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Machineries for Mechanization of Millets

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Millets, often referred to as "nutri-cereals," are gaining renewed importance due to their high nutritional value and resilience to climate stress. However, traditional millet cultivation and processing are labour-intensive and inefficient, limiting their large-scale adoption. This article explores the role of mechanization across the millet value chain, including land preparation, sowing, intercultural operations, harvesting, threshing, cleaning, and processing. It highlights how modern machinery reduces labour dependency, minimizes post-harvest losses, and improves productivity and grain quality. The article also discusses challenges such as the small grain size, lack of crop-specific equipment, and non-uniform crop maturity, which hinder effective mechanization. Government initiatives, subsidies, and institutional support aimed at promoting millet mechanization and value addition are examined. Finally, the article outlines future opportunities, including millet-specific machinery development and integration of digital technologies. Mechanization is presented as a key driver in transforming millets into economically viable, sustainable, and widely accepted crops for the future.

Introduction

Millets are a group of small-seeded annual grasses belonging to the Poaceae family that have been cultivated for over 10,000 years. Often referred to as "nutri-cereals" or "superfoods," they are recognized for their exceptional nutritional profile, being rich in dietary fibre, essential amino acids, antioxidants, and vital micronutrients like calcium, iron, and magnesium. Beyond nutrition, millets are highly valued for their climate resilience; they are drought-tolerant, thrive in low-fertility soils, require significantly less water than rice or wheat, and have short growing cycles. In recent years, there has been a global surge in interest in millets, driven by health trends aimed at combating lifestyle diseases such as diabetes and obesity, as well as a growing focus on sustainable, climate-smart agriculture. This reached a peak with the United Nations declaring 2023 the International Year of Millets. However, a core issue remains: millet farming and processing are historically labour-intensive, characterized by high drudgery and low-margin raw grain sales. To fully realize their economic potential and ensure food security, there is an urgent need for mechanization to modernize the value chain.

Importance of Mechanization in Millets

Labour shortages in rural areas have become a serious challenge in millet cultivation, especially during peak seasons like sowing and harvesting, making timely operations difficult. Mechanization helps overcome this constraint by reducing dependence on manual labour and ensuring that farm activities are completed efficiently. It also improves time and cost efficiency, as modern machines can drastically cut processing time and reduce labour requirements, thereby lowering the overall cost of production.

In addition, mechanization plays a vital role in reducing post-harvest losses by enabling efficient cleaning, drying, and handling of grains, while tools like reapers minimize field losses such as grain shattering. It further enhances productivity and farmer income by improving grain quality, shelf life, and market value, allowing farmers to access better markets and higher prices. Ultimately, mechanization helps make millets competitive with major cereals like rice and wheat by bridging technological gaps and supporting their integration into modern agricultural systems.

Challenges in Traditional Millet Farming

One of the key challenges in millet cultivation is the extremely small grain size, usually between 1 and 4 mm, which makes handling, grading, and sorting difficult with conventional equipment. These tiny grains are more prone to spillage and losses during post-harvest operations, reducing overall efficiency. Another issue is the non-uniform maturity of traditional millet varieties, where grains on the same plant or field ripen at different times. This creates complications during harvesting, as mechanical harvesters are typically designed for crops with uniform maturity, leading to higher losses if not properly managed. A further limitation is the lack of crop-specific machinery tailored to the unique characteristics of millets. Most of the available equipment is adapted from rice or wheat machinery, which does not effectively handle the hard, multilayered hulls and diverse grain structures of millets. This often results in lower processing efficiency and potential grain damage. Additionally, traditional post-harvest operations involve high drudgery, with tasks like threshing and dehulling performed manually through labour-intensive methods. These activities are physically exhausting and are largely carried out by women and children, highlighting the urgent need for efficient, ergonomic mechanization solutions to improve productivity and reduce labour burden.

Machinery for field operations of millet cultivation

The various machineries and mechanized systems used in millet cultivation and processing are discussed briefly under following sections.

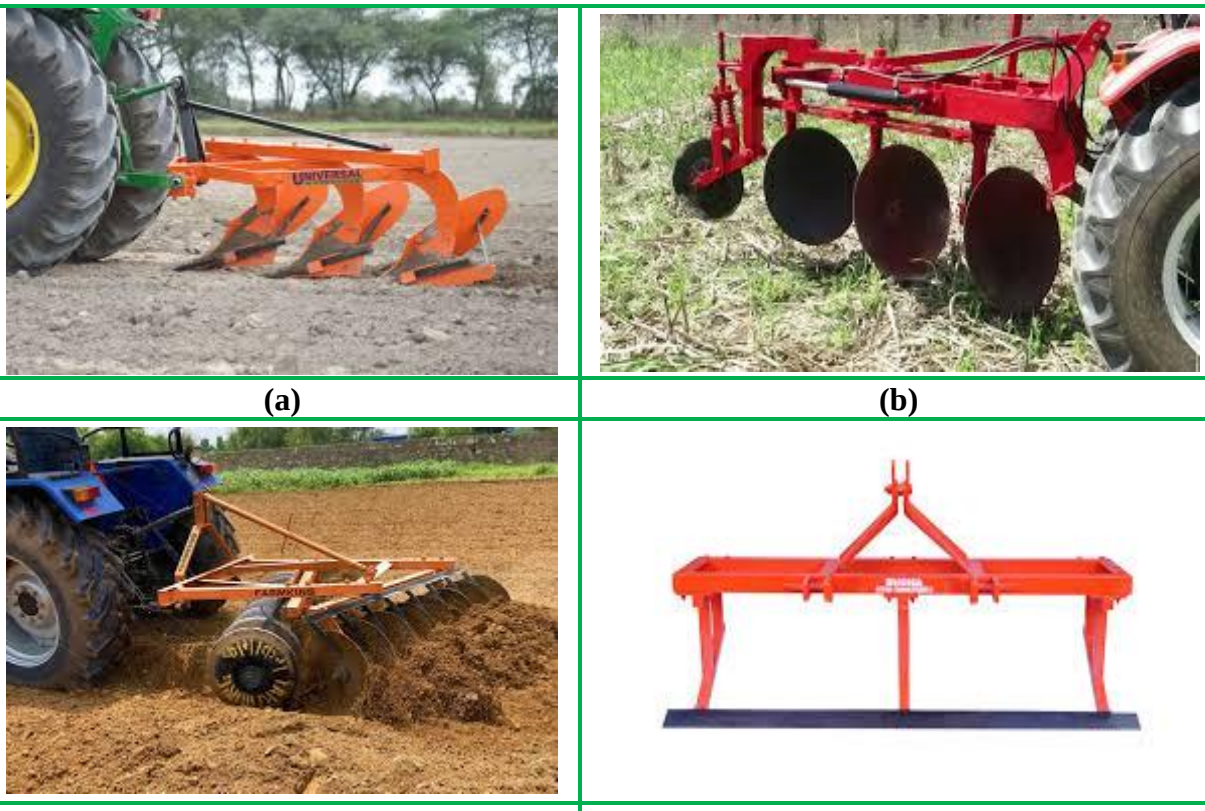
Land Preparation

Mechanized land preparation typically involves tractors and power tillers equipped with rotavators and cultivators. These technologies are critical for sustaining productivity in millet-based cropping systems by making better use of residual moisture and reducing labour intensity. For smallholder farmers, who often cultivate millets on marginal or degraded lands in semi-arid regions, the adaptability of smaller machinery is essential to handle diverse soil conditions.

Primary Tillage Equipment: Primary tillage machinery is used for the initial breaking and turning of soil to prepare the field for millet cultivation. Implements like the mouldboard plough (Fig. 1a) invert the soil to a depth of about 15–25 cm, helping to bury weeds and crop residues. Disc ploughs (Fig. 1b) are particularly useful in hard, dry, or stony soils because they can cut and lift soil effectively.

Secondary Tillage Equipment: Secondary tillage equipment is used after primary tillage to refine the soil into a fine seedbed suitable for millet sowing. Disc harrows (Fig. 1c) break large soil clods and mix plant residues into the soil. Spike tooth or spring tooth harrows further level the field and remove smaller weeds. A rotavator (rotary tiller) is widely used because it can pulverize the soil in a single pass, saving both time and fuel while producing a uniform soil texture.

Pre-sowing Tools: These tools are used just before sowing to further prepare the soil and control weeds. Cultivators loosen the soil and uproot weeds, creating a better environment for seed placement. Blade harrows (Fig. 1d), also known as bakhar in many regions, are commonly used in dryland farming to break soil crusts and conserve moisture, which is crucial for millet crops grown under rainfed conditions.



(a) **(b)**

(c) **(d)**

Fig. 1 Land preparation implements: MB plough(a) and disc plough(b) for primary tillage, disc harrow(c) for secondary tillage and blade harrow(d) as pre sowing tool

Sowing & Planting

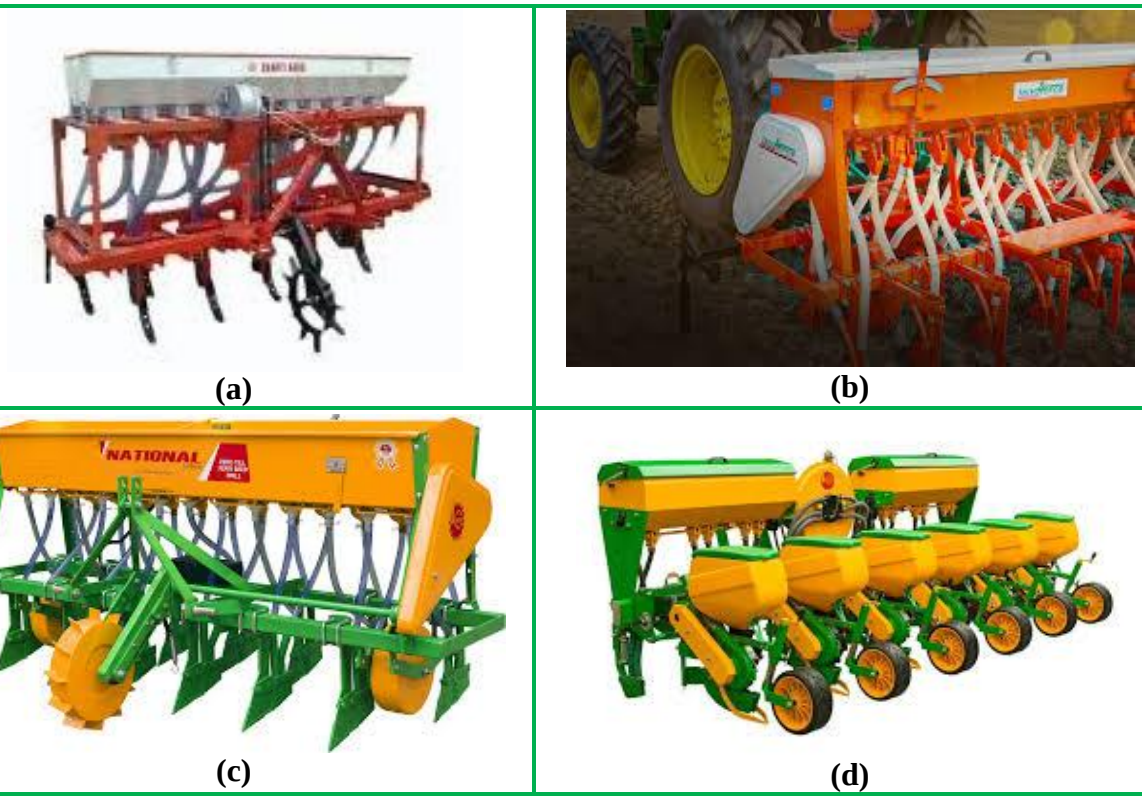
Mechanized sowing is performed using seed drills (often multi-crop versions adapted for the small size of millet) and precision planters. These machines ensure uniform spacing and depth, which are critical for optimal crop stand and productivity. Precision planting significantly reduces seed wastage compared to traditional broadcasting methods.

Seed Drills: Seed drills (Fig. 2a) are commonly used for line sowing of millet crops. They ensure proper seed placement at uniform depth and spacing, which leads to better germination and efficient use of nutrients and moisture. Tractor-operated seed drills can cover large areas quickly, reduce seed wastage, and save labour, making them suitable for medium to large farms.

Seed-cum-Fertilizer Drill: Seed-cum-Fertilizer Drill (Fig. 2b) performs dual functions by sowing seeds and applying fertilizers simultaneously. It ensures that seeds and nutrients are placed at the correct depth and position, promoting healthy early growth of millet crops. This implement improves efficiency, reduces labour costs, and ensures balanced nutrient application.

Zero till Seed Drill: Zero till seed drills (Fig. 2c) are used in conservation agriculture systems where seeds are sown without prior land preparation. These machines place seeds directly into the soil with minimal disturbance, helping conserve soil moisture and reduce erosion. They are especially useful in rainfed millet cultivation areas.

Pneumatic Planters: Pneumatic planters (Fig. 2d) use air pressure to pick and place seeds accurately in rows. These machines are highly efficient and suitable for large-scale farming. They provide precise spacing and depth, reducing seed rate and ensuring uniform crop growth, which ultimately improves yield potential.



(a) (b) (c) (d)

Fig. 2 Sowing and Planting Implements: Seed drill(a), Seed cum fertilizer drill(b), Zero till seed drill (c), and Pneumatic planter (d)

Intercultural Operations

Intercultural operations, particularly weed management, are historically high-drudgery tasks. But the mechanical solutions reduce manual labour significantly, which is crucial during peak periods when labour is scarce and expensive.

Mechanical weeders: Mechanical weeders, such as cono-weeders (Fig. 3a) and power weeders (Fig. 3b), play an important role in controlling diverse weed populations in millet fields, which can otherwise cause severe yield losses if left unmanaged. These tools help in efficient soil aeration while removing weeds between crop rows, reducing competition for nutrients and moisture. Their use significantly lowers the need for manual labour and improves overall field management.

(a) (b)

Fig. 3 Cono weeder(a) Power Weeder(b) used for intercultural operation

Harvesting

Harvesting is a high-energy operation, often consuming one-third of total production requirements.

Reapers: Reapers (Fig. 4a and 4b) are increasingly being adopted for harvesting millets due to their efficiency and ease of operation. These machines are especially useful in crops like finger millet, where precise cutting is required to minimize losses. Certain commercial

brands, are well-suited for this purpose as they can cut crops close to the ground at about 8–9 cm height. This close cutting helps in maximizing grain recovery while keeping shattering losses to a minimum. As a result, reapers significantly reduce labour requirements and speed up the harvesting process.

Combine harvesters: Combine harvesters (Fig. 4c and 4d) were originally designed for major cereals like rice and wheat, and are being adapted for millet crops with suitable modifications. Adjustments such as changing the cutting platform and regulating drum speed help accommodate the smaller grain size and different crop structure. These modifications enable combines to perform harvesting, threshing, and cleaning in a single operation, improving overall efficiency. However, further refinement is still needed to make them fully optimized for different millet varieties

(a)

(b)

(c)

(d)

Fig. 4 Millets harvesters: Reaper(a), tractor mounted multi-crop reaper(b), Track type(c) and Self-Propelled Sorghum(d) Millet Combine Harvester

Threshing

Mechanical threshing replaces the traditional method of beating panicles with sticks or using animal trampling. These machines drastically speed up the separation of grains from earheads while minimizing grain damage.

Millet threshers: Millet threshers are specially designed machines that improve the efficiency of separating grains from the earheads using mechanisms such as axial flow or spike-tooth cylinders. These systems ensure effective threshing while minimizing grain damage and losses. For example, a finger millet thresher-cum-pearler (Fig. 5a) was successfully operated by 2 hp single-phase electric motor performing all operations pertaining to finger millet processing viz. threshing, pearling, and cleaning.

Multi-crop threshers: Multi-crop threshers (Fig. 5b) are more versatile machines designed to handle different types of millets such as little, kodo, and foxtail millet. They achieve this flexibility by adjusting key operating parameters like peripheral speed and concave clearance according to the crop type. This adaptability makes them highly useful for diversified millet farming systems.

(a)

(b)

Fig.5 Threshers for millets: Finger millet thresher-cum-pearler (a) and Multi-crop thresher(b)

Cleaning & Grading

Cleaning and grading are essential steps that remove impurities and improve millet quality and market value. Machines such as winnowers, grader-cum-aspirators, destoners, and aspirators are commonly used. Grader-cum-aspirators use different sieve sizes to separate grains from stones, sand, and straw. For small millets, triple-deck graders efficiently divide large debris, good grains, and fine particles. Destoners remove heavier impurities like stones using vibration and airflow, while aspirators eliminate light materials such as dust and chaff. Advanced colour sorters further improve quality by removing defective or discoloured grains, ensuring better storage life and higher market prices.

Processing (Post-Harvest Mechanization)

This final stage is crucial for making millets suitable for consumption, as many small millets have a hard, indigestible outer husk. Efficient processing improves both edibility and market value.

Dehullers: Dehullers remove the tough outer layer while retaining the nutritious bran. Modern centrifugal dehullers use high-speed impact to separate husk from grain, offering high efficiency. Abrasive dehullers use friction through emery stones, while rubber roll shellers apply pressure and shear for effective husk removal.

Specialized machines have improved performance and scalability. The CIAE-Millet Mill (Fig. 6a), developed in Bhopal, is an eco-friendly unit with a capacity of about 100 kg/h and uses a pneumatic system for husk removal. Compact table-top dehullers (around 50 kg/h) are suitable for small-scale or village use. Double-chamber centrifugal dehullers enhance bran recovery with minimal grain breakage. Other machines are tailored for specific millets, ensuring efficient processing and reduced losses.

Milling: Milling converts dehulled grains into flour or grits by separating the edible portion from the outer layers. This step is essential for producing foods like bread, biscuits, and pasta. Different milling systems are used based on scale. Roller mills (Fig. 6b) produce fine, uniform flour suitable for commercial processing. Pulverizers (Fig. 6c) or hammer mills (Fig. 6d) are widely used at the local level due to their simplicity and low cost, though they may generate heat during operation. Traditional stone mills (chakki) and burr mills rely on friction for grinding and are still commonly used in rural areas.

Value-addition: Value addition transforms millets into convenient, nutritious, and market-friendly products. These include baked goods, noodles, snacks, breakfast cereals, and traditional foods like idli and dosa. Processing techniques such as extrusion, puffing, and fermentation improve taste, texture, and nutrient availability. Machineries for value addition include flaking machine (Fig. 7a), grain roaster (Fig. 7b), twin screw extruder (Fig. 7c) and pasta machine (Fig. 7d) etc.

Value-added products fetch higher prices than raw grains, increasing farmer income while improving shelf life and consumer acceptance.

(a) (b) (c) (d)

Fig.6 Primary Processing Machineries: CIAE millet mill(a), Attrition Mill (b), Millet Pulverizer (c)and Hammer Mill(d)

(a) (b) (c) (d)

Fig.7 Secondary Processing Machineries: Flaking Machine(a), Grain Roaster(b), Twin Screw Extruder(c) and Pasta Machine(d)

Role of Government & Institutions

Governments and institutions play a key role in promoting millets by offering financial support, policies, and technical guidance to modernize the value chain.

Subsidies for Farm Machinery

The Government of India supports mechanization through schemes like the Rashtriya Krishi Vikas Yojana (RKVY) and the Sub-Mission on Agricultural Mechanization (SMAM). These programs provide subsidies and access to machinery through custom hiring centers, enabling small farmers to use modern equipment. They help improve productivity, reduce post-harvest losses, and encourage sustainable farming practices.

Promotion of Millet Missions

To revive millet cultivation, initiatives such as declaring 2018 the National Year of Millets and 2023 the International Year of Millets have boosted awareness. Government programs provide quality seeds, inputs, and support services, along with higher Minimum Support Prices (MSP). State-level schemes also promote millet production and consumption.

Support for Startups in Agri-Machinery and Processing

Institutions support startups through incubation, funding, and training. Programs offer technical guidance, financial assistance, and market linkages, helping scale innovative millet-processing technologies and promote entrepreneurship.

Future Outlook

There is a strong need for millet-specific research and development, as most existing machinery is adapted from rice or wheat and is inefficient for millets due to their small size and multi-layered hulls. Future innovations must focus on designing equipment suited to the unique engineering and frictional properties of different millet varieties. The sector is also moving toward digital agriculture, integrating IoT sensors for storage monitoring, AI-based pest detection, blockchain for traceability, and drones for crop surveillance. To support small farmers, Custom Hiring Centers and low-cost machines like pedal threshers and tabletop dehullers are being promoted alongside improved crop breeding.

Conclusion

Mechanization is the essential bridge that connects traditional millet farming with modern market demands, making these "nutri-cereals" economically viable for the 21st century. By reducing physical drudgery—particularly for women—and enhancing product shelf life, mechanical innovations allow millets to compete with major staples on a global scale. Beyond individual farmer profit, the resurgence of millets is deeply tied to global food security, nutritional adequacy, and climate sustainability. The ongoing "millet revolution," catalyzed by the International Year of Millets 2023, represents a transformative shift that positions these ancient grains as the "golden crops" of a more resilient and healthy global food system.

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