Complete mechanization of oil seed crop cultivation 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

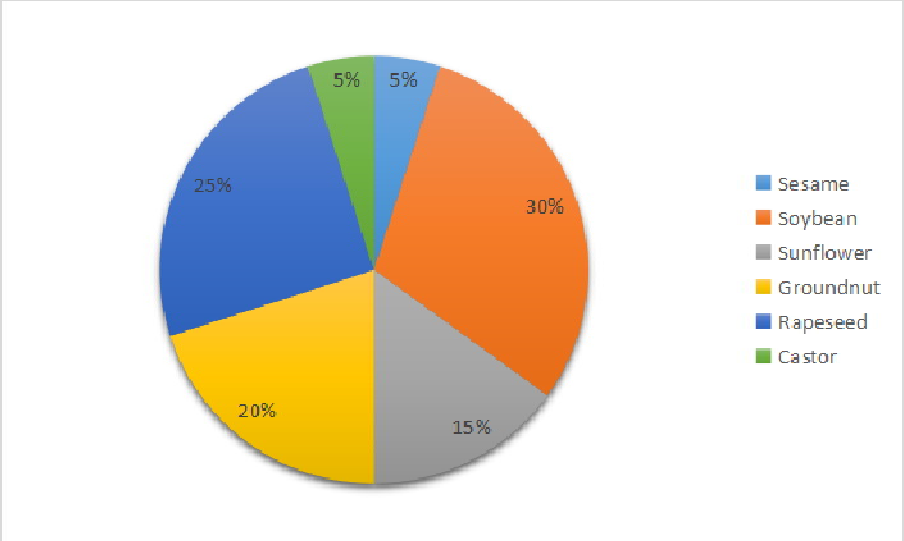
Globally, the oil seeds production is about 659.36 million metric tons during 2023-24. In India, the production of oil seeds during the 2022-23 about 41.5 million metric tons. The oil seeds cultivated in 42.5mha during 2023-24 with production of 41.5 MT. The country's edible oil demand is estimated to be 25.0 million tons during 2023-24, while domestic production only amounts to 11.2 million tonnes(FAOSTAT, 2023-24). 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). India has a low percentage of farm mechanization (40%) when compared to the US (95%), Western Europe (95%), Russia (80%), and Brazil (75%) (Renpu, 2014). Due to the introduction of major economic reforms of Liberalization, Privatization and Globalization, increased rural-urban migration, labour shortage for agriculture, increased share of non-agriculture in both employment and income, increased non-farm incomes compared to farm incomes, rising input costs including labour cost and wider adoption of farm mechanization (Satishkumar and Umesh, 2018). Grigg estimated that the share of the world workers employed in agriculture reduced from 72 to 62% between 1950 and 1990. At present scenario, the International Labor Organization (ILO) estimates that agriculture employed 27% of the world's workers in 2019 (Larson and Bloodworth,2023). In 1950 and 2020, the share of the global population living in rural areas declined from 70 to 40% (UN 2022). 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 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.*) etc. The study conduct in the crops indicated that the national yield of oilseed crops is low as compared to their yield potential (Table 1). The percent share of major oilseed crops in domestic oil production is given in Fig. 1

Table 1. Yield Potential of different Oilseed Crops.

Crop	Average yield (Kg/ha)	Yield potential (kg/ha)	Yield gap (Kg/ha)	Unachieved potential (%)
Sesame	600	700 -1,500	800	60
Groundnut	1700	2579	8000	33.04
Soybean	1500	3,000-3,500	1600	53.57
Castor	1750	3,750	1800	33.04

Sunflower	900	3000- 2500	1700	68
Rapeseed	600	2000-2500	1200	46.6

Source: Doubling Farmers' Income Committee (DFIC) , IJ Plant & Soil Science, Directorate of Oilseeds Development India,Indian Council of Agricultural Research - Oilseeds Research(ICAR) (2022-2023) .



(Directorate of Economics and Statistics, Agriculture (DESA), Agri Farming, India Briefing 2022-23)

Fig .1. Area share of major oil seed crops in mechanization

Reddy et al. (2023) revealed that mechanization has reduced the cost of cultivation of groundnut/acre by 20.6% as compared with the farmer's method of cultivation and thus decrease in the cost of cultivation will proportionately increase the net profits and the Benefit cost ratio of groundnut cultivation. The yellow revolution 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 the farming systems identify potential resource constraints of mechanization and this review primary objective is to clarify the benefits and effectiveness of mechanization in major oil seeds.

2 .SESAME

According to Singh et al. (2022) Sesame (*Sesamum indicum)* is a Pedaliaceae family. 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 and 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 revealed that 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 planter mechanically devices are operated manually by either pushing or pulling using hand pushed pulled seed drills for facililating effficient planting.hand operated operated are compact and portable for even distribution of seeds and also tractor operated seed drills efficiently sown the seeds quickly and uniformly. Pnematic sesame row planters are specialized planters use air pressure to plant sesame seed in rows Fig.2.The above soild mechinerios has increased efficiency,consistency, adaptability,resource management and reduced physical strians over traditional methods (Sharaby et al. 2019)

Power Tiller Integration The seed drill is mounted on a power tiller, which supply the necessary drive and movement. The engine powers the seed drill, allowing it to be operated more efficiently than manual methods.

Air-Assisted Mechanism The seed drill employs an air-assisted system to ensure accurate seed delivery and distribution. This system features a fan or blower that generates an airflow to transport seeds from the hopper to the furrow.The air stream helps distribute the seeds evenly and reduces the risk of clogging.

Seed Metering The seed drill features a metering mechanism that controls the seed flow from the hopper. This system manages the seed release, ensuring that seeds are distributed at uniform intervals and depths. The operator can adjust the mechanism based on the type of seed and the desired planting density. Seed drill designed for sowing small seeds like sorghum, cumbu and sesame. This machine allows the operator to adjust the row spacing between 300 mm (for four rows) and 600 mm (for two rows). By raising the tool bar, the power to the metering shaft can be disengaged. The seed drill has a field capacity of 0.15 to 0.2 hectares per hour it can cover this area in one hour of operation, which is a notable improvement over traditional sowing methods (Bandhiya et al. 2016).

Fig.2.Flow chart of different machine's in sesame cultivation

2.4 WEED MANAGEMENT

Weeding was done using a self-propelled power weeder 35 days after sowing (Divya et al.2015). It is suggested to use blade harrowing for inter-cultivation of For inter -cultivation row-seeded sesame crops, use blade harrowing for inter-cultivation (Bandhiya 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. Sesame plants should be chopped at ground level for harvesting Fig.3. The diesel single-cylinder engine operated 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 based to different needs. (Gojiya et al. 2022).

Fig. 3. Reaper Binder-Harvester

3. GROUNDNUT

One of the most important food and oil seed crops in the world is groundnut, or peanut (*Arachis hypogaea L.*; 2n = 4x = 40). One of India's main oil seed crops account for 25% of the nation's total oilseed production. Groundnuts are grown in 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 (shahid et al. 2010). A tractor – drawn rotavator is used to prepare the land after a disc harrow (Arivazhagan et al. 2023).

3.2 SOWING

According to Hari sudan et al. (2020) mechanizing groundnut cultivation through scientific intervention could potentially achieve the dual goals of increased productivity and energy efficiency. Groundnut seeds were sown using an Instituto Agronomico de Campinas (IAC) Runner in a mechanized process with a row spacing of 0.9 meters Each plot, measuring 240 square meters, had dimensions of 20 meters in length and 12 meters in width. The tractor-digger-inverter displacement speed stabilization and maneuverability were represented by a 15-meter-long plot among the longitudinal plots (Zerbato et al. 2014).

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 free of weeds are hand weeding and applying herbicides. Weeding was carried out using a nail weeder at 25 and 45 days after sowing (DAS), with a power weeder also utilized at 25 and 45 DAS Fig. 4. (Arivazhagan et al. 2023). According to Yadav and Pond (2007) 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. Chivinge (1990) revealed that mechanical 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 Fig.5.

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 and mishra 2011).

Fig.4. Nail weeder

Fig.5. Power weeder

3.4 INTERCULTURAL OPERATION

Traditionally, hand weeding was practiced by the farmers and end of the twentieth century improved 4 row ananta bullock drawn inter-culture implement were used for removal of shallow depth weeds in between rows of groundnut crop. It consists of 4 straight blades, frame, handle and beam to attach with a pair of bullocks. The blades are fixed to the frame to which handle is attached. The blades are the working components which are made from medium carbon steel or mild steel for more strength to resist soil friction and to have long life. The width of each blade is 15 cm. for operation, the weeder is passed in between the rows of crop so the blades cut and uproot the weeds. Its field capacity is 2.0 ha/day (Reddy et al. 2019).

As modern machineries, 8-row tractor operated inter-culture implement used for weeding in groundnut crop developed at Agricultural Research Station, ANGRAU, Anantapur. Its frame is provided with 8 tynes, each tyne attached with T or V-shape sweeps to work in between 30 cm row spacing of the crop without any plant damage. Two small width pneumatic tyres of 8.3" X 28" size need to be fitted to the rear axle of the tractor to run in between rows of the crop instead of normal size tyres to prevent trampling of plants under the tyres. The size of the sweeps range from 4" to 6" and its field capacity is 4 to 5 ha/day (Reddy et al. 2019).

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 (Reddy et al. 2019).

Power operated groundnut decorticator is used to shell groundnut pods and to separate kernels. This is operated with 2 H.P single phase electric motor. It consists of feed hopper, rasp bar cylinder with hard rubber linings, perforated concave screen, two oscillating sieves and a blower. The groundnut pods are shelled between the rubber linings of cylinder and fixed perforated concave screen by rubbing action. The decorticated shells and kernels fall down on oscillating sieves through the

perforated concave screen. A centrifugal blower with spiral casing provided in between the perforated concave screen and oscillating sieves separates the light weight shells from kernels. Oscillating sieves separates pods from stalk, leaves and other foreign material. Its capacity is 250 – 300 kg/h and attached with electric motor (Reddy et al 2019).

3.6 *HARVEST AND THRESHING*

Negrete et al. (2015) reported that 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. Reddy et al. (2019) stated that 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 Front-Wheel Drive 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. 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}.

Fig.6.Flow chart of different machine's in groundnut cultivation

4. CASTOR

Castor (*Ricinus communis L.)* is a significant non edible oilseed. In India castor production in 2022-23 is 18.82 lakh tonnes as against 16.19 lakh tonnes in 2021-22. (*Ricinus communis*) has 2n = 20 Chromosomes and is a member of the Euphorbiaceous family. The species known as Castor bean is indigenous to Ethiopia in Africa.

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. Manikandan et al. (2021) studied the draught needed for a five - tyn duck foot plough in clay soil at varying tractor forward speed, depth of operation, and soil moisture content.

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 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

The mini rotary weeder cum fertilizer drill, developed by Junagadh Agricultural University, is designed for wide-spacing crops like castor, pigeon pea, and cotton. It is compatible with mini-tractors and operates via the tractor's PTO, using a three-point hitch system for stable attachment. This machine performs inter-cultivation and drills fertilizer near the root zone, managing weed growth and enhancing nutrient uptake.By combining weeding and fertilizing into one operation, it significantly saves time and energy (Reddy et al. 2022).

4.4 ROTARY WEEDER-CUM-FERTILIZER DRILL

The overall dimensions of the machine were 1050 × 1460 × 1240 mm (L×W×H). 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 ready to harvest and if this process is delayed, there may be a significant loss of seed due to 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. 2019) suggest 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. (2022) the 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 (Stefanoni 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

In accordance with Naik et al. (2016), mechanized castor farming saved a significant amount of time (490 h/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 All India Coordinated Research

Project 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 h. The thresher's 85% efficiency makes it easier for farmers to operate (Reddy et al. 2022).

Fig.7.Flow chart of different machine's in castor cultivation

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 mould board 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

Generally sunflowers are sown using a U-650M tractor as well as SPC 4F seeder (copcea et al. 2020) Single-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 (Khizhnyak et al. 2021).

5.3 FERTILIZER APPLICATION

According to (copcea et al. 2020) fertilization done with a U-650M tractor and a NORDAGRI 500 fertilizer machine.

5.4 WEED MANAGEMENT

U-650M Tractor designed for versatile agricultural operations, including soil preparation, planting, and crop maintenance and CPPM-4 Cultivator Specialized for soil cultivation, weed control, and aeration the weed control is up rooting weeds, reducing competition with crops (copcea et al. 2020).

5.5 HARVEST

The components of a sunflower header typically include the frame, auger, cutting units, dividers, choppers stems, and seed conveyors (Startsev 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 (copcea et al. 2020) . 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).

Fig.8.Flow chart of different machine's in sunflower cultivation

6. SOYBEAN

6.1 FIELD PREPARATION

When compared to soybeans planted on flatbeds and ridges and furrows, the net monetary return was noticeably higher when soybeans were sown in bunkers. A comparable pattern was noted in the (B:C) ratio. Complete mechanization significantly improved the B:C ratio. when compared to flat bed cultivation, the traditional method. Considering the increase in soybean yield, (Khambalkar et al. 2014) also 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). Jia et al. (2019) developed 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 traditional methods. 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

The 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 and langat,2005). Wheel hoeing twice at 20 and 40 Day After Sowing 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 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. 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 (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 seeds (Devvrat 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). 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.

Fig.9.Flow chart of different machine's in soybean cultivation

Table 2. Farm machinery and operations used under various levels of mechanization in soybean crop

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)

7. RAPESEED

Rapeseed (*Brassica napus*), also known as oilseed rape family Brassicaceae (mustard or cabbage family). In India total production of 12.64 million metric tons and area under cultivation of 9.2 million hectare during 2022-23(Ministry of Agriculture & Farmers Welfare,2022-23). In this rapeseed crop multiple values for oil production,the world wide second oleaginous plant (Friedt et al.2018).

Table 3. Mechanization in rapeseed crop

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.	
		• Blade for rotary tillage Rotating tillage blades, Roller Design T245 and T225	
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**	• pneumatic granular fertilizer spreaders (MPGFSs).	(Wang et al. 2023)
		• Application of fertilizer A Pro-Til 4T hybrid machine	(Jaskulska et al . 2020)
4.	**Harvest**	• Lodging Management and Biomass and Lodging and Breakage Handling in impacts on mechanized combine harvester.	(Qing et al. 2021)
		• The kinematics and dynamics of the cutting platform in combine harvesters.	(Tang et al. 2017)

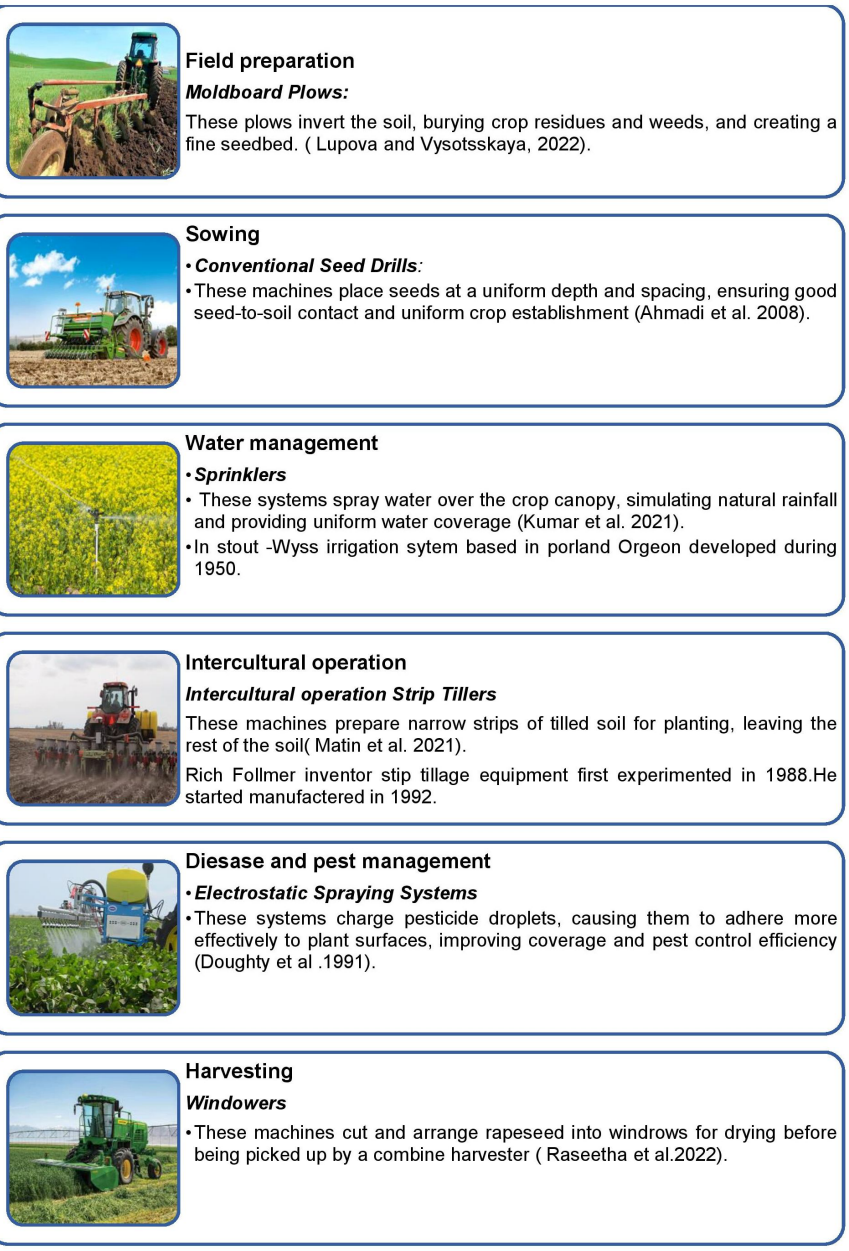


Fig.10.Flow chart of different machine's in rapeseed cultivation

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 oil seed crop, the scale of farming operations, and local conditions. Additionally,farmers should consider sustainable practices and environmental impacts when adopting mechanization in oil seed crop production. A combination of various machines, technologies, and precision farming techniques are needed for full mechanization. Furthermore, the field of agricultural mechanization for oil seed 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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