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REVOLUTIONIZING COTTON HARVESTING: A COMPARATIVE STUDY OF MODIFIED AND EXISTING KNAPSACK COTTON PICKER

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ABSTRACT

Cotton is a major fibre crop in India, accounting for 33% of global cultivation, yet its harvesting process remains predominantly manual, resulting in labour-intensive and time-consuming operations. This study compares an existing knapsack cotton picker, a modified knapsack cotton picker and traditional manual harvesting methods. The modified picker, with improved design for better cotton flow, achieved a higher picking capacity of 7.62 kg/h, surpassing the existing picker at 6.06 kg/h and manual methods at 3.72 kg/h. Both mechanical pickers exhibited high picking efficiency, with the modified picker achieving 95.79% and the existing picker 95.71%, compared to 96.93% for manual picking. The modified picker produced cotton of higher quality, as indicated by superior span length, uniformity ratio and fibre strength, compared to both the existing picker and manual harvesting. However, the modified picker exhibited a drawback of higher trash content (8.13%) relative to the existing picker (6.33%) and manual picking (3.59%). Despite this, the modified picker significantly reduced harvesting time by 51.44% and lowered costs by 14.86% compared to manual methods. Although, it had higher energy consumption, the modified picker still offered a net realization 3.27% greater than manual picking. These findings suggest that the modified knapsack cotton picker, despite its higher trash content, is a viable option for increasing the efficiency and cost-effectiveness of cotton harvesting, particularly in labour-constrained regions.

Key words : Cotton Harvesting, Cotton quality, Knapsack Cotton Picker, Picking capacity, Picking efficiency.

Introduction

Cotton (*Gossypium herbaceum*) is one of the most important fibre crops globally and holds a significant place in India's agricultural economy. As a versatile crop, cotton provides several valuable by-products, including lint, oil, seed, hulls and linters. Among these, lint is the most crucial product, supplying high-quality fibre to the textile industry. India has a long history with cotton, dating back to ancient civilizations. The earliest references to cotton in India appear in the Hindu Rig-Veda hymen, written around 1500 BCE and the Manus "*Dharmashastra*" from 800 BCE. The Sanskrit term "*karpasa*-i," used in ancient texts, evolved into the modern Hindi word "*kapas*," highlighting the crop's deep historical and cultural roots (Khanpara and Kathiria, 2023).

Belonging to the genus *Gossypium*, cotton has 20 species, of which 16 are wild and 4 are cultivated for their spinnable lint. The major cultivated species include *G. arboreum*, *G. herbaceum*, *G. hirsutum* and *G. barbadense*. *G. hirsutum* dominates 50% of the cotton-growing area in India, followed by *G. arboreum* (29%) and *G. herbaceum* (21%), while *G. barbadense* occupies a smaller area. Approximately 30% of the total cotton area is planted with hybrid varieties (Khanpara and Vala, 2023).

Cotton fibres contribute nearly 70% of the raw materials for India's textile industry, which accounts for 20% of the country's industrial output and employs around 27 million people. Additionally, cotton contributes approximately 32% of India's foreign exchange earnings. India is the world's second-largest cotton producer after China, producing 6.16 million tonnes annually. Cotton is cultivated across three agro-climatic zones in India: the North (Punjab, Haryana, Rajasthan), Central (Maharashtra, Gujarat, Madhya Pradesh) and South zones (Tamil Nadu, Karnataka, Andhra Pradesh). While 60% of cotton cultivation is rain-fed, the remaining 40% relies on irrigation (Ramasundaram and Gajbhiye, 2001).

Cotton harvesting, a labour-intensive process, remains largely manual in India. The cotton crop requires a series of farm operations, including ploughing, sowing, weeding, plant protection and finally, harvesting. While about 30% of the global cotton crop is harvested mechanically, India, along with other major producers such as China and Pakistan, continues to rely primarily on manual picking. Mechanical pickers, such as spindle pickers and strippers, are used in countries like the U.S., Australia and Israel, where mechanization dominates cotton harvesting. Spindle pickers selectively remove cotton bolls, leaving unopened bolls for later harvesting, while strippers remove all bolls in a single pass.

In India, manual harvesting continues to be the norm due to staggered flowering patterns and the characteristics of Indian cotton varieties. Hand-picking, though effective in terms of cotton quality, is time-consuming and physically demanding. The process requires approximately 1565 man-hours per hectare, making it both labour-intensive and costly (Selvan *et al.*, 2012). With the decreasing availability of labour and rising wages, the need for mechanized cotton harvesting has become increasingly urgent. However, due to the small land holdings of Indian farmers and the unique agronomic conditions of Indian cotton, current mechanical harvesters used in industrialized countries are not suitable.

To address this challenge, our study compares a knapsack cotton picker with a modified knapsack cotton picker, in addition to evaluating both machines against the traditional method of manual harvesting. The modifications to the knapsack cotton picker include improvements in the flow path of the cotton from plant to storage, aiming to enhance its operational efficiency. This comparison aims to determine which method offers the best combination of labour efficiency, picking capacity and efficiency, cotton quality and economic feasibility in Indian conditions. By providing insights into these factors, the study seeks to contribute to the ongoing efforts to mechanize cotton harvesting, especially for small and medium-scale farmers in India.

Materials and Methods

This chapter outlines the design and development of the existing and modified knapsack cotton pickers.

Existing Knapsack Cotton Picker

The existing knapsack cotton picker is a manually operated device powered by a petrol/kerosene air-cooled engine (Fig. 1). The primary components of the existing picker include an engine, aspirator, suction assembly, mounting frame, fuel tank and shoulder straps (Kathiria, 2011).

Fig. 1 : View of existing knapsack cotton picker (Kathiria, 2011). **A -** Engine, **B -** Aspirator, **C -** Sucking assembly, **D -** Mounting frame, **E -** Fuel tank, **F -** Shoulder straps.

Major components of the existing knapsack cotton picker

Prime mover : The knapsack cotton picker is powered by a 0.9 kW petrol/kerosene-run air-cooled engine with a speed range of 2500-5500 rpm. Necessary modifications were made to adapt the engine for use in

Table 1 : Specifications of existing knapsack cotton picker (Kathiria, 2011).

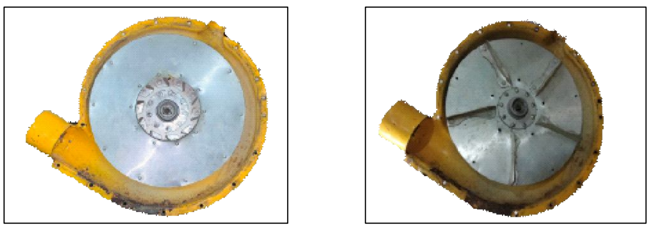
Sr.	Particulars	Specifications
A	**Engine**	
	1 Power	0.9 kW
	2 Speed	Max. 5500 rpm, Min. 2500 rpm
	3 Fuel	Petrol / kerosene
	4 Fuel tank capacity	1.5 lit
	5 SFC	350 g/kWh
B	**Cotton picker**	
	1 Dimensions	450 mm × 310 mm × 60 mm
	2 Weight	11.4 kg
	3 Impeller	Straight vane open type aluminium rotor of 250 mm diameter
	4 Mounting	Back cushion and padded shoulder straps

the knapsack cotton picker. The original mist-blower was converted into a vacuum cotton picker by interchanging the suction and blowing pipes.

Aspirator : The aspirator transfers energy between a rotating element and a continuous fluid stream. It consists of a rotor and a casing, where the impeller (rotor) increases the energy of the moving air, creating suction. The primary components are the rotating impeller, which transfers energy and the stationary casing, which controls the size of system and pressure rise.

Impeller of aspirator

The impeller is critical for creating suction in the aspirator. The knapsack mist-blower used a ten-curved vane closed-type impeller, which was modified to a five-straight vane open-type impeller to allow better passage of the picked cotton to the collecting sack (Fig. 2).



a. curved vane close type **b.** Straight vane open type

Fig. 2 : View of impeller.

Sucking assembly : The suction assembly includes a suction lance and a picking spout. A flexible pipe (63 mm in diameter, 1120 mm in length) was used as the suction lance. The picking spout is a PVC nipple with varying diameters of 50, 40 and 32 mm, connected to the lance with a reducer and clamp.

Collecting sack : A nylon mosquito net was used to fabricate the collecting sack (Fig. 3), designed to allow air to pass through while holding the cotton. The sack's size, 780 x 400 mm, was determined based on the bulk density of raw cotton and operator height.

Fig. 3 : Collecting sack.

Mounting frame : The existing frame of mist-blower was made from 20 mm MS conduit pipe with additional supports for strength. To accommodate the new suction assembly, the frame was extended using 22-gauge GI sheet and equipped with a cushion and belt for operator comfort.

Accessories : Accessories such as handles, shoulder straps and an engine shut-off device were included for operator comfort. The picking spout served as the handle grip and the straps were adjustable for various operator needs.

Problems with existing knapsack cotton picker : In the existing design, the picked cotton had to pass through the impeller, reducing airflow and damaging the cotton quality (Fig. 4). This issue necessitated modifications to the picking mechanism to prevent cotton from entering the impeller.

Modified Knapsack Cotton Picker : Using Creo 4.0 software, a detailed drawing (Fig. 5) of the cotton-picking mechanism and collecting device for the existing knapsack cotton picker was developed.

The main components include the engine, aspirator, suction assembly, mounting frame, collector with filter, fuel tank, and shoulder straps (Fig. 6). A cotton collector with a filter was introduced before the aspirator to prevent the picked cotton from entering the impeller, thereby preserving cotton quality (Fig. 7).

Modified component of the knapsack cotton picker

Impeller of aspirator : Since the issue of blockage caused by cotton was eliminated by diverting the cotton away from the impeller, the original curved vane, closed-

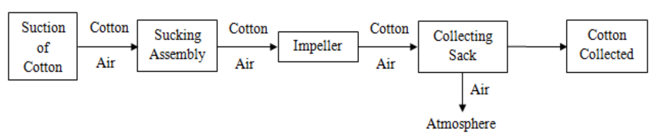
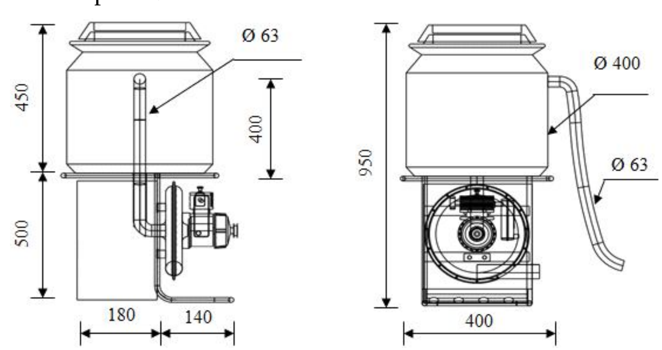


Fig. 4 : Flow path of picked cotton in existing knapsack cotton picker.



a. Side view **b.** Front view

Fig. 5 : Detailed drawing of modified knapsack cotton picker. All dimensions are in mm.

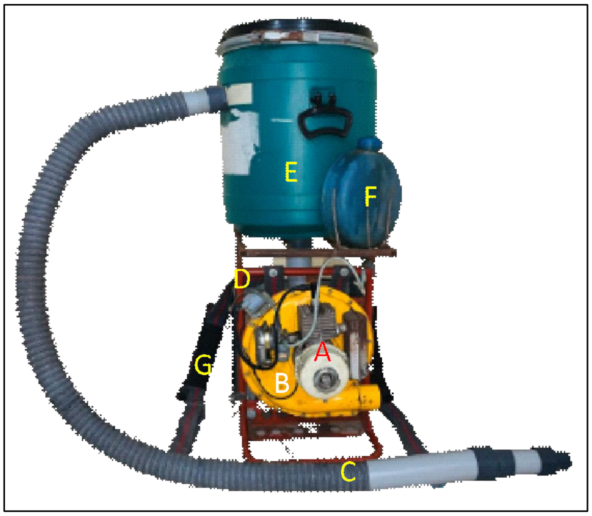


Fig. 6 : Modified knapsack cotton picker. **A** - Engine, **B** - Aspirator, **C** - Sucking assembly, **D** - Mounting frame, **E** – Collector with filter, **F** - Fuel tank, **G** - Shoulder straps.

type impeller with ten vanes was utilized. This design generated higher suction pressure, enhancing the efficiency of picking open cotton bolls.

Cotton collector : A 40-litre polypropylene container was used as the cotton collector (Fig. 8), mounted on the frame. The cotton was directed into the collector via a PVC pipe connected to the impeller.

Filter : A nylon mesh filter (100 mesh) was installed in the centre of the collector to allow air to pass through while preventing cotton from entering the aspirator (Fig. 8). The filter had a diameter of 63 mm and a height of 400 mm.

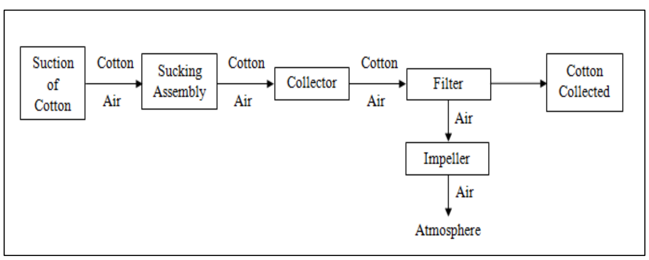


Fig. 7 : Flow path of picked cotton in knapsack cotton picker with picking mechanism.

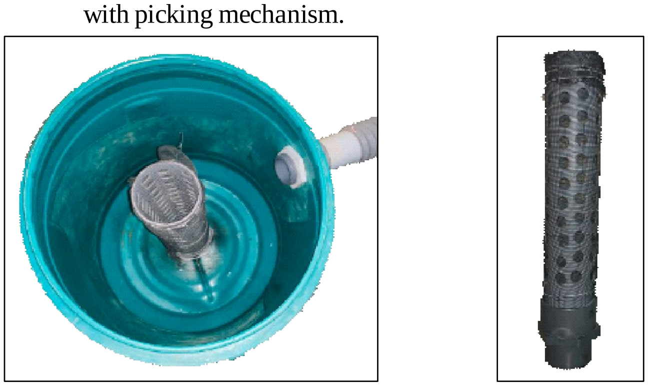


Fig. 8 : View of collector along with filter.

Mounting Frame : The existing frame was enlarged to accommodate the suction assembly and cotton collector. The modified frame (Fig. 9) had dimensions of 320 × 180 × 350 mm and was made from 22-gauge GI sheet. A second frame of 320 × 370 mm made from 18 mm MS conduit pipe was welded to the top to support the collector. Cushions and belts were added for comfort and safe operation.

Fig. 9 : Modified mounting frame.

Evaluation of both Knapsack Cotton Pickers : The evaluation was conducted both in the laboratory and in the field. Two independent variables were considered for the study: picking spout diameter (32 mm, 40 mm, 50 mm) and aspirator speed (3000, 4000, 5000 rpm). These parameters were chosen based on recommendations from previous studies (Rangasamy *et al.*, 2006; Selvan *et al.*, 2004).

Laboratory testing

Air velocity : The air velocity at the air inlet of the picking spout was measured using a hand-operated digital anemometer. This measurement was taken at different operating speeds to assess how airflow varies with changes in aspirator speed and picking spout diameter.

Sucking pressure : Sucking pressure at the tip of the picking spout was measured with a U-tube manometer. This measurement was conducted for various combinations of picking spout diameters and aspirator speeds to determine the impact of these variables on suction efficiency.

Field testing and evaluation : Field testing was carried out as per the BIS test code at the Cotton Research Farm of Junagadh Agricultural University, Junagadh. The testing evaluated picking capacity, picking efficiency, harvesting losses, trash content, cotton quality and operational costs for both cotton pickers.

Harvesting losses : Harvesting losses were calculated using the following formula (Khanpara and Kathiria, 2023):

$$Harvesting\ \ losses(\%) = \frac{W_c}{W_d} \times 100 \quad (1)$$

Where,

W_c = Weight of seed cotton left on the plant after picking, kg

W_d = Weight of total yield, kg

Picking capacity : The picking capacity was determined as the weight of seed cotton picked per unit time, calculated using (Rangasamy *et al*., 2006).

$$C_p = \frac{W_p}{t} \times 100 \quad (2)$$

Where,

C_p = Picking capacity, kg/h

W_p = Weight of cotton picked from plant, kg

t = Time taken, h

Picking efficiency : Picking efficiency was calculated as the percentage of net seed cotton picked to the total yield, including pre-harvest and harvesting losses (Khanpara and Kathiria, 2023).

$$n_p = \frac{W_p}{W_t} \times 100 \quad (3)$$

Where,

n_p = Picking capacity, kg/h

W_p = Weight of cotton picked from plant, kg

W_t = Weight of total cotton on plant, kg

Quality assessment of picked cotton : The quality of machine-picked cotton was compared with hand-picked cotton using the High-Volume Instrument (HVI) at the Cotton Research Station laboratory. The HVI measured span length, uniformity ratio, fiber strength and trash content after processing samples through a trash separator.

Results and Discussion

The performance evaluation of the knapsack cotton pickers was carried out as per the research plan. The evaluation focused on various parameters such as air velocity, sucking pressure, picking capacity and picking efficiency.

Effect of Picking Spout Diameter and Aspirator Speed on Air Velocity and Sucking pressure

The air velocity and sucking pressure were measured under laboratory conditions as detailed in the Materials and Methods section. The variation in picking spout diameter and aspirator speed had a significant effect on both air velocity and sucking pressure for both cotton pickers. It was observed that both parameters increased with a decrease in spout diameter and an increase in aspirator speed.

It is notable from the data that the modified knapsack cotton picker exhibited higher air velocity and sucking pressure compared to the existing picker due to the redesigned impeller of the aspirator. The maximum air velocity and sucking pressure were achieved with a 32 mm diameter picking spout at 5000 rpm aspirator speed for both pickers (Table 2). This confirms the role of impeller modification in enhancing performance under these conditions.

Effect of Picking Spout Diameter and Aspirator Speed on Picking Capacity and Picking efficiency

The variation in picking spout diameter and aspirator speed significantly affected both the picking capacity and picking efficiency of the cotton pickers. Initially, a decrease in picking spout diameter led to an increase in picking capacity, but it decreased beyond a certain point due to blockages caused by larger-sized cotton bolls at smaller diameters. The 40 mm picking spout diameter provided the best overall performance by balancing sufficient sucking pressure with the ability to handle larger bolls.

Picking efficiency also improved with decreasing spout diameter and increasing aspirator speed. The modified knapsack cotton picker showed higher picking capacity than the existing one, primarily due to its enhanced sucking pressure and an improved filter system that prevented cotton with seeds from entering the aspirator, minimizing blockages. While the modified picker's picking capacity was superior, the difference in picking efficiency between the two machines was negligible.

The highest picking capacity and efficiency were observed at a 40 mm spout diameter and 5000 rpm aspirator speed (Table 2). While a smaller spout diameter (32 mm) should provide more picking capacity due to higher sucking pressure, it led to blockages from larger bolls. In practice, the 40 mm spout diameter offered an optimal balance between sufficient sucking pressure and the ability to handle larger-sized bolls without blockages. Therefore, the 40 mm spout diameter and 5000 rpm aspirator speed were considered optimal for both pickers.

Table 2 : Performance of both knapsack cotton pickers.

Diameter of picking spoutmm	Speed of aspirator rpm	Air velocity, m/s		Sucking pressure N/mm²		Picking capacity kg/h		Picking efficiency %	
		EKCP	MKCP	EKCP	MKCP	EKCP	MKCP	EKCP	MKCP
50	3000	12.27	18.41	0.00163	0.00228	3.68	5.09	89.91	89.26
	4000	16.36	24.54	0.00217	0.00359	4.17	5.37	91.71	91.82
	5000	19.66	30.72	0.00271	0.00430	4.59	5.80	93.49	93.50
40	3000	15.34	25.63	0.00216	0.00387	4.78	6.00	93.08	93.43
	4000	20.45	31.26	0.00289	0.00442	5.43	6.93	94.43	94.20
	5000	24.57	36.86	0.00362	0.00481	6.06	7.63	95.71	95.79
32	3000	19.17	30.48	0.00258	0.00423	3.56	5.11	95.31	95.16
	4000	25.56	37.19	0.00344	0.00490	4.06	5.23	95.46	95.25
	5000	30.72	43.15	0.00430	0.00506	4.59	5.88	96.11	96.10

*EKCP = Existing Knapsack Cotton Picker, MKCP = Modified Knapsack Cotton Picker.

Field Performance Testing and Evaluation of Cotton Pickers

The optimized picking spout diameter of 40 mm and aspirator speed of 5000 rpm were used for field performance evaluation at the Cotton Research Farm of Junagadh Agricultural University. The performance parameters were determined following the BIS test code with three replications for accuracy.

Determination of performance parameters

Harvesting losses : The harvesting losses, calculated based on cotton left on the plant after the picker passed, were found to be 4.21% for the modified knapsack picker, 4.29% for the existing picker and 3.07% for manual picking. The modified picker's performance aligns closely with the existing picker, with minimal difference in terms of losses.

Picking capacity : The picking capacity was observed as 7.62 kg/h (61.00 kg per day of 8 hours) for the modified picker and 6.06 kg/h (48.48 kg per day of 8 hours) for the existing picker. In comparison, manual picking resulted in a capacity of 3.72 kg/h (29.76 kg per day of 8 hours). The results are in line with those reported by Goyal *et al.* (1979) and Rangasamy *et al.* (2006).

Picking efficiency : The picking efficiency was determined to be 95.79% for the modified knapsack picker, 95.71% for the existing picker and 96.93% for manual picking. These results show that the difference in efficiency between the machine-based methods and manual picking is negligible, confirming the practicality of both machines for field use. The findings align with those of Asota (1996) and Rangasamy *et al.* (2006).

Trash content : The amount of trash in machine-picked cotton was higher than in manually picked cotton. The trash content was determined to be 8.13% in the modified picker, 6.33% in the existing picker and 3.59% in manually picked cotton. Most of the trash consisted of broken dry leaves, which can be easily separated by shaking the cotton mass. These results are supported by findings from Asota (1996) and Rangasamy *et al.* (2006).

Quality Assessment of Picked Cotton : The quality of the cotton fibres picked by machine was compared with manually picked cotton using the High-Volume Instrument (HVI) system. The parameters measured included span length, uniformity ratio and fiber strength. It was observed that the quality of cotton fiber was unaffected by the modified knapsack picker, whereas the existing picker had a minor negative impact due to the impeller's effect on the cotton.

Economical Parameters : The economic parameters in terms of time, energy and cost of operation were also evaluated. The modified knapsack cotton picker was found to require 0.13 h/kg and 367.0 h/ha, consuming 1.48 MJ/kg and 4144 MJ/ha at a cost of 9.98 ` /kg and 27941 `/ha (IS Test Code, 1979). These results show that the cost of machine picking was approximately 16.96% of the market price of picked cotton.

In comparison, manual picking required 0.27 man-h/kg and 756 man-h/ha, consuming 0.53 MJ/kg and 1484 MJ/ha at a cost of 11.72 `/kg and 32816 `/ha. The machine-based picking method offers a significant reduction in time and labour costs while maintaining a comparable quality of cotton fiber.

Economical Comparison of Cotton-Picking Methods : It is evident from the results that the knapsack cotton picker significantly reduces the time required for harvesting by approximately 51.44% compared to manual picking methods. The picking cost was also reduced by 14.86%. While the machine-based method consumed more energy, the overall net realization was 3.27% higher than manual picking. These findings support the knapsack picker as a viable alternative to manual picking, especially for small-scale operations. Similar findings were reported by Rangasamy *et al*. (2006).

Conclusion

In conclusion, the performance evaluation of both the existing and modified knapsack cotton pickers highlights several critical insights regarding their efficiency, design and economic impact. The study demonstrated that the picking spout diameter and aspirator speed play a significant role in determining air velocity, sucking pressure, picking capacity and efficiency. A 40 mm picking spout diameter, combined with a 5000-rpm aspirator speed, was found to be optimal for balancing the need for high performance and operational reliability while minimizing blockages caused by larger cotton bolls.

The modified knapsack cotton picker showed improved picking capacity compared to the existing model, primarily due to its enhanced impeller design, which increased sucking pressure and featured an improved filtration system to prevent blockages. Although the difference in picking efficiency between the two pickers was negligible, the modified version demonstrated superior performance in field tests.

Quality assessments revealed that the machine-picking process did not significantly affect the fibre properties of the cotton, though the modified picker produced higher trash content. Despite higher energy consumption, the modified picker significantly reduced harvesting time by 51.44% and costs by 14.86% compared to manual picking methods.

Future improvements to the design could focus on integrating multiple picking spouts to further enhance operational efficiency and capacity. Additionally, converting the knapsack-type picker into a trailed-type machine could reduce the physical strain on operators and improve mobility in larger fields, making the system more adaptable for various scales of farming operations.

Overall, the modified knapsack cotton picker represents a significant advancement in mechanized cotton harvesting, with the potential to greatly improve productivity, reduce labour costs, and promote the adoption of efficient cotton-picking technologies in small and large-scale farming environments.

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