



POPULAR ARTICLE

Mechanization of millet cultivation: technologies and future prospects

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Intricacies of the subject

Millets are important crops in dryland agriculture owing to their adaptability to low water availability, high temperature and other adverse climatic conditions. However, many millet production activities still require considerable human effort, especially during crop establishment, weed control, field operations, harvesting and the handling of produce after harvest. Mechanization is therefore essential for ensuring timely completion of farm operations, reducing labour requirements and drudgery and improving the efficiency of millet production. The availability of suitable machinery can facilitate operations from land preparation and sowing to weed management, harvesting, threshing and grain processing. Recent advances in precision agriculture, robotic weed management, drone-based crop protection and improved harvesting and processing machinery have further expanded the scope for mechanized millet production. These developments can improve the efficiency of farm operations and help in reducing losses during crop production and post-harvest handling. However, the high cost and limited

availability of suitable machinery continue to restrict mechanization, especially among small and marginal farmers. Therefore, priority should be given to the development and promotion of simple, affordable and farm-size-appropriate machinery for different operations in millet cultivation. Mechanization covering the complete production and post-harvest chain can reduce dependence on manual labour and improve the efficiency, profitability and sustainability of millet production.

Introduction

Millets are important cereal crops of dryland and rainfed agriculture, particularly in regions where water availability and soil fertility limit the production of other cereals. Their nutritional value, including the presence of proteins, minerals, vitamins and other beneficial components, has increased interest in these crops as part of diversified diets. The millet group includes several important crops, such as sorghum, pearl millet, finger millet, foxtail millet and little millet. Beyond their value as nutrient-rich cereals, these crops are well adapted to water-limited environments and can produce satisfactorily with fewer

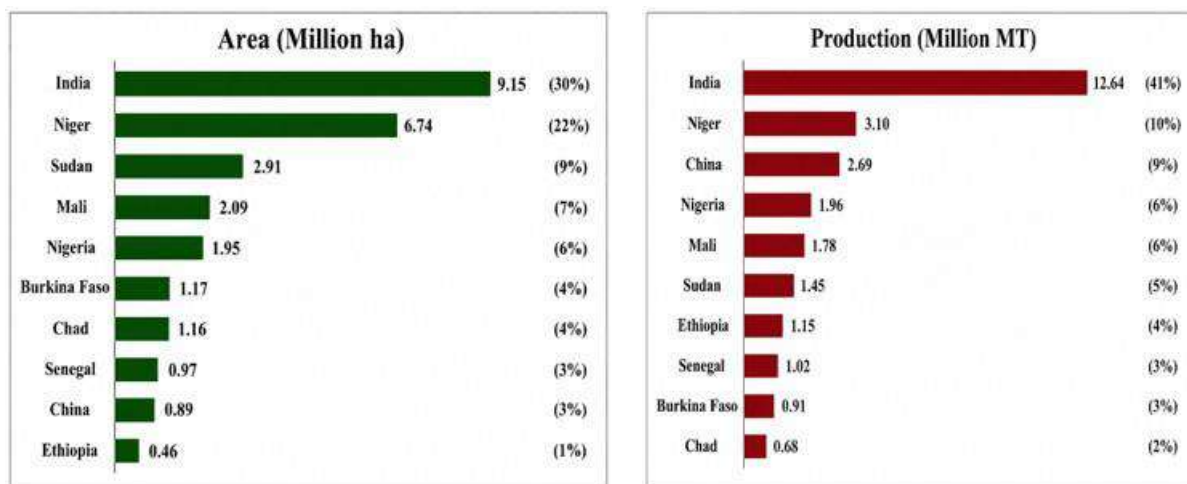


external inputs. These characteristics make millets valuable for developing sustainable cropping systems that can better cope with climate variability. Thus, millet-based production systems have potential to support food and nutritional security while making better use of limited natural resources. Even though India's higher in production and consumption, the adoption of machines in millet cultivation remains less. The declaration of 2023 as the International Year of Millets further highlighted the importance of these crops and created greater interest in improving their production and value chains. Mechanization provides an opportunity to address some of the labour and time constraints associated with millet cultivation. Appropriate machinery can improve the timeliness and precision of field operations from land preparation and sowing to weed management, harvesting, threshing and

processing. Millets can contribute to climate-resilient farming because they generally require less water and can tolerate periods of moisture stress. However, machinery developed for large-scale cereal production may not always be suitable for millet farming because of differences in seed size, crop geometry, farm size and field conditions. Therefore, there is a need for compact, affordable and millet-specific equipment that can be easily operated and maintained by farmers. Custom hiring services, farmer training and locally adapted machinery can improve access to mechanization, particularly for small and medium holdings. Further development of efficient seeders, mechanical weeders, harvesters, threshers and processing machines can reduce labour needs and increase the efficiency of millet cultivation, while also improving its economic returns and long-term sustainability.

Global status of millet cultivation and production

Fig.1: Cultivated area and production of millets in major millet-producing countries



Millet cultivation covers about 30.86 million hectares worldwide, with a total production of nearly 30.59 million metric tonnes. India has the largest area under millet cultivation, covering 9.15 million hectares (30%), followed by Niger with 6.74 million hectares

(22%). Sudan, Mali and Nigeria account for 2.91, 2.09 and 1.95 million hectares, respectively. In terms of production, India ranks first with 12.64 million metric tonnes (41%), followed by Niger (3.10 million metric tonnes; 10%) and China (2.69 million metric



tonnes; 9%). Nigeria, Mali and Sudan contribute 1.96, 1.78 and 1.45 million metric tonnes, respectively (Fig.1). Other major millet-producing countries include Ethiopia, Senegal, Burkina Faso and Chad. Overall, the distribution shows that India has a clear lead in both millet production and cultivated area, while several African countries occupy the major positions in terms of area and production.

Millet production and yield in major producing states of India

Millet cultivation in India shows considerable variation across states in terms of area, production and productivity. Rajasthan had the

largest area under millets (4,801.07 thousand ha) and the highest production (4,885.68 thousand tonnes), while Maharashtra also contributed substantially with an area of (2,271.60 thousand ha) and production of (2,163.74 thousand tonnes). Karnataka recorded significant millet production (2,161.54 thousand tonnes) from an area of (1,792.00 thousand ha). Andhra Pradesh achieved the highest productivity among the major millet-producing states (2,543 kg/ha), despite having a relatively smaller area (168.54 thousand ha). Overall, India cultivated millets over (13,145.16 thousand ha), producing (17,571.62 thousand tonnes) with an average productivity of (1,337 kg/ha).

Table 1. State-wise area, production and productivity of millets, 2023–24

State	Area (^{'000} ha)	Production (^{'000} tonnes)	Productivity (kg/ha)
Andhra Pradesh	168.54	428.59	2,543
Arunachal Pradesh	27.76	28.79	1,037
Assam	8.73	6.76	775
Bihar	7.28	7.01	962
Chhattisgarh	44.62	25.94	581
Gujarat	584.65	1,408.90	2,410
Haryana	546.96	1,171.12	2,141
Himachal Pradesh	3.00	2.08	691
Jharkhand	32.92	31.95	970
Karnataka	1,792.00	2,161.54	1,206
Madhya Pradesh	615.00	1,302.01	2,117
Maharashtra	2,271.60	2,163.74	953
Nagaland	18.04	19.82	1,099
Odisha	115.73	94.83	819
Rajasthan	4,801.07	4,885.68	1,018
Tamil Nadu	495.75	676.37	1,364
Telangana	114.00	255.58	2,242
Uttar Pradesh	1,348.00	2,699.53	2,003
Uttarakhand	109.26	167.57	1,534
West Bengal	7.21	6.61	917
Others	33.04	27.20	823
India	13,145.16	17,571.62	1,337

Source: Indiatat, Selected State-wise Area, Production and Productivity of Total Millet in India, 2023–24

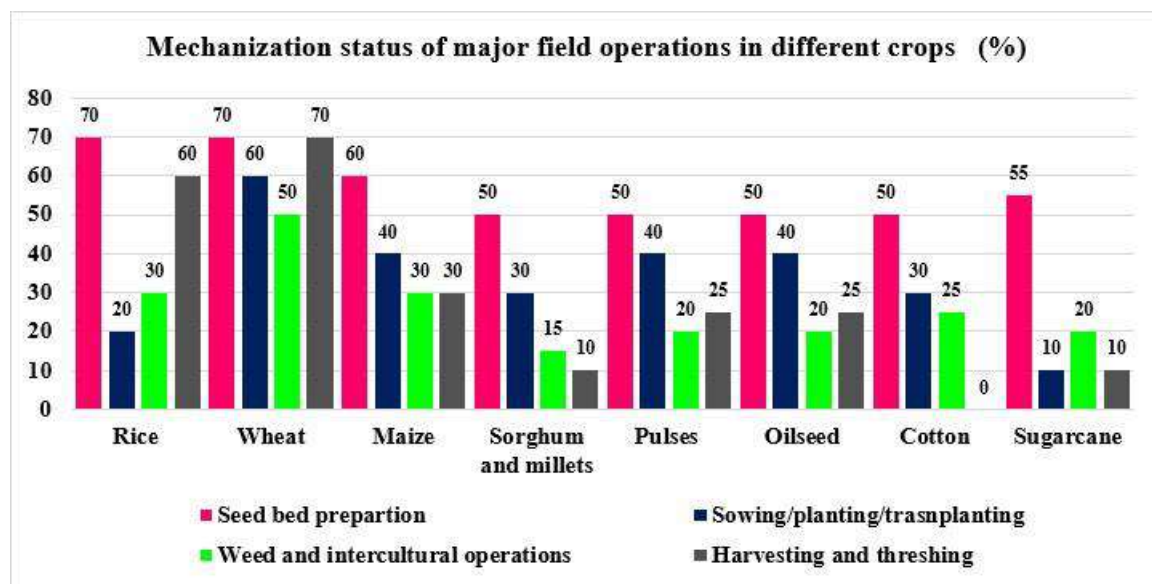


Status of mechanization in field operations across major crops

Mechanization status of major field operations in different crops (Fig.2). Seed bed preparation had the highest level of mechanization in most crops, reaching 70% in rice, wheat and maize, followed by 50% in sorghum and millets, pulses and oilseeds, 55% in sugarcane and 50% in cotton. Mechanization for sowing, planting or transplanting was highest in wheat (60%), while rice had only 20%. Weeding and

intercultural operations showed moderate mechanization, with the highest level in wheat (50%) and the lowest in sorghum and millets (15%). Harvesting and threshing was highly mechanized in wheat (70%) and rice (60%), but remained low in sorghum and millets (10%) and sugarcane (10%). Overall, the figure indicates that mechanization is more advanced in seed bed preparation and harvesting, whereas weeding and planting operations have comparatively lower mechanization levels in several crops.

Fig. 2: Mechanization status of major field operations in different crops



Enhancing millet production through farm mechanization and improved agronomic practices

Farm mechanization is essential for increasing the efficiency of crop production by supporting various operations, including field preparation, harvesting, storage and post-harvest processing. It is not limited to tractor use but includes machinery and tools used throughout the crop production and value chain. Proper mechanization can reduce labour requirements, ensure timely farm operations, improve input-use efficiency and increase crop

productivity. In India, the predominance of small and marginal farms, which account for about 86% of operational holdings, creates difficulties in adopting large-scale machinery. Other constraints include cropping systems, crop prices, labour availability, government policies and the high cost of machinery. In Rice and Wheat crops uses of mechanization is high while pulses, millets, oilseeds and sugarcane has less adoption. Overall, India's farm mechanization level is about 40%, indicating considerable scope for further mechanization, particularly through affordable and small-farm-friendly technologies.



Selection of improved varieties

Selection of suitable varieties is important for achieving higher millet productivity. Varieties should have good yield potential, resistance to major pests and diseases, adaptability to local conditions and better nutritional quality. Millets are resilient crops that can be cultivated in tropical and subtropical regions. They can perform well even in soils with low fertility and under conditions of limited water availability. The suitable soil for millet production is loam with well drained and also it will grow in alluvial and sandy soil. Proper land preparation helps in good crop establishment and early root growth. A fine, levelled and well-drained seedbed can be prepared through ploughing followed by harrowing.

Sowing and nutrient management

Millet sowing time varies with season, with kharif crops generally planted during June-July, rabi crops during October-November and summer crops during January-February. Proper seed rate and spacing are important for obtaining a uniform crop stand. A row spacing is based on the millet type. Most of the millets crops suits in 20-30 cm between rows and 10 – 15 between plants. Millets respond well to balanced nutrient application, particularly nitrogen and phosphorus. Phosphorus and potassium are generally applied at sowing, while nitrogen is supplied in split doses. Under areas with adequate and reliable rainfall, 50% of the recommended nitrogen is applied at sowing and the remaining 50% is divided into two equal applications at 25-30 and 40-45 days after sowing. Where rainfall is uncertain, 50% nitrogen is applied at sowing and the remaining 50% is applied around 35 days after sowing.

Mechanization for sowing and fertilization

Modern seeders and fertilizer applicators can

improve sowing precision, reduce labour requirements and promote efficient use of inputs. Sowing robots and automated seeding systems can be used for several agricultural operations such as placing seeds into the soil, soil covering, fertilizer application and irrigation. These technologies can improve field efficiency and reduce time and labour costs. Machinery should be selected according to farm size, crop type, soil conditions and local climate. Different seed-cum-fertilizer machines have been developed for millet cultivation, with variations in row configuration, field capacity and power source according to the crop and farm conditions.

Water and weed management practices

Small millets are mostly cultivated with dependence of rainfall and generally need supplementary irrigation. Water should be provided critical growth stages such as tillering, flowering and grain formation. The required number of irrigations may vary depending on the soil type, growing season and prevailing weather conditions. Effective weed control is important during the early stages of millet growth to reduce competition for nutrients, water and sunlight. In millets manual weeding commonly used practice. Mechanical weed control using suitable tools and improved equipment can reduce labour requirements and improve the efficiency of weed management.

Harvesting and post-harvest mechanization

Harvesting should be carried out when the crop reaches full maturity and the grains are properly ripened. Small millet crops can be harvested manually using sickles or with suitable mechanical harvesters, depending on farm size and available resources. Improved harvesting machines can help reduce labour requirements and grain losses. After harvesting, threshing is carried out to separate the grains from the plant material by manual or



mechanical methods. Proper harvesting and threshing methods are important for reducing grain loss and maintaining grain quality. Post-harvest machinery used in millets presented in Table 5. In millets the grain size is small and fragile germplasm. So the post-harvest operation such dehulling and policing operations is highly challenging which may damages the grains. More processing may decrease grain quality and shelf life . Mechanical cleaners, graders, dehusers, destoners and millet mills can reduce

processing time and labour requirements compared with traditional methods. Integrated millet-processing machines can increase the efficiency of dehulling and milling while preserving the quality of the grains. Suitable pretreatments, including soaking followed by controlled drying, can also support better dehulling and milling. Hence, the use of appropriate post-harvest equipment is essential for efficient millet processing, minimizing grain losses and preserving its nutritional value.

Table 2. Operational performance of seed-cum-fertilizer equipment in millet cultivation

Crop	Machinery developed	Working row	Field capacity (ha/hr)	Power source
Kodo millet, little millet	Seed-cum-fertilizer plot drill	Single row	0.048 ha/hr	Manual
Pearl millet	Seed-cum-fertilizer drill	Four rows	0.17 ha/hr	Tractor
Ragi	Drum seeder-cum-fertilizer	11 furrow openers	0.77 ha/hr	Tractor
Finger millet	Multi-crop seed-cum-fertilizer drill	24 orifices drum	1.5 km/hr	Manually operated
Multi-millets	Single-row millet planter-cum-fertilizer drill	18 gauges	0.069 ha/hr	Animal drawn
Multi-millets	Manual-drawn pull-type three-row planter	Single row	0.05 ha/hr	Manually operated
Kodo millet, little millet	Seed-cum-fertilizer drill	Three rows	0.09 ha/hr	Manually operated

Future prospects

Future millet mechanization should focus on improving field operations such as sowing, weeding, irrigation and crop monitoring, where machinery is still limited. New equipment should be designed according to millet-specific requirements, including small seed size, crop spacing, soil conditions and rainfed cultivation. Low-cost, lightweight

machines suitable for small farms and intercropping systems are especially needed. Advanced seeders, efficient weed-control machines, and sensor-guided irrigation and input application can make farm operations more precise and efficient. Developing affordable and climate-suitable machinery will be important for reducing labour dependence and supporting sustainable millet production.



Conclusion

Millets offer good potential for sustainable farming because of their tolerance to drought and low-input conditions. Combining improved varieties, efficient nutrient and water management, and suitable farm machinery can increase productivity while reducing labour requirements. Mechanization of sowing,

weeding, harvesting and post-harvest operations can improve timeliness and reduce crop losses. The successful adoption of these practices depends on the availability of good-quality seed, proper farmer training, affordable farm machinery and strong extension services. Millet cultivation supports food security, household income and climate-resilient agriculture.

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