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Performance evaluation of safflower harvester

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Abstract

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop cultivated in the semi-arid regions of India, particularly in Maharashtra. Harvesting of safflower is predominantly carried out manually due to the non-availability of suitable harvesting machinery. Manual harvesting is labour-intensive, time-consuming and hazardous because of the crop's spiny nature, while increasing labour scarcity and harvesting costs have further emphasized the need for mechanization. The present study was undertaken to modify the existing engine-operated safflower harvester by incorporating a vibration isolator and to evaluate its field performance, ergonomic suitability and economic feasibility. The modified harvester was evaluated at the Oilseed Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola, using safflower variety AKS-351 (PDKV White-351). Performance evaluation included measurement of crop and field parameters, harvesting losses, stubble height, cutting efficiency, field capacity, field efficiency, fuel consumption. The average forward speed of the machine was 2.5 km h^{-1} with an effective cutting width of 1.2 m. The theoretical and effective field capacities were 0.30 and 0.25 ha h^{-1} , respectively, resulting in a field efficiency of 81.8%. The average fuel consumption was 2.8 L ha^{-1} (0.8 L h^{-1}). The total cost of safflower harvester is 35580/-.

Keywords: Safflower, modified safflower harvester, field efficiency, harvesting losses, fuel consumption, cost economics

Introduction

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop widely cultivated in the arid and semi-arid regions of India because of its excellent drought tolerance and adaptability to marginal soils. The crop is valued for its high-quality edible oil, which is rich in unsaturated fatty acids, and is widely used in the food, pharmaceutical, and industrial sectors. Despite its economic and nutritional importance, safflower harvesting is still performed mainly by manual labour. The crop's spiny stems, strong branches, and non-uniform maturity make harvesting labour-intensive, time-consuming, and physically demanding. In recent years, increasing labour shortages and rising harvesting costs have highlighted the need for mechanized harvesting systems. However, most harvesting machines developed for cereal crops are not suitable for safflower because of its unique morphological characteristics. Consequently, considerable research has focused on the development, modification, and performance evaluation of safflower harvesting machinery to improve harvesting efficiency, reduce labour requirements, minimize crop losses, and enhance operator comfort. This review presents an overview of recent advances in safflower harvesting technologies, machine performance, ergonomic aspects, and future research opportunities for efficient and economical mechanized harvesting.

Materials and Methods

This section outlines the materials and methods used for the modifications and performance evaluation of safflower harvester. The study relies on calculations, field data, and recognized engineering principles. It encompasses evaluating crop parameters, performance equations, and integrating ergonomic factors to improve operator comfort and effectiveness.

Functional components of existing safflower

The existing engine operated safflower harvester was designed in Department of Farm Power and Machinery. The components were fabricated and assembled in the workshop of Department of

Farm Power and Machinery, Dr. PDKV, Akola. The functional components of safflower harvester include main frame, handle, engine, star wheel, crop lifter, crop divider, cutter bar, levers, lugged belt and cage wheels.

Modifications of existing safflower harvester

The existing safflower harvester was modified by incorporating a vibration isolator, a cutter bar height adjustment mechanism, and a repositioned drive pulley. These modifications reduced vibration and operating noise, maintained the desired cutting height, prevented component interference, and improved the machine's operational efficiency, stability, and operator comfort during harvesting.

Crop parameters

The performance of safflower harvesting machinery is greatly influenced by crop characteristics. Therefore, important crop parameters such as plant height, row and plant spacing, minimum pod height, stem diameter, plant population, stem and grain moisture content, stubble height, soil moisture content, and pre-harvest losses are evaluated to assess machine suitability and harvesting performance.

Soil Moisture Content

Soil moisture content was determined using the oven-dry method. Soil samples were dried at 105°C for 24 h, and moisture content on a dry basis was calculated using the following equation.

$$\text{Moisture content (db)\%} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where,

W_1 = Weight of container, g

W_2 = Weight of container and wet soil, g

W_3 = Weight of dry soil, g

Pre-harvest Losses

Pre-harvest losses were determined by collecting the grains or pods that had fallen on the ground before harvesting from randomly selected 1 m² sampling areas. The losses were expressed as a percentage of the total grain yield.

$$\text{Pre harvest losses (\%)} = \frac{\text{Pre harvest grain losses} \left(\frac{\text{kg}}{\text{ha}} \right)}{\text{Total grain yield} \left(\frac{\text{kg}}{\text{ha}} \right)} \times 100$$

Harvesting Losses

Harvesting losses refer to the grain losses that occur during the harvesting operation. These include pre-harvest losses, shattering losses, and uncut losses, and the total harvesting loss is calculated as the sum of these components.

$$W_{gt} = W_{g1} + W_{g2} + W_{g3}$$

Where,

W_{gt} - Total grain losses (g/m²)

W_{g1} - Pre harvest losses (g/m²)

W_{g2} - Shattering losses (g/m²)

W_{g3} - Uncut losses (g/m²)

Cutting Efficiency

Cutting efficiency was determined by comparing the number of plants cut to the total number of plants within a 1 m² test area. It was expressed as the percentage of plants successfully cut during

harvesting, with higher values indicating better cutting performance of the harvester.

$$\text{Cutting efficiency, \%} = \frac{\text{No. of plants cut per m}^2}{\text{Total no. of plants per m}^2} \times 100$$

Theoretical Field Capacity

Theoretical field capacity is the maximum area a machine can cover per unit time under ideal operating conditions. It is determined from the effective working width and forward speed of the machine and serves as an indicator of its potential field performance.

$$\text{T.F.C} = \frac{S \times W}{10}$$

Where,

T.F.C = Theoretical field capacity, ha/h

W = Theoretical width of Implement, m

S = Speed of operation, km/h

Field Efficiency

Field efficiency is the ratio of effective field capacity to theoretical field capacity, expressed as a percentage. It indicates how efficiently a machine performs under actual field conditions, with higher values reflecting better machine utilization and lower operational time losses.

$$\text{FE} = \frac{\text{EFC}}{\text{TFC}} \times 100$$

Where,

FE = field efficiency, %

EFC = effective field capacity, ha/h

TFC = theoretical field capacity, ha/h

Cost economics of safflower harvester

The economic feasibility of the safflower harvester was evaluated by estimating the cost of operation based on the procedures outlined in IS: 9164–1979. The analysis included the estimation of fixed and operating costs to determine the overall cost of harvesting and assess the machine's economic viability for field use.

Fixed cost

Depreciation

This cost reflects the reduction in value of a machine with use (wear) and time (obsolescence). While actual depreciation would depend on the price of the machine after its use, based on different computational method depreciation can be estimated by straight line method as given below.

$$D = \frac{P - S}{L \times H}$$

Where,

D = Average annual depreciation, Rs/annum,

P = Purchase price of the machine, Rs,

S = Salvage value, taken as 10 per cent of the purchase price,

L = Life of machine, years, and

H = Working hours per year.

Interest

Interest on investment was considered as a fixed cost and calculated based on the average value of the machine over its

service life. An annual interest rate of 10% was assumed in accordance with IS: 9164–1979 to estimate the interest cost.

$$I = \frac{P+S}{2} \times \frac{R}{H}$$

Where,

I = Interest to be paid per hour

P = Purchase price of the machine, Rs,

S = Salvage value of the machine, Rs,

R = Rate of interest per year (taken as 12 per cent)

H = Working hours per year, hours.

Variable Cost

Variable cost includes the expenses incurred during machine operation and varies with the duration of use. It comprises fuel, lubrication, repair and maintenance, and operator wages, which together constitute the operating cost of the safflower harvester.

$$C_{variable} = FC + LC + Rm + OW$$

Where,

$C_{variable}$ = Variable cost (₹ h⁻¹)

FC = Fuel cost (₹ h⁻¹)

LC = Lubrication cost (₹ h⁻¹)

Rm = Repair and maintenance cost (₹ h⁻¹)

OW = Operator wage (₹ h⁻¹)

Results and Discussion

The field performance of modified safflower harvester was conducted on PDKV, Akola, AKS-351 (PDKV White-351) variety of safflower in oilseed research unit field, Akola. The overall performance of the machine was evaluated on the basis of height of cut, no of uncut plants, harvesting losses, field capacity, field efficiency, cutting efficiency, and fuel consumption and cost economics of harvester.

Crop parameters

Crop conditions of the field were studied and different relevant parameters were observed. The mean values of these different crop parameters for safflower crop are given in table 1.

Table 1: Crop parameters of safflower

Sr. No	Crop parameters	Average values
1	Variety	AKS-351 (PDKV White 351)
2	Rainfed / irrigated	Rain fed
3	Normal period of maturity, days	136-140
4	Crop height, mm	855
5	Row to Row spacing, mm	450
6	Plant to Plant spacing, mm	200
7	Minimum pod height from ground surface, mm	450
8	Stem diameter, mm	10.93
9	Plant population, m ²	9-10
10	Pre harvest losses, %	4.75
11	Moisture content of stem, %	13.54
12	Moisture content of pods, %	11.41
13	Stubble height, mm	80
14	Branches per plant, no	8
15	Pods per branches	6
16	100 grains weight, g	6.2

Table 2: Machine parameters of safflower harvester

Sr. No	Machine parameters	values
1.	Effective working width, mm	1200
2.	Theoretical field capacity, ha/hr	0.3
3.	Effective field capacity, ha/hr	0.25
4.	Field efficiency, %	81.8
5.	Fuel consumption, l/ha	2.8

Harvesting losses

Losses occurred during the harvesting of crop are called as harvesting losses. Total harvesting losses include the pre harvesting losses, shattering losses and uncut losses.

Cutting efficiency

No uncut plant found in field, therefore cutting efficiency was 100 per cent.

Effective working width

The working width of the safflower harvester is the distance between 2 rows as the machine was able to cut 2 rows of safflower crop spaced at a distance of 450 mm. The effective working width or cutting width of the machine was found to be 1200mm.

Theoretical field capacity

The theoretical field capacity of the safflower harvester was found to be 0.3 ha/hr by using above mentioned equation in chapter 3.

Effective field capacity

The effective field capacity of safflower harvester was time consumed for actual work and lost for other works such as turning and break downs. The average effective field capacity was found as 0.25 ha/h.

Field efficiency

The field efficiency of safflower harvester was determined by above equation. It was found as 81.8%.

Fuel consumption

The fuel consumption of safflower harvester was found as 2.8 lit/ha.

Cost estimation of harvester

The total cost of operation of the developed soybean harvester was Rs 165.38/h, comprising Rs 18.49/h fixed cost and Rs 146.88/h variable cost. The purchase price of the machine was Rs 35,580, while depreciation and interest costs were Rs 10.67/h and Rs 7.82/h, respectively.

Conclusion

The average pre-harvest loss of the experimental field was 2.69%, while the soil moisture content was 6.69%. The modified safflower harvester achieved a total harvesting loss of 2.88%, consisting of 2.29% shattering loss and 0.59% uncut loss, with an average stubble height of 80 mm and 100% cutting efficiency under the test conditions. The machine operated at an average forward speed of 2.5 km h⁻¹, attaining a theoretical field capacity of 0.30 ha h⁻¹, an effective field capacity of 0.25 ha h⁻¹, and a field efficiency of 81.8%. The average fuel consumption was 2.8 L ha⁻¹ (0.8 L h⁻¹), indicating economical and efficient field performance.

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