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Energy use Efficiency and Economic Feasibility of Self-propelled Single Row Cotton Picker over Traditional Cotton Picking Practices

S. Sai Mohan[1], C. Ramana[2], A. Ashok Kumar[3], K. Madhusudana Reddy[4], N. Sunitha[5]

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ABSTRACT

Background: Over the years, cotton cultivation and production has been increasing quantitatively in the country. India, being one of the five largest cotton producing countries in the world, the entire cotton is picked manually. Increase in the wage rate of human labour is the major factor responsible for the drastic rise in cost of cotton cultivation which accounts for 30% of the total cost of cultivation. Considering the issues and challenges with respect to high operation costs, labour scarcity and adaption to various field condition, a research work has been undertaken to develop a self-propelled single row cotton picker.

Methods: A self-propelled single row cotton picker was developed and evaluated for its performance. Energy spent in the field and energy use efficiency in both machine picking and traditional practices was measured in terms of man hour's expressed in megajoules per hectare (MJ ha^{-1}). Straight line method was adopted for performing the cost economics.

Result: Energy use efficiency was found to be less in case of manual picking *i.e.*, 17.4% compared to 31.7% in machine picking. Similarly, energy productivity in case of manual and machine picking was calculated to be 1.48 kg MJ^{-1} and 2.65 kg MJ^{-1}, respectively. Cost of self-propelled single row cotton picker was calculated to be is Rs. 8,50,000. Cost of operation using developed prototype was found to be 789 Rs h^{-1} and 5,175 Rs ha^{-1} with a saving of 70% compared to manual picking. Also, 90% saving in labour hours spent in harvesting was noted. Payback period of the machine was calculated as 4.8 years. Breakeven analysis was found to be 275 h yr^{-1}.

Key words: Break-even point, Depreciation, Energy productivity, Energy use efficiency, Pay-back period.

INTRODUCTION

Cotton cultivation and production has been increasing quantitatively in the country over the years which is estimated to be around 13 million hectares with a productivity of 486 kg ha^{-1} and a production of 343.47 lakh bales in the year 2022-23 (Committee on Cotton Production and Consumption (COCPC), 2023), respectively. Cotton farming in India provides livelihood to 6 million farmers and around 40 -50 million people are employed in its trade and processing. Although 41 per cent of the total area under cotton in the world is accounted by India, the average productivity of cotton is still low as compared to the world average of 762 kg ha^{-1} (COCPC, 2023) because of the cultural practices and staggered blooming characteristics. More than 4 million cotton farms in India are less than 5 acres making them incapable of practicing large scale mechanization.

India, being one of the five largest cotton producing countries in the world, the entire cotton is picked manually. Seed cotton (kapas) picking consumes 231 to 975 (average 517) labour-h ha^{-1} with conventional practice of hand picking. An exceptionally good picker in a heavy crop will pick up to 68 kg day^{-1} of clean cotton but average lies much below than 50 kg day^{-1} (Prasad *et al.,* 2007). Since labour is fast becoming a bottleneck and important cost factor and therefore manual picking will soon become unviable in Indian cotton production. Increase in the wage rate of

[1]Department of Farm Machinery and Power Engineering, Dr. NTR College of Agricultural Engineering, Acharya N.G. Ranga Agricultural University, Bapatla-522 101, Andhra Pradesh, India.
[2]Department of Farm Machinery and Power Engineering, Director of Research and University Head, Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Tirupati-517 502, Andhra Pradesh, India.
[3]All India Coordinated Research Project on Functional Independence Measure Scheme, Dr. NTR College of Agricultural Engineering, Acharya N.G. Ranga Agricultural University, Bapatla-522 101, Andhra Pradesh, India.
[4]Department of Agricultural Engineering, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati-517 502, Andhra Pradesh, India.
[5]Department of Agronomy, Sri Mekapati Goutham Reddy Agricultural College, Udayagiri-524 226, Odisha, India.

Corresponding Author: S. Sai Mohan, Department of Farm Machinery and Power Engineering, Dr. NTR College of Agricultural Engineering, Acharya N.G. Ranga Agricultural University, Bapatla-522 101, Andhra Pradesh, India. Email: samalasaimohan@gmail.com
ORCIDs: 0000-0002-4899-8864

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human labour is the major factor responsible for the drastic rise in cost of cotton cultivation which accounts for 30% of the total cost of cultivation (Reddy *et al.,* 2018). Hence, the key in reducing the cost of cultivation of cotton is by reducing the dependency on human labour which can be achieved by the advent of mechanization.

Mechanization in cotton picking is considered to be of vital importance at present situation. Efforts were made in the past by various research organizations in developing knapsack pneumatic cotton pickers, power tiller mounted and tractor drawn pickers but none of them could find its place and satisfy the requirement of small land holding farmers. Barring these few instances, this area of research and development was not given much attention and a holistic approach has been lacking. Considering the issues and challenges with respect to high operation costs, labour scarcity and adaption to various field condition, a research work has been undertaken to design, develop and evaluate a self-propelled single row cotton picker.

A self-propelled single row cotton picker was developed and evaluated for its performance. The current paper highlights the economic feasibility of the developed self-propelled single row cotton picker and its impact on the traditional cotton picking practices. Energy use efficiency and net energy spent in machine harvesting and manual picking were calculated.

MATERIALS AND METHODS

Traditional cotton picking practices

Cotton picking in India has predominantly been a manual process. Cotton picking is an important source of employment for women in rural areas providing supplementary income. Workers, often women and children, would go into the fields and carefully handpick cotton bolls from the plants. This method allows for selective harvesting, ensuring that only mature cotton bolls are collected while leaving immature ones to ripen further. Manual pickers typically carry baskets or cloth bags to collect the harvested cotton. These containers are lightweight and easy to carry, allowing pickers to move efficiently through the fields (Fig 1).

In many rural areas of India, cotton picking has traditionally been a communal activity. Families or groups of villagers would come together to help each other with the harvest, fostering a sense of community and cooperation. In Manual picking, workers spend 75 to 85% of their time in the intermediate storage and collection whereas only 15 to 25% of the time is spent on actual picking of cotton buds (Brittany *et al*., 2017).



Fig 1: Manual cotton picking practice.

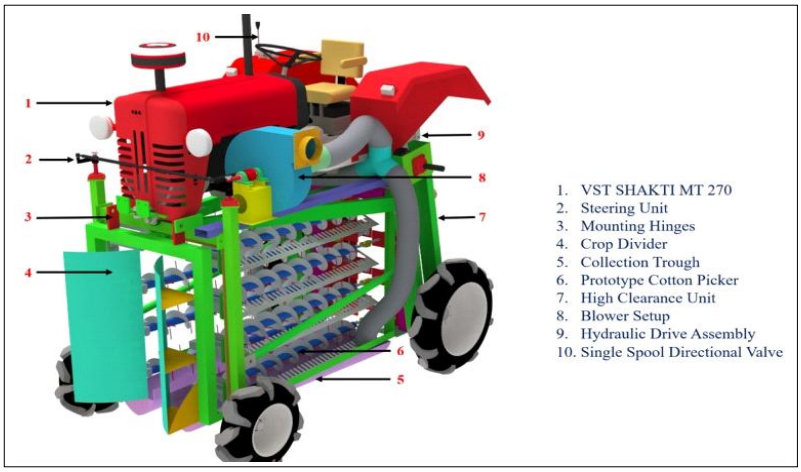


Fig 2: Isometric view of self-propelled single row cotton picker.

Labour availability has dropped from 70.3% of the population in 1961 to 48.9% in 2010 and cost of picking cotton from the farm has increased to Rs. 10-12 a kg now from Rs. 4 in 2007 (Business Line, 2012). Hence, the key in reducing the cost of cotton production is by reducing the dependency on human labour which can be achieved by the advent of mechanization.

The time taken for manual picking of cotton was collected by noting the time taken to pick open cotton bolls on each plant and replicated it for a hectare. On an average 44,444 plants are sown in a hectare with a spacing of 120 × 40 cm (row to row × plant to plant) (Gunasekaran *et al.,* 2020). The average time noted for manual picking of cotton was calculated as 517 labour hr ha^{-1}.

Self-propelled single row cotton picker

Machine with an overall working volume of 1 m^3 with 8 picking rollers and provision to adjust the converging angle between 4-8°. It consisted of gearbox, picking rollers, main frame, hydraulic drive system, crop guiding unit and inspection system (Fig 2). Main frame constitutes two parts *viz*., gearbox frame and picker roller frame held together by bolt and nut connection. Gearbox with hydraulic motors is welded to the front end of the main frame. Output shafts of the gearbox are connected with universal couplings. One end of the picking roller is connected to universal coupling and other end to the 3-way adjustable supporting frame. Rubber embedded stripper plates are arranged parallel to rotating rollers to clean the picking elements. Crop guiding unit is provided at the bottom along with collection trough to collect and avoid ground loss. Crop inspection system consists of a camera arranged at the plant entrance and a display at drivers' dashboard to guide the operator in the field. Machine travels over cotton crop canopy for picking of cotton bolls from all the sides without crushing the plant.

Field capacity

It is the actual area covered by the machine based on its total time consumed and actual working width under field condition. It is expressed in terms of area covered per unit time of operation. It is calculated by Kepner *et al.,* 2005 as

$$\text{Field capacity (ha h}^{-1}) = \frac{\text{Actual area covered}}{\text{Total time consumed}}$$

Field efficiency

Field efficiency is the actual average rate of coverage by the machine, based upon the total operation set time. It is a function of the rated width of the machine, speed of operation and the amount of time lost during the operations. Effective field capacity is usually expressed as hectare per hour (Kepner *et al.,* 2005).

$$\text{Field efficiency (\%)} = \frac{\text{Actual field capacity}}{\text{Theoritical field capacity}}$$

Energy consumption

Efficient use of the energy resources is vital in terms of increasing production, productivity, competitiveness of agriculture, as well as ensuring sustainability. Energy spent in harvesting the crop by manual and machine picking was assessed to predict the energy use efficiency, productivity and net energy through inputs spent.

Energy input in traditional picking include man hour's alone expressed in megajoules per hectare (MJ ha^{-1}). Energy value of human was taken as 1.96 MJ h^{-1} and cotton as 11.80 MJ ha^{-1} (Gokdogan *et al.,* 2016). Energy input in the mechanical picking include the amount of diesel fuel consumed and the man hour's spent during harvesting. Diesel fuel energy input was determined by:

$$E_f = 47.78\ D \qquad \text{…(Pandey } et\ al.,\ 2022)$$

Where,

E_f = Fuel (diesel) energy spent, MJ h^{-1}.

47.78 = Unit energy value of diesel, MJ l^{-1}.

D = Amount of fuel consumed, l h^{-1}.

Energy use efficiency, energy productivity, specific energy and net energy were calculated by given formula (Yilmaz *et al.,* 2004) (Zahedi *et al.,* 2014) (Gokdogan *et al.,* 2016), respectively. Energy output is the cotton yield obtained through traditional and mechanized sowing expressed in terms of megajoules per hectare (MJ ha^{-1}). The crop output was measured by weighing the cotton (collected cotton and ground loss) during the harvest and averaged.

$$\text{Energy use efficiency, \%} = \frac{\text{Energy output , MJ ha}^{-1}}{\text{Energy input, MJ ha}^{-1}}$$

$$\text{Energy productivity, kg MJ}^{-1} = \frac{\text{Crop output, kg ha}^{-1}}{\text{Energy input, MJ ha}^{-1}}$$

$$\text{Specific energy, MJ ton}^{-1} = \frac{\text{Energy input, MJ ha}^{-1}}{\text{Crop output, t ha}^{-1}}$$

Net energy = Energy output (MJ ha^{-1}) - Energy input (MJ ha^{-1})

Cost economics

Cost of operation (Rs. h^{-1} and Rs. h^{-1}), Break-even point, Payback period and Benefit cost ratio of the self-propelled single row cotton picker was calculated as per the procedure described by IS: 9164-1979. The fixed and variable costs were taken into consideration to estimate the cost of operation per hectare and cost of operation per hour. Straight line method was adopted and detailed calculations are given in Table 1 (Hunt, 2001).

Also, conventional practices of manual picking were studied and capacity of the manual labours in terms of man-hours ha^{-1} and kg day^{-1} were determined. The costs incurred in both conventional and mechanical cotton picking were compared and savings in cost was pointed out.

Break-even point

The break-even point is defined as the point at which neither profit is made nor loss incurred. The break-even point is equal to the annual fixed cost divided by difference between the custom rate per hour and the operating cost per hour. The break-even point was calculated as (Mohan *et al*., 2023).

$$\text{Break-even point, h yr}^{-1} = \frac{\text{AFC}}{\text{CF - C}}$$

Where,

AFC = Annual fixed cost for the machine, Rs. yr^{-1}.

CF = Custom fee, Rs. h^{-1}.

C = Operating fee, Rs. h^{-1}.

CF = Cost of operation h + 25% overhead charges) + (25% profit over new cost.

Payback period

It is the number of years it would take for an investment to return its original cost through the annual cash revenue it generates, if the net cash revenues are constant each year. the payback period is calculated as (Mohan *et al*., 2023).

$$\text{PBP} = \frac{\text{IC}}{\text{ANP}}$$

Where,

PEP = Payback period, yr.

IC = Initial cost of the machine, Rs.

ANP = Average net annual profit, Rs yr^{-1}.

ANP = (CF - C) AU.

AU = Annual use, h yr^{-1}.

Benefit cost ratio

Benefit cost ratio is used to determine the relationship between the cost and benefits from the machine. Benefit cost ratio should be more than one.

Benefit cost per hectare =
Cost of manual picking - Cost of machine picking

Therefore,

$$\text{Benefit cost ratio, Rs. ha}^{-1} = \frac{\text{Benefit cost}}{\text{cost of machine picking}}$$

(Mohan *et al*., 2023)

RESULTS AND DISCUSSION

Impact of traditional cotton picking on the production cost and energy spent in the field was analyzed and compared with mechanized harvesting and is presented under the following subheads. Fixed and variable costs of the manual and machine picking were calculated and tabulated in Table 1. Energy consumption in both practices was calculated and presented below.

Field capacity

The actual field capacity and efficiency of single row cotton picker was found to be 0.14 ha h^{-1} at a forward speed of 1.0 km h^{-1}, 0.22 ha h^{-1} at a forward speed of 1.7 km h^{-1} and, 0.30 ha h^{-1} at a forward speed of 2.5 km h^{-1}. Maximum field capacity was noted at a travelling speed of 2.5 km h^{-1} and maximum efficiency was found to be 85.4% at a forward speed of 1.0 km h^{-1}.

Performance parameters

Single row cotton picker was evaluated for its performance with picking capacity, collection efficiency, ground loss and thrash content. Maximum picking capacity was found to be 379.10 kg h^{-1} at a forward speed of 2.5 kmph with a roller speed of 177 rpm. Increasing the forward speed from 1.0 to 2.5 kmph resulted in an increased picking capacity by 50% but has a significant effect on the unpicked and trash content. Higher cotton output of 1459.09 kg ha^{-1} was noted when forward speed 1.7 km h^{-1} matched with a picking roller speed of 177 rpm. Optimum picking efficiency, collection efficiency and trash content of 76.24%, 63.05% and 43.87% was noted at 1.7 km h^{-1} and 155 rpm, respectively.

Energy consumption

Energy spent in case of manual and machine picking was calculated to predict the energy use efficiency, productivity and net energy through inputs spent. Average yield collected during the harvest from traditional varieties was noted as 1500 kg and short duration high yielding varieties as 1800 kg. Energy use efficiency was found to be less in case of manual picking *i.e*., 17.4% compared to 31.7% in machine picking. Energy productivity in case of manual and machine picking was calculated to be 1.48 kg MJ^{-1} and 2.65 kg MJ^{-1}, respectively. Specific energy per tonne in case of manual picking was high (675.5 MJ ton^{-1}) due to higher energy input in relation to less crop output. Similar net energy spent was noted by Yilmaz *et al.* (2004 and Gokdogan *et al.* (2016). And net energy available per hectare was high in case of machine picking (20,562.0 MJ ha^{-1}) due to high density sowing practices and high crop output.

Economic feasibility of the developed single row cotton picker

Cost of self-propelled single row cotton picker was calculated to be is Rs. 8,50,000.

Initial assumptions for self-propelled single row cotton picker (Sahey, 2004)

Initial cost of high clearance tractor (C), Rs	:	5,25,000
Salvage value (S), Rs	:	10% of C
Useful life (IS 9164:1979), (L), years	:	10
Annual usage (IS 9164:1979) of tractor, (H), hours	:	480
Interest rate (i), %	:	10
Initial cost of single row cotton picker (C), Rs	:	3,00,000
Useful life (IS 9164:1979), (L), years	:	10
Annual usage (IS 9164:1979), (H), hours	:	400

Cost of operation using developed prototype was found to be 789 Rs h^{-1} and 5,175 Rs ha^{-1} (Table 2). Cost of manual

picking was noted as 37.5 Rs h^{-1} (Rs. 300 per day) and 18,000 Rs ha^{-1} (Considering 3 pickings with 10 manual pickers for 2 days) (Fig 3). About 70% saving in cost and 90% saving in labour hours was noted with machine picking. Custom hiring cost (Rs h^{-1}) was calculated by adding 25 percent overhead charges and 25 percent profit over new cost and found to be Rs. 1,232.8 h^{-1}.

Labours hours spent in manual picking was calculated to be 480 man h ha^{-1} (Considering 3 pickings per season with 10 manual pickers for 2 days). On the other hand, machine picking consumed 13.62 man h ha^{-1} with 90% saving in labour hours compared to manual picking. Similar labour saving was noted by Sharma *et al.* (2015).

Payback period

To return the investment through annual cash revenues, the machine should be operated for custom hiring. Custom hiring charges are defined as 25% over cost of machine operation.

Initial cost of machine, Rs = 8,50,000

Custom hiring charge, Rs h^{-1} = (Cost of operation, h^{-1} + 25 per cent over head charges) + 25 per cent profit over new cost

= 1,232.8

Average net annual benefit, Rs = (CHC - TOC) × Annual utility

= (1232.8-789) × 400

= 1,77,520

$$\text{Payback period, yr} = \frac{\text{Initial investment}}{\text{Average net annual benefit}}$$

$$= \frac{8,50,000}{1,77,520}$$

= 4.8

Benefit-cost ratio

Benefit cost ratio is an indicator that summarize the overall value for money of the machine. Higher the benefit cost ratio greater the profit for the investment and it should always be more than 1. The benefit-cost ratio of the developed machine was 2.5:1.

Breakeven analysis

Breakeven analysis was done using two methodologies *i.e.*, theoretical and graphical to ensure the degree of correlation.

Custom hiring charge, Rs h^{-1} = 1232.8

Total operating cost, Rs h^{-1} = 789

Total fixed cost per year, Rs = 1,21,680

Breakeven point, h yr^{-1} ≈ 275

Breakeven point, Rs yr^{-1} = BEP×CHC

= 3,38,006

In first methodology, *i.e.*, from the formula, breakeven was calculated as 275 hours per year with a revenue of Rs. 3,38,006 yr^{-1}.

Table 1: Optimized results of prototype from field evaluation.

Parameters @ 155 rpm	Picker roller arrangement		
Picker roller speed	1 kmph	1.7 kmph	2.5 kmph
Field capacity, ha h^{-1}	0.14	0.22	0.30
Picking capacity, kg h^{-1}	176.13	258.63	311.61
Net seed cotton output, kg ha^{-1}	1285.61	1197.35	1031.82
Field efficiency, %	85.4	79.4	75.5
Picking efficiency, %	80.1	76.2	70.9
Collection efficiency, %	67.6	63.0	50.1
Trash content, %	36.5	43.8	74.2
Stock loss, %	19.8	23.7	29.0

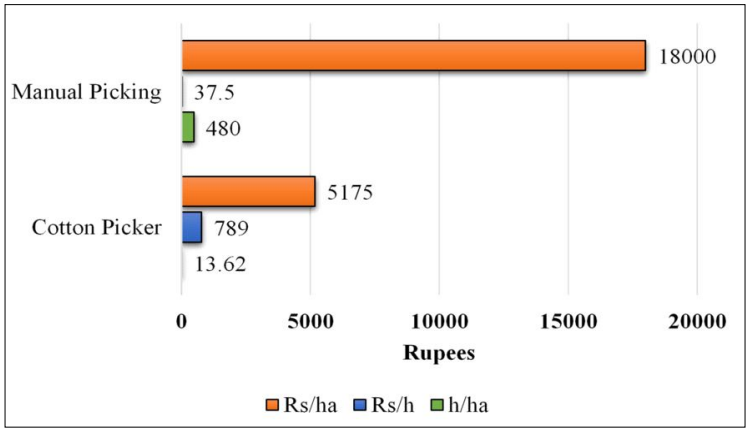


Fig 3: Cost economics in manual picking Vs mechanical picking.

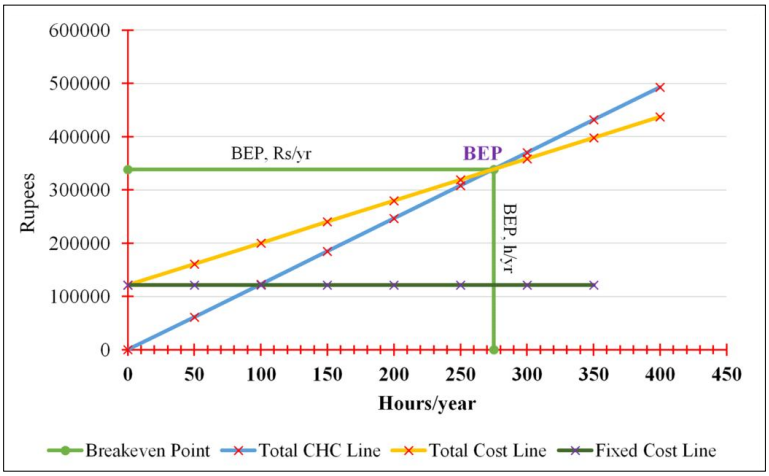


Fig 4: Breakeven analysis.

Table 2: Cost economics calculations (Mohan *et al.,* 2023).

Variables	Formula	Cost, Rs h^{-1}
High clearance tractor		
Fixed cost		
Depreciation	$\frac{C - S}{L \times H}$	98.4
Interest	$\frac{C + S}{2} \times i$	60.1
Insurance and taxes	1.5 % of initial cost	16.4
Housing	0.5% of initial cost	5.5
Variable cost		
Fuel cost	Average diesel consumption = 3.5 l h^{-1}	300
Lubrication	10% of fuel cost	30
Repair and maintenance	5 % of initial cost	54.7
Operator wages	Rs. 700/day of 8 hours	62.5
Total operating cost of tractor = fixed cost + variable cost = 627.6 Rs h^{-1}		
Single row cotton picker		
Fixed cost		
Depreciation	$\frac{C - S}{L \times H}$	67.5
Interest	$\frac{C + S}{2} \times i$	41.3
Insurance and taxes	1.5 % of initial cost	11.3
Housing	0.5% of initial cost	3.75
Variable cost		
Repair and maintenance	5 % of initial cost	37.5
Total operating cost of single row cotton picker = fixed cost + variable cost = 161.3 Rs h^{-1}		
Operating cost of self-propelled single row cotton picker = 789 Rs h^{-1}		
Field capacity of the machine = 0.14 ha h^{-1}		
Total operating cost of single row cotton picker = 5,175 Rs ha^{-1}		
3. Manual cotton picking practices		
Labour hours spent for manual picking = 517 Labour hours ha^{-1} (Prasad *et al.,* 2007)		
Labour cost per person, Rs h^{-1} = 37.5 (Rs. 300 per day)		
No. of labours = 60 (Considering 3 pickings with 10 manual pickers for 2 days)		
Total labour cost = Rs. 18,000 ha^{-1}		
Cost saved in percentage over manual picking = $\frac{18,000 - 5,175}{18,000}$ =70%		

In second methodology, to construct a breakeven chart, number of hours per year (x) is plotted on X-axis and revenue or cost (Rs.) on Y-axis. Breakeven hours per year and revenue per year are mapped on the chart meeting at a point (275,338006) as depicted in Fig 4. Total fixed cost line *i.e.*, Rs. 1,21,680 is constant for any number of working hours and represented by a straight line passing parallel to X-axis. Custom hiring cost (CHC) starts at point (0,0), increases with increasing working hours and passes through theoretical breakeven point. Total cost line (TCL) represents 'variable cost(x)+fixed cost' with increasing working hours and coincides with total CHC line and theoretical breakeven point. From the Fig 4, before BEP (275,338006) the TCL is greater than CHC that means the area between the total CHC line and total cost line represent losses during that period. Whereas, after BEP the TCL is lower than CHC which means the area between CHC and total cost line represent profit.

From the graph, breakeven hours per year was found to be 275 h yr^{-1} and revenue per year was calculated to be 3,38,006 Rs yr^{-1}.

CONCLUSION

Cost of self-propelled single row cotton picker was calculated to be is Rs. 8,50,000. Cost of operation using developed prototype was found to be 789 Rs h^{-1} and 5,175 Rs ha^{-1} with a saving of 70% compared to manual picking. Labours hours spent in manual picking was calculated to be 480 man h ha^{-1} (Considering 3 pickings per season with 10 manual pickers for 2 days). On the other hand, machine picking consumed 13.62 man h ha^{-1} with 90% saving in labour hours compared to manual picking. The benefit-cost ratio of the developed machine was 2.5:1. Payback period of the machine was calculated as 4.8 years. Breakeven analysis was done using two methodologies *i.e.*, theoretical and graphical to ensure the correctness and was found to be 275 h yr^{-1}. Energy use efficiency was found to be less in case of manual picking *i.e.*, 17.4% compared to 31.7% in machine picking. Similarly, energy productivity in case of manual and machine picking was calculated to be 1.48 kg MJ^{-1} and 2.65 kg MJ^{-1}, respectively. And net energy available per hectare was high in case of machine picking (20,562.0 MJ ha^{-1}) due to high density sowing practices and high crop output.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

No personal or identifiable information was collected, ensuring confidentiality and anonymity. The study adhered to ethical research standards and data was collected with the full awareness and consent of the involved stakeholders.

Conflict of interest

The authors declare no conflict of interest. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Brittany, N.B., Guillermo, F.D.L., Steven, P.G., Brandon, D.J., Rahul, N., Astera, S.T., Matthew, R.T. and Amos, G.W. (2017). Design of an integrated cotton picking system for small-scale Indian agriculture, Proceedings of 11th International Conference on Micro- and Nanosystems. 6 August 2017. doi: http://dx.doi.org/10.1115/DETC2017-68132.

Business Line. (2012). India Faces Uphill Task in Mechanizing Cotton Farming (Online), Dec.13.https://www. thehindubusinessline. com/economy/agri-business/india-faces-uphill-task-in-mechanising-cotton-farming/article20370291.ece1.

Gokdogan, O., Erdogan, O., Eralp, O. and Zeybek, A. (2016). Energy efficiency analysis of cotton production in turkey: A case study from Aydin province. *Fresenius Environmental Bulletin*. **55(11):** 4959-4964.

Gunasekaran, M., Premalatha, N., Kumar, M., Mahalingam, L., Sakthivel, N., Senguttuvan, K., Latha, P., Meenakhshiganesan, N., Rajeswari, S and Geetha, S. (2020). Cotton CO17- A short duration, high yielding compact variety suitable for high density planting system. *Electronic Journal of Plant Breeding*. **11(4):** 993-1000.

Hunt, D. (2001). Farm Power and Machinery Management. Ames, IA, Iowa State University Press. ISBN: 0813805805.

IS 9164 (1979): Guide for Estimating Cost of Farm Machinery Operation.

Kepner, R.A., Bainer, R and Barger, E.L. (2005). Principles of Farm Machinery (3rd Ed.). CBS Publishers and Distributors Pvt. Ltd., New Delhi, P. 23 .

Mohan, S.S., Babu, P. and Jayan, P.R. (2023). Economic analysis of tractor powered manure pulverizer cum applicator over traditional manure application practices. *Agricultural Science Digest.* **43(3):** 390-395. doi: 10.18805/ag.D-5341.

Pandey, A., Vadher, A.L., Kathiria, R.K., Gaikwad, S.A. and Choudhary, J. (2022). Comparative analysis of traditional method and mechanical method of cotton sowing. *Pantnagar Journal of Research*. **20(3):** 500-506.

Prasad, J., Kapur, T., Sandhar, N.S., Majumdar, G., Patil, P.G., Shukla, S.K., Jaiswal, B.N. and Patil, A.B. (2007). Performance evaluation of spindle type cotton picker. *Journal of Agricultural Engineering.* **44(1):** 38-42.

Reddy, A.R., Blaise, D. and Anuradha, N. (2018). Cost escalation in cotton cultivation: An analysis. *Economic Affairs*. **63(4):** 833-838. doi: https://dx.doi.org/10.30954/0424-2513.4.2018.6.

Sahay, J. (2004). Elements of Agricultural Engineering. 4th Edition. A.K. Jain (Prop.) for Standard publishers Distributors.

Sharma, K., Singh, M., Kohli, S.S., Mishra, P. and Sharma, A. (2015). Design and development of self-propelled walk behind finger type cotton stripper. *Agricultural Engineering*. **4:** 35-46.

The cotton corporation of India Ltd. Committee on Cotton Production and Consumption (COCPC). 25 January 2023. doi: https://cotcorp.org.in/national_cotton.aspx.

Yilmaz, I. Akcaoz, H and Ozkan, B. (2004). An analysis of energy use and input costs of cotton production in turkey. *New Medit Journal*. **2:** 58-64.

Zahedi, M., Eshghizadeh, R.H. and Mondani, F. (2014). Energy use efficiency and economical analysis in cotton production system in an arid region: A case study for Isfahan province, Iran. *International Journal of Energy Economics and Policy*. **4(1):** 43-52.