FIELD PREPARATION

One of the newly popularized tools used by farmers for primary tillage work is the tractor-driven 5 or 8-tyne duck foot, cultivator, and disc plough, which enhances castor root growth for deep penetration and yields higher yields Figeure7. Manikandan et al. 2021studied the draught needed for a five-tyne duck foot plough in clay soil at varying tractor forward speed, depth of operation, and soil moisture content.

Figure 7 Field Preparation of Five tyne Ploughing

4.2 SOWING

TRACTOR DRAWN ANANTA PLANTER FOR CASTOR

Tractor-drawn Ananta groundnut planter (3 rows) is introduced to mechanize castor sowing for timely operation and mechanical advantage. To cover the furrows after seeding, a 5 cm wide covering blade is installed behind the furrow openers. The inclined disc plate seed metering mechanism provides accurate seed-to-seed distance and maintains the recommended seed rate for dry land crops. There is very little damage to the seeds, and they are planted at the right depth of 4-5 cm. With a field capacity of 6 to 7 ha/day, a sizable area can be covered before the soil moisture dries up Reddy et al. 2022.

4.3 WEED MANAGEMENT AND FERTILIZERS APPLICATION

Considering all these factors in view, a mini rotary weeder cum fertilizer drill has been developed in Junagadh Agricultural University Rotary weeder cum fertilizer drill was developed for wide spacing crops like castor, pigeon pea and cotton. This machine is operated by the mini-tractor power take off (P.T.O) using three-point hitch system and performs inter-cultivation in between the rows and drills the fertilizer near root zone. Simultaneous weeding and fertilizer application helps in energy and time saving.

4.4 ROTARY WEEDER-CUM-FERTILIZER DRILL

The overall dimensions of the machine were 1050 × 1460 × 1240 mm in length, width, and height. The machine's main frame, weeding system, and fertilizer application system are its three main parts**.** The implement's width of coverage was intended for 1.2 m row crops. When weeding is at its worst, eight hours of manual labour are needed for weeding and fertilizer application. However, if a rotary weeder cum fertilizer drill is used, inter-culturing and fertilizer operations can be finished in as little as 5.1 hours of labour with just one worker Venkat et al. 2020.

4.5 HARVEST

When the capsules are fully dry, they are harvested, and if this process is delayed, there may be a significant loss of seed for shattering. Thus, a certain amount of aerial biomass which, in the case of castor plants, is not in significant is transported within the cleaning system. Zhao et al. 2019suggest an alternative method, Particular the potential to harvest the capsules alone that is, to avoid chopping and threshing the entire plant. The cutting bar that is installed on the combine harvester's header is to be replaced with a vibrating system in this novel approach.

According to Stefanoni et al. 2022the implementation of a sunflower header on a conventional combine harvester may serve as a precursor to the eventual development of a fully automated castor bean harvest phase. This would result in reduced seed loss and maintain the combine harvester's cleaning capabilities. Many plant varieties and threshers are still in the testing stage. The mechanical harvesting method has been employed due to the suitability of dwarf hybrid castor plants. Moreover, the right defoliant is needed. The plants' residual moisture content was sufficiently decreased by the defoliant to enable mechanical harvesting Haleem et al. 2022 Combine harvesters are able to work faster and more effectively, which benefits farmers by increasing grain yield and quality. Additionally, the work is completed faster than it would have with human labour. Overall, Indian farmers may increase the economy and profitability of their agricultural operations by utilizing combined harvesters Stefanoni et al. 2022.

4.6 THRESHING

According to Naik et al. 2016mechanized castor farming saved a significant amount of time (490 hrs/ha) and labor (58 man-days/ha) when performing various agronomic tasks. It also helped in completing all field operations on time and with high precision. The AICRP on Castor designed and developed two power-operated and hand-operated threshers that are suitable for small and marginal farmers, both of which are farmer-friendly and small-scale. The castor thresher is powered by a 10 hp diesel engine with a coolant oil engine at 1440 rpm, capable of threshing 500 kg per hour at 91% efficiency. The Mini Power-operated Castor Thresher uses a 0.5 HP motor at 220 RPM to produce approximately 50 kg per hour. The thresher's 85% efficiency makes it easier for farmers to operate Reddy et al. 2022.

5.SUNFLOWER

5.1 LAND PREPARATION

Before the plants sprout, sunflower maintenance involves harrowing the culture with an adjustable coulter harrow or a rotative hoe to level the ground, crush the crust, and remove any weeds before sunrise. It is a very significant piece of work in sunflower Tudorache *et al.,* 2013.According to Kheiralla et al. 2004 the disk harrow (as opposed to the rotor tiller, disk plough, and mouldboard plough) was the most energy-efficient piece of equipment in terms of fuel consumption and specific energy. Ploughing with a FENDT FARMER 311 LSA tractor and a reversible HUARD plough copcea et al. 2020.

5.2 SOWING

Sowing sunflowers using a U-650M tractor as well as SPC 4F seeder copcea et al. 2020Single-seeded seeders are used to sow sunflower seeds in a dotted pattern. Pneumatic and mechanical seeding units are included with these seeders. Due to their greater versatility, pneumatic seeding devices are more commonly used. Conversely, extrabaric seed metering systems or vacuums are used by pneumatic seeding devices. The sowing disc moves the seeds pressed against the holes to the work area of the extra seed spreader, with the goal of leaving one seed in each sowing disc hole. When there are two or more seeds in the hole, the spreader operation is required. Therefore, ejectors can be plate, roller, brush, or combination. Kizhnyak et al. 2021.

5.3 FERTILIZER APPLICATION

According to copcea et al. 2020fertilization with a U-650M tractor and a NORDAGRI 500 fertilizer Machine.

5.4 WEED MANAGEMENT

U- 650M tractor and cultivator CPPM-4 copcea et al. 2020 for weeding.

5.5 HARVEST

The components of a sunflower header typically include the frame, auger, cutting units, dividers, choppers stems, and seed conveyorsStartsev et al. 2020.Sunflower header use is typically linked to 2% seed loss values Chaplygin et al. 2019.These sieve holes, which resembled sunflower seeds in shape, allowed for area adjustment based on the features of the harvested cultivar's seeds. By comparing the hopper heap with an unequipped combine harvester, these enhancements allowed for a notable 38–42% weight reduction in superfluous material Startsev et al. 2020. The chopper unit was made up of four bearings, three blade modules, a main shaft, three bevel gear mechanisms, and a main body. Harvesting sunflowers using a JOHN DEERE 1052 combine and RFS tools[12] . By doing the chopping concurrently with the harvesting process, a second operation was avoided, saving time, labour, and energy. In the field, the average height of the stalks was 15 cm, which was comparable to the average size of the material chopped during a standard second-passage chopping operation.1.00 l h^{-1} was reported as the additional fuel consumption of the combine harvester because of the chopping unit Dalmis et al. 2013.

6. SOYBEAN

6.1 FIELD PREPARATION

When compared to soybeans planted on flatbeds and ridges and furrows, the NMR was noticeably higher when soybeans were sown in bunkers. A comparable pattern was noted in the (B: C) ratio. Complete mechanization significantly improved the benefit: cost ratio when compared to flat bed cultivation, the traditional method. Considering the increase in soybean yield, Khambalkar et al. 2014also received comparable outcomes. Soybean yield increases when soil physical qualities and soil microbial activity are improved by the land preparation system (Mould board one pass + Rotation one pass + Levelling)Attafyet al.2017**.**

6.2 SOWING

After studying different sowing devices, H.L. Jia created a device that allowed airflow with a pad drum directly on the machine without the need for a ventilator. The device's diameter was 11 mm, and the work quality at a high operating speed of 12 km/h surpassed that of the previously used pneumatic planting device, which had a range of 24.4 mm and a slit number of 13 Jia et al. 2018. Liu et al. 2016 developed experimental platforms with vertical sowing discs and optimized their parameters. Jia et al. 2019developed a horizontal sowing apparatus with an 11 mm diameter that allows airflow with a pad drum directly on the machine without a ventilator.The device outperformed the existing pneumatic planting device with a range of 24.4 mm and a slit number of 13 at high operating speeds. SChX-4, a mechanical seeding machine, is widely used in Uzbekistan Astanakulov et al. 2020. The highest

soybean yield (18.45% more) was achieved with complete mechanization, which was found to be significantly better than the other treatments. Furthermore, it is concluded that in-situ moisture conservation methods have been shown to be effective in improving soil water availability and raising soybean yield Khambalkar et al. 2014.

6.3 WEED MANAGEMENT

These commercially available tools are designed to control weeds in between rows and plants in sown rows; the two most famous are the Garford Farm Machinery model Robo crop and the Einbock model Row-guard. In addition, harrowing before planting can also help to reduce the weeds in soybean Gesimba et al. 2005. Wheel hoeing twice at 20 and 40 DAS recorded the highest seed yield (9.07 q ha-1).

6.4 HERBICIDE APPLICATOR-CUM-PLANTER

The PREHAP, tractor-drawn equipment, consists of a sturdy frame equipped with a cat-II 3 – point linkage. It also includes a tool bar, a herbicide solution tank, a single action piston pump, a pressure gauge, hose connections, a fertilizer box, six modular seed boxes with spray - nozzle assembly. Additionally, it features furrow openers and a ground wheel drive power system to efficiently operate the seed and fertiliser metering mechanisms Potdar et al. 2023. The granular fertilizer application on the main frame is facilitated by a fluted roller type metering mechanism installed in the fertiliser box.

6.5 FERTILIZERS MANAGEMENT

A significant advancement in enhanced intercropping systems is the automated process of planting, fertilizing, and harvesting. The wheel distance (2870 × 1300 × 1900 mm) is reduced with a special four-wheel tractor Xue et al. 2016.An additional punji is fastened to the tractor-operated seed-cum-fertilizer drill machine's back tines in order to create the ridge and furrow system Basediya et al. 2018.

6.6 INTERCULTURAL OPERATIONS

This tractor-operated sweep seed drill was used to continually drill the soybean crop, ensuring row planting at a 45-centimeter row-to-row spacing and 70 kg of seed per hectare. One important factor taken into account when designing the sweep seed drill was tilling the ground in between crop rows without interfering with the simultaneous sowing of seedsDevvrat et al. 2012.

6.7 HARVEST

In order to effectively monitor mechanical soybean harvesting losses, a pair of Massey Ferguson combine harvesters, specifically the MF9790 model, was employed. These combine harvesters were equipped with an advanced axial flow threshing system, boasting an impressive engine power rating of 261 kW (355hp). Furthermore ,they featured a substantial grain tank capacity of 10.570l the harvesting process was facilitated by a 10.7m(35 feet) power flex draper header and a 9.1 m (30 feet) screw conveyor(auger). Two distinct travel speeds were utilized: V_1 at 6 km h^{-1} and v_2 8km h^{-1}Menezeset al. 2018. This finding supports the notion that draper headers exhibit superior harvesting quality compared to screw conveyors.

Table. 1 Farm machinery and operations used under various levels of mechanization

List of implements / machineries used			
Operations	**Complete mechanization**	**Partial mechanization**	**Traditional method of cultivation**
Ploughing	MB plough tractor drawn	MB plough tractor drawn	Bullock-drawn plough Bullock drawn harrow.

Sowing	BBF planter for Seed drill (tractor drown)	BBF planter for seed drill (tractor drown)	Bullock drawn BBF-Bullock drawn seed drill
Spraying	Tractor drawn boom spray	Tractor drawn boom spray	Manual spray
Intercultural	Tractor drawn implement	Tractor drawn implement	Manual
Harvesting	Combine harvester	Harvesting manually and threshing	Manual harvesting and threshing

Mould board (MB), Broad Bed Furrow (BBF)

Asewar et al. 2019

7. RAPESEED

Table. 2 Rapeseed Cultivation for different machinery

S.NO	Operation	Machine	Reference
1.	**Field Preparation**	• John Deere 1206 tractor was accompanied by a SC-900 soil compaction meter, an MS-350 Combined with a GB/T 5668-2008 "Rotary Tiller," the rotation speed of the rotary tillage blade roller.	Jiang et al. 2022
		• The 1LZ-5.4 combined land preparation machine and the 1ZML-210 subsoiling combined soil preparation machine were developed.	Jiang et al. 2022
		• Blade for rotary tillage Rotating tillage blades, Roller Design T245 and T225	Jiang et al. 2022

2.	**Sowing**	• To open the furrow, the 2BFQ-6 type combined rapeseed seeder uses both the front and back plows.	Chen et al. 2023
3.	**Weed management**	• Rotary cultivator and sweep cultivator	Naderi et al. 2015
3.	**Fertilizer Application**	• In Rapeseed, pneumatic granular fertilizer spreaders (MPGFSs)..	Wang et al. 2023
		• Application of fertilizer A Pro-Til 4T hybrid machine was used for the operations.	Jaskulska et al . 2020
4.	**Harvest**	• The impacts of LMB and LBH on the mechanized harvest.	Qing et al. 2021
		• The cutting platform kinematics and dynamics of a combine harvester	Tang et al. 2017

8.CONCLUSION

Mechanization has a prime role as a force multiplier to compensate labour shortage and for carrying out the operation in time resulting in higher productivity. Mechanization serves the dual purpose of increasing productivity on the land that is already there and achieving higher land productivity by utilizing machinery as a complementary input. The shortage of labour in agriculture has been caused in recent years by a constant movement of rural residents toward the services sector in search of better working conditions, increased urbanization and village migration in search of better opportunities, the rise of rural entrepreneurs, etc. It's important to note that the degree of

mechanization may vary based on factors such as the type of oilseed crop, the scale of farming operations, and local conditions. Additionally,farmers should consider sustainable practices and environmental impacts when adopting mechanization in oilseed crop production. A combination of various machines, technologies, and precision farming techniques are needed for full mechanization. Furthermore, the field of agricultural mechanization for oilseed crops is advanced through continuous research and development. For many large-scale, contemporary agricultural operations, the long-term advantages of greater productivity, decreased reliance on labour, and enhanced yield outweigh the initial cost of achieving total mechanization.

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