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Advances and limitations in maize harvesting technologies: An overview

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Abstract
The review discusses the production, importance, and limitations of maize harvesting in India, highlighting the shift from manual to mechanical methods. In India Maize crop is grown primarily during the Kharif season, with significant regional variations in production. Manual harvesting remains common, though it is labor-intensive and poses risks such as musculoskeletal disorders (MSDs) among workers. Mechanical harvesting technologies, such as self-propelled maize combine harvesters and tractor-mounted maize fodder harvesters, offer efficiency but are often too costly for smallholder farmers. Innovations in maize harvesting machines, including reapers and cob pickers, have shown potential to reduce labor and costs, but challenges like ergonomic issues and post-harvest collection remain. The review calls for the development of affordable, ergonomic, and multifunctional harvesting solutions to enhance productivity and reduce physical strain, particularly for small-scale farmers. Future research should focus on optimizing machine design, improving post-harvest operations, and increasing accessibility through cost-effective technologies.

Keywords: Harvesting technologies, maize harvester, fodder harvesting, ergonomics

1. Introduction

1.1 Production and importance of maize in India

Maize production has increased in recent years to meet the rising food demand of the growing population [1]. Maize is grown in 170 different nations. Around 193 million hectares of maize are grown globally, and 1147.7 million metric tonnes are produced globally [2]. In the country like India where the main source of income is agriculture [3]. In the 17th century, the Portuguese introduced maize to India. It is also an important cereal crop of India with around 10.04 million ha area under this crop in the year 2021-22 and 33.62 million tonnes annual production and 3349 kg/ha productivity. India accounts for 2.9 percent of global maize production in 2022-2023. After rice and wheat, maize is the third-most significant food grain in India. India ranks seventh in terms of global production and fifth in terms of global area. Worldwide, it is considered to be one of the fastest-growing cash crops. In India maize production according to state wise are Karnataka (15.53 percent), Madhya Pradesh (13.59 percent), Maharashtra (10.51 percent), Tamil Nadu (8.36 percent), West Bengal (7.86 percent), Bihar (7.51 percent), Telangana (6.35 percent), Andhra Pradesh (6.09 percent), Rajasthan (6.08 percent), and Others (18.12 percent), which together account for 100 percent which is country's total output [4].

Maize in northern India grows mainly during the Kharif (monsoon) season, while in the south, it can be sown from April to October means in both Kharif and Rabi season. Ideal germination temperature is 21°C, with optimal growth at 32°C. It thrives at altitudes up to 3,000 meters and on diverse soils, with a pH between 7.5 and 8.5. Maize requires deep, fertile, well-drained soils and is sensitive to salinity and water stress. Sowing is done in rows 600-750 mm apart, with plant spacing of 200-250 mm. For grain, 17-20 kg of seed per hectare is needed, and for fodder, 35-40 kg. About 28 percent of the maize grown in India is utilized for food purpose, about 11 percent is used as livestock feed, 12 percent is used in the wet milling industry (for example starch and oil production), and 48 percent as poultry feed and 1 percent as seed [5-6].

Maize cultivation in India is distributed across farms of different sizes, with the majority (60%) being carried out by marginal farmers who own less than one hectare of land. Overall, individual landholdings in India are considerably smaller compared to those in other major agriculture-based countries, and this trend is reflected in maize farming as well [7].

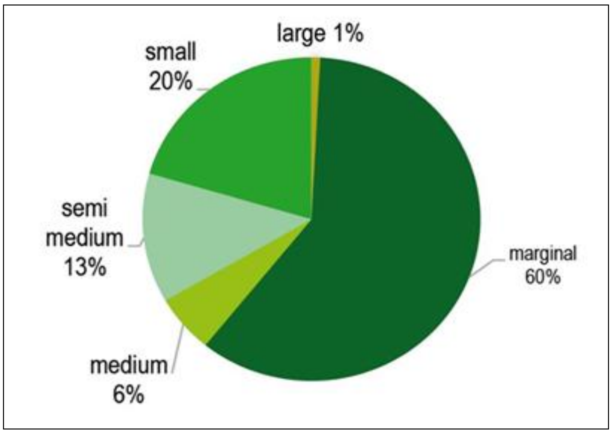

Fig 1: Landholding pattern of maize in India

1.2 Maize harvesting technologies

Maize harvesting should be done just after flowering (at 60-70 Days after sowing) for better quality maize fodder. [8]

In India, maize is harvested primarily through two methods:

a) Manual Harvesting

This traditional approach involves using a sickle to cut maize stalks and hand-picking the cobs. It remains prevalent among smallholder farmers due to factors such as small and fragmented landholdings, limited access to mechanized equipment, and financial constraints. A study conducted in Karnataka revealed that a significant proportion of maize growers had not adopted mechanized harvesting and threshing methods, indicating a strong reliance on manual practices [9].

b) Mechanical Harvesting

This method employs machinery like self-propelled maize combine harvesters and tractor-mounted maize fodder harvesters, which can efficiently harvest and thresh maize, reducing labor requirements and time. However, the adoption of mechanical harvesting is limited among smallholder farmers due to factors such as high costs and fragmented landholdings [9].

2. Harvesting technologies and limitations

2.1 Manual harvesting and limitations

Agriculture is considered one of the most hazardous operations in developed and developing countries [10] as it involves strenuous physical activities and high levels of manual labor [11-12]. Maize harvesting is one of the most important filed operations of maize production [13].

Manual harvesting is a physically demanding occupation with several work-related issues in which musculoskeletal disorders (MSDs) happen most commonly. The risk factors for MSDs among manual harvesting farmers are not investigated properly in low and low-middle-income nations. Therefore, a study among 140 farmers of Rajasthan, India was carried out through the usage of Nordic Musculoskeletal Questionnaire and the Rapid Upper Limb Assessment (RULA) technique to identify ergonomic risks. x^2 analysis was used to find the relationship between the MSDs and various factors. Also, logistic regression methodology was applied to get the most influencing factor for MSDs in different body regions. The lower-back, fingers, shoulders and wrists/hands were the body parts in which more than 50% workers reported MSDs. MSDs in one or more body regions were found to be associated with age, daily working in farms, farming experience, gender, hand dominance and perceived work fatigue. The age was majorly associated with MSDs in all body regions except the shoulder and neck as per the outcome of logistic regression. The outcome of RULA grand score had been found higher than or equal to 5 in 92% of the farmers which give directions for further research and changes. Such methods are not only time-consuming but also expose workers to the risk of injuries from sickles, contributing to fatigue and inefficiency [14-15].

Manual harvesting of maize crop is an arduous job because at the time of harvesting of these crops' climate is very hot and humid. Labourers do not prefer to work in fields and also work productivity is low. Cutting and chopping required 225-275 man-h per hectare for kharif forage crops while for rabi crops it was 574-825 man-h per hectare on different category of farms. Manual maize harvesting process takes costs ₹2,650 per hectare [16-17]. In India, agriculture is facing serious challenges of scarcity of agricultural labour not only in peak seasons but almost throughout the year. It is very time consuming and stressful operation [18].

2.2 Mechanical harvesting and limitations

In India, Mechanization level for harvesting of maize crop is 30% only [19]. In India self-propelled maize combine harvester is available in the market. It is fully mechanized and used for direct harvesting and threshing of maize crop. It has specially designed cutter bar for maize. It has a gathering unit to guide the stalks into the machine and snapping rolls to remove the ears from the stalks. It can harvest one ha in an hour [20]. The major issue regarding the self-propelled maize combine harvester is the very high cost. Their design is limited to a specific task. Hence these machines being so costly cannot be used for any other productive work. The high degree of automation in such machines makes it unpopular among the farmers. Proper training has to be given to the operator for precise work. The self-propelled maize combine harvesters thus are sophisticated considering the current scenario of a typical Indian farmer [21].

Tractor mounted maize fodder harvester is also available in market. This harvester is also suitable for fodder crops like bajra, sorghum, maize, berseem and oats with up to 80 plants/m^2 and 100-282 cm plant height. It can harvest 1.12-1.26 m width in single pass and can fill one trailer with chopped fodder in just 22 min. It is also capable of harvesting over mature and lodged crop. The cost of harvesting one trailer of fodder ranges between ₹ 59-104. The field capacity is 0.2 ha/h. and cost of operation ₹ 1114 /ha. One tractor driver and one other person are needed during the whole operation. It can save 90 percent labour and 75 percent operation cost. The harvested fodder can be used as direct feeding or silage making [22]. Tractor-mounted maize fodder harvesters are popular among a handful of rich farmers. However, due to their overall size and the requirement of tractors, also due to unavailability of roads during harvesting time because of another farmer's crop is in the neighbouring field. The tractor mounted maize fodder harvesters are not used on small farms [23-26].

Mechanical harvesting methods involve self-propelled maize combine harvester and tractor mounted maize fodder harvester. While effective, these machines remain unaffordable for small-scale farmers due to high costs, specific design constraints, and operational challenges. The high harvest losses associated with the mechanical harvesting of maize are currently a major barrier to the adoption of this technology [27].

2.3 Required advancement in recent developments

A developed single-row, self-propelled maize cob picker cum stalk cutting machine [7] that combines cob removal, cob collection and stalk cutting. This innovation reduces labor by 89% and costs by 52.6% compared to manual harvesting. However, drawback of this machine is after cutting operation, the cut stalks are completely destroyed in small pieces and scattered in the field which was collected manually with continuous bending posture due to this reason, it is unsuitable for stalk harvesting purpose.

A developed small-scale maize harvester [23] was designed for developing countries, integrating a harvester header, chain conveyor, drive unit, and tricycle. Performance evaluation at 15% kernel moisture showed a machine capacity of 0.05 ha/hr, with 97.30% driving efficiency, 84.11% picking efficiency, and 98.21% conveying efficiency. However, the drawback of this machine is after cutting one row and turning the machine to cut another row, the machine must pass through the maize in the adjacent row, causing damage to the maize crops in the side row. Efforts to develop portable and small-scale harvesters have shown promise but require further optimization.

The developed maize reaper machine [28] consists of a 14 cm cutting disc with two blades, designed to efficiently harvest maize in various farm conditions. It performs faster and with lower losses than manual harvesting, while being operated by a single worker and requiring minimal maintenance. The reaper is affordable for farmers, with a power consumption of 0.373 kW and a cutting energy of 12.09 kJ/m². The machine's forward speed is 1 m/s, and its cutting width is 30 mm per cutter. However, the drawback of this machine is, after cutting operation, the cut stalks are completely scattered in the field was collected manually with continuous bending posture due to this reason, it is unsuitable for stalk harvesting purpose.

A developed maize cob harvester [29] this machine combines both cob removal and stalk cutting operations. The performance of harvester based on forward speed (1.7–2.1 km/h), snipper speed (55–68 m/min), and crop variety. The machine performed best at 1.9 km/h and 62 m/min, with 0.197% stripping loss, field capacity of 0.081 ha/h, efficiency of 75.7%, and operational cost of ₹337.65/hour. Its breakeven point was 149.64 hours, with a payback period of 2.5 years and an output of 75 q/ha. However, one drawback of this harvester is after the cutting operation, the stalks are broken into small pieces and scattered across the field, requiring manual collection in a continuous bending posture. This makes it unsuitable for stalk harvesting purposes.

A developed portable shoulder mounted forage harvester [30] imposed ergonomic strain on operators due to cutting of maize stalk is done by swinging of cutting unit by hand which is ergonomically non-efficient and the whole weight of the machine comes on the operator's body.

Developed maize stalk harvester [31] had 96.52% cutting efficiency but failed to address post-harvest maize stalk collection challenges. Such innovations highlight the potential for improvement through ergonomic and functional enhancements.

3. Ergonomic Considerations

Ergonomic design plays a critical role in enhancing the usability and safety of maize harvesting machines. To minimize musculoskeletal disorders (MSDs), machines should reduce tasks involving repetitive bending, twisting, and heavy lifting. Controls and handles must be positioned at appropriate heights and angles for operator accessibility and comfort. Efforts should focus on reducing vibrations, noise, and machine weight to prevent operator fatigue. Portable machines must distribute weight effectively with ergonomic harnesses, minimizing strain on the operator's body. Adjustable seating and supportive features in larger machines are essential for long-term comfort. Simplified and intuitive control layouts should also be prioritized to facilitate ease of operation and reduce training requirements.

4. Conclusion

Maize harvesting in India faces significant challenges, primarily due to low mechanization and a heavy reliance on manual labor, which is both time-consuming and physically demanding. The manual harvesting method increases the risk of musculoskeletal disorders, reduces productivity, and raises the cost of labor. Although mechanical harvesting methods, such as tractor-mounted maize fodder harvester and self-propelled maize combine harvesters, can improve efficiency, their high cost and design limitations make them inaccessible for small-scale farmers. Innovations such as self-propelled cob pickers and portable harvesters have shown promise but still require further optimization, particularly in terms of ergonomics and functionality.

5. Future Directions

To address the challenges associated with maize harvesting, future advancements should focus on developing cost-effective, ergonomically optimized, and multifunctional mechanized solutions tailored for small-scale farmers. Innovations should prioritize lightweight, portable designs with adjustable and user-friendly features to reduce physical strain and enhance productivity. Improving post-harvest stalk collection mechanisms and minimizing crop waste are essential for maximizing resource efficiency. Training programs for operators and the integration of affordable automation can further support the adoption of these technologies. Collaborative research and development efforts between engineers, ergonomists, and farmers can ensure the creation of sustainable and practical harvesting solutions.

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