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Development of ergonomic manual cutters for finger millet earhead harvesting

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Abstract
Finger millet (*Eleusine coracana* L. Gaertn.) is a nutrient-rich and climate-resilient cereal, but its harvesting is constrained by the limitations of sickle use, which causes operator fatigue, musculoskeletal strain, and grain losses. Mechanized solutions such as combine harvesters are unsuitable for smallholder fields due to the crop's short height, slender stalks, and compact earheads. To address these issues, two ergonomic manual cutters were developed by integrating crop morphology, anthropometric data of Indian agricultural workers, and ergonomic principles. The first, a Sliding Blade Cutter (Cutter 1), is a lightweight (60 g), palm-mounted tool adapted from an okra cutter-holder and modified with a shearing-type mechanism for selective earhead harvesting. The second, a Scissor-Type Cutter with Lever and Collection Box (Cutter 2), incorporates a bypass pruner blade, spring-return lever mechanism, and curved polycarbonate collection box to reduce muscular effort and minimize shattering losses. A supplementary collecting bag was also designed to reduce repetitive bending and allow storage of up to 2 kg of earheads. Together, these innovations demonstrated ergonomic and functional advantages over the sickle, offering safe, low-cost, and farmer-friendly solutions suitable for smallholder and women farmers in millet-growing regions.

Keywords: (*Eleusine coracana* L. Gaertn.), Sliding Blade Cutter, Indian agricultural, earhead harvesting

Introduction
Finger millet (*Eleusine coracana* L. Gaertn.) is an important nutri-cereal widely cultivated in semi-arid and tribal regions of India (Kumar *et al*., 2018; NIN-ICMR, 2020) [10]. Despite its resilience and nutritional superiority, the crop faces several production bottlenecks, the most critical being harvesting (Gaikwad *et al*., 2020) [1]. Manual harvesting with traditional sickles continues to be the predominant method. Although the sickle is simple and affordable, it is poorly suited to the unique structure of finger millet earheads. Operators are required to bend continuously and perform repetitive wrist motions, leading to high physical strain and musculoskeletal discomfort (Gupta and Bisht, 2018; Mishra *et al*., 2024) [5, 11]. Furthermore, open blade designs pose safety risks, and imprecise cutting often results in grain shattering and post-harvest losses. Attempts at mechanization using tractor-mounted or combine harvesters have had limited success. The short plant height, slender stalks, and compact earheads of finger millet restrict the use of large-scale mechanized solutions (Kharb *et al*., 2013; Nisha *et al*., 2022) [7, 13]. When employed, such machines frequently cause excessive shattering, high header losses, and poor adaptability in fragmented smallholder plots (Ghimire *et al*., 2019; JETIR, 2021) [2]. These limitations underline the need for crop-specific, ergonomic hand tools that are simple, low-cost, and accessible to small and marginal farmers.

Ergonomic Considerations
In designing the cutters, ergonomic principles were prioritized to minimize operator drudgery and improve safety. The tools were required to reduce repetitive wrist flexion, lower muscular effort, and avoid continuous bending postures common with sickle use. Handle dimensions were optimized to match recommended grip sizes, and overall weight was kept within comfortable limits for long-duration use.

In Cutter 1, the elastic double-riveted straps were designed to distribute pressure evenly across the palm, ensuring comfort and stability during operation. In Cutter 2, the lever-spring actuation mechanism was introduced to reduce the cutting force required, thereby minimizing wrist strain and improving operational efficiency. Protective guards and smooth finishing were incorporated in both prototypes to reduce the risk of accidental injury. These ergonomic considerations guided the design and fabrication process, ensuring that the cutters were safe, efficient, and user-friendly for smallholder farmers. Therefore, the present study was undertaken with the objective of developing manually operated finger millet earhead cutters. The focus was on integrating ergonomic principles with crop-specific design features to overcome the limitations of the sickle. Two prototype cutters were designed and fabricated:

1. A Sliding Blade Cutter (Cutter 1) - a lightweight, hand-mounted device for selective earhead harvesting.
2. A Scissor-Type Cutter with Lever and Collection Box (Cutter 2) - a two-handed ergonomic cutter equipped with a spring-loaded mechanism and integrated collection system to minimize losses and reduce operator effort.

The development of these tools represents an important step toward addressing drudgery in finger millet harvesting, improving safety, and offering a practical solution for smallholder farmers.

Materials and Methods

The development of manually operated finger millet earhead cutters was carried out with the objective of creating farmer-friendly tools that combine crop-specific suitability with ergonomic safety. The methodological approach considered the morphological properties of finger millet, anthropometric characteristics of agricultural workers, and ergonomic principles of hand tool design.

The design process was first guided by the structural features of finger millet earheads. The crop variety used in this study, *Phule Nachani*, produces compact earheads measuring 9-11 cm in length, with 6-9 fingers per head and an average weight of 3.5-4.0 g. These features indicated the need for a precise cutting mechanism capable of handling small and delicate earheads without inducing shattering losses. Simultaneously, anthropometric data of Indian agricultural workers (Gite and Yadav, 1990) [3] were consulted to determine optimal tool dimensions. The average hand length was found to be 183 mm, with an appropriate grip diameter ranging between 30 and 40 mm and a handle length of 10-12 cm. The total tool weight was restricted to less than 500 g to allow prolonged use without excessive fatigue. Ergonomic considerations emphasized minimizing awkward postures, repetitive wrist motion, and open-blade risks while ensuring a safe and effective cutting action. Based on these parameters, two prototype cutters were conceptualized and fabricated.

Sliding Blade Cutter

Modifications from previous design

Cutter 1 was adapted from an okra cutter-holder earlier developed at Dr. ASCAET, MPKV, Rahuri. To accommodate the morphological differences between okra pods and finger millet earheads, several design modifications were introduced:

- Blade and shell were enlarged and reinforced to withstand the tougher peduncles of finger millet.
- Strap design was improved with elastic, double-riveted attachments for greater comfort and stability during prolonged use.
- Passage slot was widened to allow smoother cutting and reduced blockage.
- Alignment tolerances were tightened to enhance cutting reliability.
- Cutting mechanism was changed from an anvil type (used in okra) to a shearing type, suitable for the higher cutting force required for finger millet stalks.

These modifications ensured that Cutter 1 became a crop-specific, ergonomic device capable of safe, efficient, and reliable harvesting under field conditions.

Constructional details

Cutter 1 is a palm-mounted device designed for use on either hand. Its main constructional features are:

- **Body:** Cylindrical PVC pipe (5 cm diameter, 12 cm height) split vertically into two halves to form a shell.
- **Hinge assembly:** The halves were joined on one edge using adhesive tape, enabling opening and closing around the stalk.
- **Blade:** Stainless steel blade (4 cm × 1.5 cm, 1 mm thick) embedded in one half; the opposite half provided a 2 mm slot for blade passage.
- **Cutting mechanism:** Cutting occurs when the user slides/pushes the hand, bringing the stalk into contact with the fixed blade in the throat of the shell.
- **Strapping:** Two elastic straps (12 cm each), riveted on either side of the shell, fasten the device to the palm for stability and ease of use.
- **Optimization:** Blade sharpness and alignment were refined through iterative testing to ensure minimal cutting force and prevent crop damage.

With a total weight of 60 g, Cutter 1 can be mounted on either the left or right hand, allowing independent operation without gripping the crop. This design enables selective harvesting, reduces cumulative wrist and arm fatigue, and improves safety compared with the traditional sickle (Vishwakarma *et al*., 2020) [17].

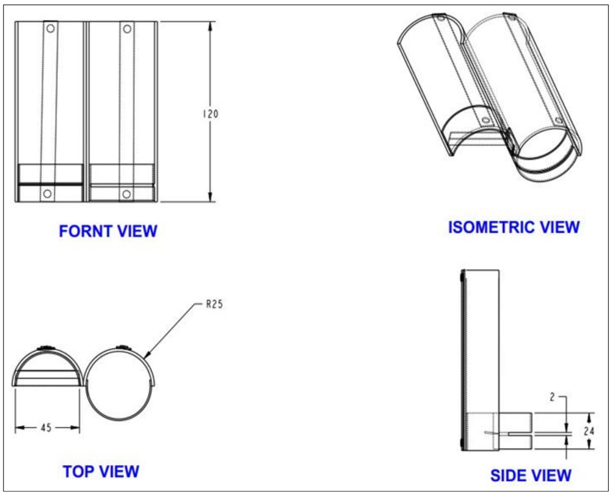

Fig 1: Design of Sliding Blade Cutter

Table 1: Specifications table for Sliding Blade Cutter

Sr. No.	Parameter	Value/Material
1.	Device type	Palm-mounted
2.	Shell material	PVC, 5 cm diameter, 12 cm length
3.	Blade	Stainless steel, 4 cm × 1.5 cm, 1 mm thick
4.	Slot (opposite half)	2 mm wide
5.	Strap	Elastic, 12 cm, double-riveted
6.	Weight	60 g
7.	Operation	Single hands; no need to hold crop

A Scissor-Type Cutter with Lever and Collection Box

Cutter 2, the Scissor-Type Cutter, was specifically developed to address the shortcomings of hand-held sickles in finger millet earhead harvesting. The tool uses a two-handed scissor with actuation mechanism that eliminates the need to grip the crop during cutting, thereby reducing wrist strain, improving cutting precision and enhancing operational safety. (Vishwakarma *et al*., 2020) [17].

Developmental process

The design of Cutter 2 evolved through several stages, with emphasis on reducing weight, improving ergonomics, and enhancing handling efficiency:

- **Initial prototype:** Constructed from a metal sheet body with a straight blade. This version was heavy, poorly aligned, and ineffective in cutting earheads.
- **Material substitution:** The metal sheet was replaced with polycarbonate to reduce weight. A rectangular collecting box with a mounted pruner shear was fabricated.
- **Shape and material refinement:** The rectangular box obstructed neighboring earheads. To overcome this, the box was redesigned with a curved profile, and lightweight fiberglass side walls were introduced, reducing weight while maintaining durability.
- **Guiding mechanism:** A small curved front extension (3 × 1.5 cm) was added to channel earheads directly into the cutting zone, improving accuracy and operator control.

Through these iterative modifications, the final model of Cutter 2 was developed, integrating a bypass pruner blade actuated by a lever on a PVC pipe frame. The inclusion of a compression spring for blade return, along with the curved collecting box, provided an effective balance of ergonomic comfort, material efficiency, and crop-specific suitability for finger millet harvesting.

Constructional details

The Cutter 2 (scissor-type earhead cutter) was designed to optimize ergonomics, cutting efficiency, and ease of collection. Its primary construction features are described as follows:

- **Blades:** The cutting mechanism comprises two curved scissor-type blades, each measuring 5 cm in length, fabricated from high carbon steel. One blade is fixed, while the other is actuated via a lever mechanism, enabling precise cutting with minimal effort.
- **Frame:** The main frame of the cutter consists of a 46 cm long, 2 cm diameter PVC pipe, which serves a dual function as both the handle and structural support for the tool.
- **Spring Mechanism:** A compression spring is positioned between the blades to ensure automatic return of the movable blade after each cut, thereby enhancing operational efficiency and reducing operator fatigue.
- **Brake Mechanism:** The movable blade is connected to a 7 cm lever via a 40 cm long cable. The lever is ergonomically shaped to fit the operator's hand, and manual actuation transmits force to the blade, resulting in controlled and precise cutting.
- **Collecting Box:** Positioned immediately behind the blades, a curved collecting box receives the cut earheads. The base of the box is constructed from polycarbonate sheet to ensure durability, while the side walls, with a height of 10 cm, are fabricated from lightweight fiberglass to reduce overall tool weight.
- **Front Extension:** A curved front extension (2.5 cm × 1 cm) guides the earheads directly into the blade zone, allowing rapid and accurate alignment during operation.

The integrated design of Cutter 2 ensures seamless alignment with the earhead, effortless blade actuation, and direct collection of cut material, thereby minimizing physical contact and operator fatigue.

Table 2: Specifications table for Scissor-Type Cutter

Sr. No.	Parameter	Value / Material
1.	Overall length	58 cm (PVC handle + frame)
2.	Handle diameter	2 cm (PVC)
3.	Handle length	47 cm
4.	Blade type/length	Curved scissor, high carbon steel, 5 cm
5.	length	7 cm, curved (bicycle-style, ergonomically shaped)
6.	Spring mechanism	Compression spring (for blade return)
7.	Brake cable length	40 cm
8.	Collecting box	Curved, polycarbonate (base), fiberglass (side walls)
9.	collection Capacity	765 g
10.	Front extension	Curved, 3 cm × 1.5 cm (earhead guide)
11.	Weight	550 g
12.	Operation	Two-hand, lever actuated, crop not held

Finger millet collecting bag

To complement the manual cutters and improve ergonomics during harvesting, a finger millet collecting bag was developed as a supplementary tool. The bag was designed to reduce repetitive bending and ground placement by allowing operators to directly store harvested earheads while working. Constructed from durable stitched cotton, it featured a conical, tapered shape that funneled earheads toward the base for optimal capacity utilization. A threaded drawstring at the lower end enabled quick unloading into larger containers without removing the bag.

For ergonomic support, two adjustable shoulder straps and a waist belt distributed weight evenly and minimized swinging during field movement, allowing the bag to comfortably carry 1.5-2 kg of earheads. The wide top opening facilitated easy deposition of earheads when using Cutter 1, Cutter 2, or even the traditional sickle. By integrating durability, ergonomics, and ease of handling, the collecting bag effectively reduced operator fatigue and enhanced overall harvesting efficiency.

The main specifications of the finger millet collecting bag are as follows:

Table 3: Specifications of finger millet collecting bag

Sr. No.	Parameter	Specification
1.	Shape	Conical, tapered
2.	Fabric	Cotton, stitched
3.	Length of bag	32 cm
4.	Width of bag	16 cm
5.	Length/Depth	40 cm
6.	Collection Capacity	Up to 2 kg earheads
7.	Straps	Two adjustable shoulder straps, one waist belt
8.	Weight (empty)	225 g
9.	Reinforcement	Double-stitched load points, reinforced seams
10.	Special Features	Hands-free, quick unload

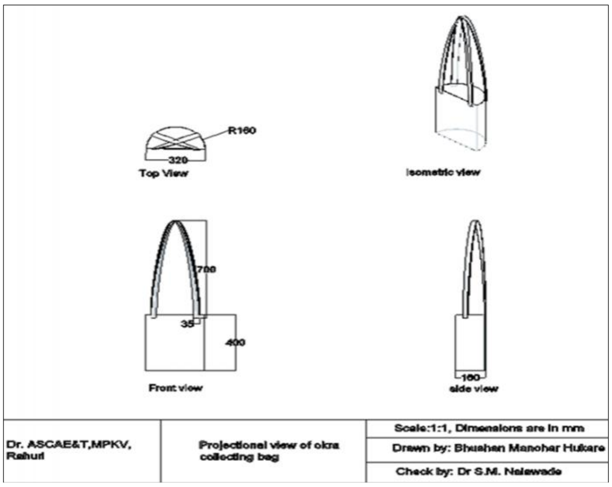

Fig 2: Design of finger millet collecting bag

Results and Discussion

The development work resulted in the successful fabrication of two manually operated finger millet earhead cutters, namely the Sliding Blade Cutter (Cutter 1) and the Scissor-Type Cutter with Lever and Collection Box (Cutter 2), along with a supplementary finger millet collecting bag. These innovations were specifically designed to overcome the shortcomings of traditional sickle harvesting by integrating crop-specific requirements with ergonomic principles.

The Sliding Blade Cutter (Cutter 1) was adapted from an okra cutter-holder previously developed at Dr. ASCAET, MPKV Rahuri. To suit the structural characteristics of finger millet, substantial modifications were introduced. The blade and shell were enlarged and reinforced to manage the thicker and tougher peduncles of mature earheads, while the strap design was improved with elastic, double-riveted attachments for greater comfort and stability during prolonged use. The passage slot was widened to allow smooth and unobstructed cutting, and tighter alignment tolerances ensured reliable operation. Importantly, the cutting mechanism was shifted from an anvil-type, suitable for soft crops like okra, to a shearing-type mechanism capable of handling the higher cutting force required for finger millet stalks. These adaptations made Cutter 1 field-ready for actual harvesting conditions, addressing crop-specific needs for safety, efficiency, and comfort.

The palm-mounted design allowed mounting on either hand, freeing operators from the need to grip the crop, and the lightweight construction (60 g) enabled prolonged use without fatigue. The ability to use both left and right hands independently further increased harvesting rate and reduced cumulative wrist and arm strain.

Fig 3: Developed Sliding Blade Cutter

The Scissor-Type Cutter with Lever and Collection Box (Cutter 2) was developed through several stages of refinement to improve ergonomics, cutting performance, and material handling. The initial prototype, constructed with a straight metal blade and sheet body, proved heavy and inefficient. To address these issues, polycarbonate and fiberglass materials were introduced, resulting in a lighter and more durable frame. The collecting box was redesigned with a curved profile to prevent obstruction of adjacent earheads, while a front guiding extension ensured accurate alignment of earheads into the cutting zone. The final design incorporated a bypass pruner blade actuated by a lever connected through a brake cable to the handle, supported by a compression spring for automatic blade return. This system reduced muscular effort, improved precision, and minimized wrist strain by eliminating the need to grip the crop. The curved collecting box, positioned behind the blades, directly received earheads during cutting, reducing shattering losses and improving workflow efficiency. With a total weight of 550 g and a collection capacity of 765 g, Cutter 2 successfully combined ergonomic comfort with functional efficiency, making it suitable for sustained use in field conditions.

To complement the manual cutters, a Finger Millet Collecting Bag was also developed to improve post-harvest ergonomics. Constructed from durable stitched cotton, the bag featured a conical, tapered design that allowed earheads to funnel naturally toward the base, while a threaded drawstring at the bottom enabled fast unloading. Two adjustable shoulder straps and a waist belt distributed weight evenly across the body, minimizing fatigue and reducing swinging during movement. With a carrying capacity of up to 2 kg, the bag allowed operators to store harvested earheads without frequent bending or ground placement, thereby reducing drudgery. The wide top opening made it compatible for use with Cutter 1, Cutter 2 or even the traditional sickle.

Fig 4: Developed Scissor-Type Cutter

When compared with the conventional sickle, the developed tools clearly demonstrated their advantages. The sickle requires continuous bending, awkward wrist movements, and exposes operators to injury risks due to its open blade. It also contributes to grain shattering losses of 3-5%. By contrast, Cutter 1 provided a lightweight, selective harvesting option with improved operator comfort, while Cutter 2 offered a more comprehensive ergonomic solution through its integrated lever mechanism and collection box. The collecting bag further reduced post-harvest fatigue, complementing the cutters in improving overall efficiency. Together, these innovations represent a practical, low-cost, and crop-specific solution for finger millet harvesting, addressing both ergonomic and functional limitations of traditional tools.

Conclusion

Two manually operated finger millet earhead cutters were successfully developed to overcome the drawbacks of traditional sickle harvesting. The Sliding Blade Cutter (Cutter 1) provided a lightweight, palm-mounted option for selective harvesting, while the Scissor-Type Cutter with Lever and Collection Box (Cutter 2) offered enhanced ergonomics, reduced muscular effort, and minimized shattering losses through its lever mechanism and integrated collection system. A supplementary collecting bag further improved field efficiency by reducing repetitive bending and operator fatigue. Together, these innovations demonstrated clear ergonomic and functional advantages over the sickle, presenting low-cost, crop-specific, and farmer-friendly solutions especially suited to smallholder and women farmers. The study highlights the importance of integrating ergonomic design with crop morphology and establishes a basis for future refinements and field evaluations to promote wider adoption in finger millet cultivation.

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