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Conceptual design of a safflower harvester

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Abstract
Safflower (*Carthamus tinctorius* L.), an economically valuable oilseed crop, is primarily cultivated in arid and semi-arid regions of India. Despite its potential, its harvesting process is still dependent on manual labor, making it inefficient, time-consuming, and costly, especially due to the crop's thorny nature. Mechanized harvesting solutions are scarce due to the unique morphology of safflower. This study presents a conceptual design for a walk-behind three-row safflower harvester that addresses these specific challenges. The machine comprises a reciprocating cutter bar, crop lifters, star wheel gatherers, and a belt-type windrower powered by a 5 HP diesel engine. The design is intended to increase harvesting efficiency, reduce drudgery, and lower operational costs for small and marginal farmers. The paper includes detailed component specifications, theoretical calculations, and field adaptability analysis.

Keywords: Safflower, mechanization, conceptual design, cutter bar, windrowing, small farm equipment

Introduction
Safflower (*Carthamus tinctorius* L.) is a resilient, drought-tolerant oilseed crop primarily cultivated in semi-arid and dryland regions. It holds significant economic importance due to its oil-rich seeds, which are used in culinary and industrial applications, as well as its petals, which yield natural dyes and medicinal compounds. India ranks among the top producers of safflower globally, with Maharashtra accounting for a substantial share of the national acreage.

Despite its agronomic and economic value, the harvesting of safflower continues to rely heavily on manual labor. The crop presents several unique challenges during harvest, stemming from its botanical and morphological characteristics. Notably, safflower plants are densely branched and possess sharp spines on stems and leaves, which deter manual handling and increase the risk of physical injury to farm workers. Additionally, the crop often exhibits non-uniform maturity across branches, complicating the timing and execution of harvest operations.

Therefore, there exists a critical need to design and develop a dedicated, compact, and cost-effective safflower harvester that is tailored to the crop's morphological traits, compatible with smallholder farming systems, and capable of reducing labor dependence and harvest losses. A conceptual design targeting these goals forms the core focus of this research.

Objectives
To design a walk-behind self-propelled safflower harvester.

Materials and Methods
Crop Morphology Considerations: A thorough understanding of the morphological characteristics of safflower is essential for designing effective harvesting machinery. The physical structure of the safflower plant presents both challenges and design opportunities. Key traits such as plant height, branching pattern, spine distribution, and lodging tendency directly influence the type and configuration of cutting, lifting, conveying, and collecting mechanisms in a harvester.

Safflower plants exhibit the following prominent morphological features:

Table 1: Morphological Characteristics of Safflower Relevant to Harvester Design

Parameter	Typical Range / Value	Design Implication
Plant height	90-150 cm	Determines vertical clearance and cutter bar height
Branching height (from ground)	20-30 cm	Cutter bar should cut below first branch
Number of primary branches	8-20	Influences bulk handling and gathering mechanism
Head (capitulum) diameter	2.5-4.5 cm	Determines size of collection belt or windrower
Stem diameter	6-10 mm	Affects cutting force and blade design
Seed shattering susceptibility	Medium (in late harvest)	Harvest timing and gentle handling essential
Row spacing	25-30 cm	Influences harvester row configuration (e.g., 3 rows = 90 cm width)

Design Requirements: The conceptualization and engineering of a safflower harvester must begin with a clear understanding of the crop's physical traits, user needs, field conditions, and operational constraints. The following design requirements serve as essential benchmarks to ensure functional efficiency, farmer acceptability, and feasibility of manufacture and deployment.

Minimize Damage to Seed Heads and Stalks: Safflower has a moderate tendency for seed shattering when the crop is over-mature. The capitulum (flower head) holds the seeds in a tight whorl, but mechanical shocks or rough handling during harvest can lead to seed loss. Moreover, damaging stalks leads to structural failure of the plant before it is windrowed or collected. Therefore:

- The cutting mechanism must deliver a clean, low-resistance cut with minimal vibration.
- The crop conveyance system (e.g., belt, star wheel) must be soft-contact or padded, ensuring gentle handling.
- The machine should minimize vertical drop or impact shocks during transfer of the cut crop to the windrower.

Harvest Both Standing and Lodged Crops: Lodging in safflower occurs frequently due to wind, heavy rain, or poor root anchorage during maturity. A versatile harvester must handle both vertical and inclined plants. Therefore:

- Crop lifters at the base of the cutter bar are essential to raise lodged stems to cutting height.
- Star wheels should gently gather inclined plants and guide them toward the cutter bar.
- The machine should have adjustable lifting angles and flexible supports to accommodate variable lodging patterns.

Functional Components

The primary components and their functions are elaborated below:

Cutter Bar

1. **Function**: Performs a clean, horizontal cut 10-15 cm above ground level, just below the first branching node of the safflower plant.
2. **Type**: A reciprocating cutter bar mechanism using guard fingers and ledger plates with high-carbon steel knife sections.
3. **Design Considerations**

- Must be sharp and wear-resistant to handle semi-woody stalks.
- Cutting speed of ~1.5-1.7 m/s is optimal to reduce shattering losses.
- Bar length of 1.2 meters is ideal to cover three rows spaced 30 cm apart.

Crop Lifters

1. **Function**: Lift lodged and inclined plants into the cutter path to ensure uniform cutting.
2. **Type**: Finger-like spring-steel or flat MS lifters mounted ahead of the cutter bar.
3. **Design Considerations**:

- Must be angled (15°-30°) to scoop without uprooting or damaging the base.
- Spacing aligned with each plant row to maximize contact efficiency.
- Rounded or tapered ends to prevent plant snagging or dragging.

Star Wheels

- **Function**: Gather the cut stalks and direct them centrally toward the conveyor or windrower.
- **Type**: Rotating star-shaped wheels with flexible fingers.
- **Design Considerations**: o Mounted at an inclined angle (~10-15° from vertical) on each side of the cutting path. o Made of MS pipe or aluminum hubs with rubber-tipped fingers. o Synchronized rotational speed with ground speed to avoid excessive impact or plant throw.

Conveyor Belt

- **Function**: Transports and deposits the cut crop in a central windrow for manual bundling or pick-up.
- **Type**: Lugged or flat rubber belt conveyor running behind the cutter assembly.
- **Design Considerations**: o Belt speed slightly higher than ground speed to ensure effective crop movement. o Inclined design (5°-10°) for natural crop guidance. o May include side panels or baffles to prevent crop spillage.

Frame and Wheels

- **Function**: Provide structural support and field mobility.
- **Type**: Welded MS box-section frame with two large ground wheels (tractor-tyre type) and a caster wheel for steering.
- **Design Considerations**: o Compact footprint (~1.2 m width × 1.5 m length) for small field maneuverability. o Ground clearance of ~25 cm to avoid obstruction by clods or ridges.
- Wheel diameter 400-500 mm for field operability with traction.

Power Unit

1. **Function**: Supplies mechanical power to the cutter bar, conveyor belt, and optionally, the wheels via a gearbox.
2. **Type**: Air-cooled, 5 HP diesel engine (commonly available with power tillers).
3. **Design Considerations**:

- Engine mounted on the main frame with direct or belt-pulley transmission to PTO shaft.
- Fuel-efficient, vibration-dampened mounting.
- Provision for engine throttle control and clutch disengagement by the operator.

Working Principle: The conceptual safflower harvester operates on the principle of synchronized mechanical action to cut, lift, guide, and deposit the crop in a streamlined manner. It is designed as a walkbehind, self-propelled machine, allowing a single operator to control and maneuver it through safflower fields with minimal effort.

Operational Flow
1. Forward Movement
2. Crop Engagement by Lifters
3. Cutting Mechanism
4. Guidance by Star Wheels
5. Transportation by Conveyor Belt
6. Windrow Formation
7. Power Transmission

Design Specifications
The crop is guided by crop morphology, field conditions, and operational feasibility. The following table summarizes the key technical parameters proposed for the machine to ensure optimal performance, efficiency, and farmer usability.

Table 2: Design Specifications of design of conceptual design of a walk-behind safflower harvester

Parameter	Value	Remarks
Effective Cutting Width	1.2 m	Covers 3 safflower rows spaced 30 cm apart
Cutter Bar Stroke	50 mm	Sufficient to provide smooth reciprocating knife action
Cutter Bar Frequency	600 strokes per minute	Balances cutting speed and seed retention
Forward Speed	4 km/h	Matches cutting and conveying capabilities
Engine Power	5 HP @ 3000 rpm	Petrol engine commonly available in rural areas
Star Wheel Diameter	400 mm	Ensures effective gathering and guiding of cut crop
Conveyor Belt Width	1.2 m	Matches cutter width for smooth crop transportation
Traction Wheel Size	600 mm diameter, lugged	Provides traction and mobility on uneven field terrain
Total Weight (Estimated)	180-200 kg	Lightweight for easy maneuverability by one operator

Design Calculations
1. Theoretical Field Capacity (TFC)
$TFC = (W \times S) / 10 = (1.2 \times 2.5) / 10 = 0.30$ ha/h

Effective Field Capacity (EFC) $= 0.30 \times 0.75 = 0.225$ ha/h

2. Cutter Bar Dynamics
Knife speed $= 2 \times f \times s = 2 \times 10 \times 0.05 = 1.0$ m/s

3. Power Transmission (Gear Ratio)
Engine RPM = 3000, Required RPM = 600, Reduction = 4.67

4. Windrow Conveyor Speed
$v = \pi \times D \times N / 60 = 3.14 \times 0.4 \times 300 / 60 \approx 6.28$ m/min

Conclusion
The conceptual design of the safflower harvester addresses the critical need for crop-specific mechanization solutions suitable for small farms and dryland conditions. By incorporating a compact structure and operational features tailored to the unique characteristics of safflower, the proposed design offers a practical and costeffective alternative to labor-intensive harvesting. It lays a strong foundation for the development of a functional prototype and future performance evaluation, ultimately contributing to improved harvesting efficiency, reduced drudgery, and enhanced farm productivity for smallholder safflower growers.

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