International Journal of Agricultural Sciences
Volume **19** | Issue 1 | January, 2023 | 145-152 ■ ISSN : 0973-130X
☞DOI:10.15740/HAS/IJAS/19.1/145-152
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RESEARCH PAPER

Development and performance evaluation of picking mechanism for knapsack cotton picker

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Abstract : One of the most significant fibre cash crops in both India and the rest of the world is cotton (*Gossypium herbaceum*). India is the world's second-largest cotton producer. Cotton is hand-picked by human labours in India, which is a laborious and time-consuming task. In existing knapsack cotton picker, the cotton quality was compromised due to the impact of the impeller vanes during conveying of picked cotton to collector. Keeping all these aspects in mind, a picking mechanism for knapsack power driven cotton picker was developed with considering the agronomical parameters, functional requirements, engineering requirements and ergonomic aspects. As a power source, a 0.9 kW, 5500 rpm petrol engine was used. The remaining components of the knapsack cotton picker, such as the aspirator, impeller, sucking assembly, collecting sack, mounting frame and so on, were developed according to design specifications. It was evaluated how effectively the knapsack cotton picker performed in terms of picking capacity, picking efficiency, harvesting losses, trash content, the quality of machine-picked cotton, and operation costs. Based on trial results using cotton varieties as GPG-3, a knapsack cotton picker's picking capacity was determined to be 7.62 kg/h. The average picking efficiency for cotton picking using a knapsack cotton picker was 95.79%. The harvesting losses and trash content were determined as 4.21% and 8.13%, respectively in case of knapsack cotton picker. The fiber quality in terms of span length, uniformity ratio and strength was not affected by knapsack cotton picker. There was reduction in time requirement and the picking cost by 51.44 and 14.86%, respectively over manual picking method. Cotton picking with a knapsack cotton picker showed a 3.27% increase in overall net realization over manual picking.

Key Words : Cotton picker, Harvesting losses, Knapsack, Picking capacity, Picking efficiency, Picking mechanism, Pneumatic

View Point Article : Khanpara, B. M. and Kathiria, R. K.(2023). Development and performance evaluation of picking mechanism for knapsack cotton picker. *Internat. J. agric. Sci.*, **19** (1) : 145-152, **DOI:10.15740/HAS/IJAS/19.1/145-152.** Copyright@2023: Hind Agri-Horticultural Society.

Article History : **Received :** 08.09.2022; **Revised :** 28.10.2022; **Accepted :** 30.11.2022

INTRODUCTION

Cotton is a soft, fluffy staple fibre produced by cotton plants of the *Genus gossypium* and grows in a boll around the seeds. The plant is a shrub native to tropical and subtropical regions around the world, including America, Africa and India. It is cultivated in maximum countries of the world. It is the world's most common natural fibre crop, generating textile and vegetable oil, as well as medicinal compounds, meal and hull for livestock feed, energy sources, organic matter to enhance soil and industrial lubricants. The cotton industry holds an important position as a commercial crop

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worldwide, especially in the U.S, China, India and Brazil, who are the leading producers of cotton. However, the cotton industry has several challenges, particularly in cotton harvesting. Timely harvesting of the quality cotton fibre is among the most pressing challenges in the cotton production industry.

According to the International Cotton Advisory Committee (ICAC), the global yield of the fibre crop would be around 25.7 million tonnes, up 6% from the previous year (Anonymous, 2021b). India remained the world's second-largest cotton producer, following China, with 6.162 million tonnes (6.423 million tonnes).

Cotton is the second largest *Kharif* crop of the country, after rice contributing 6-7% of the net sown area. Cotton is grown in three separate agro-climatic zones in India: the North zone, which includes Punjab, Haryana and Rajasthan; the Central zone, which includes Maharashtra, Gujarat and Madhya Pradesh and the South zone, which includes Tamil Nadu, Karnataka and Andhra Pradesh. Cotton cultivation is rainfed in nearly 60% of cases, with the remaining 40% being an irrigated crop.

G. herbaceum, *G. hirsutum*, *G. arboreum* and *Intra-hirsutum* are the most common cotton species grown in India. Apart from *G.hirsutum* and *G. arboreum*, *G. herbaceum* is grown in Gujarat. So far, 7 *G. hirsutum* varieties, 4 *G. arboreum* variants and 11 *G. herbaceum* varieties have been released in this state. Two *G. hirsutum* varieties (G. Cot 12 and G. Cot 16), three *G.arboreum* varieties (Sanjay, G. Cot 15 and G. Cot 19) and three *G. herbaceum* varieties (G. Cot 13, G. Cot 17 and G. Cot 19) are now being grown (Phundan and Kairon, 2020).

Cotton harvesting takes approximately 170 to 200 days. Cotton bolls are typically plucked using one of two methods: hand picking (manual) or machine picking. Due to a lack of labour during peak season, the hand picking method incurs numerous losses and has an impact on following farm operations. Mechanical pickers, on the other hand, lessen the labour of cotton picking and aid in the operation's timeliness.

Any solution that would reduce cotton losses and improve quality would be welcomed by the industry. In most cases, the mechanical combine machines are very big and expensive (the current six-row cotton picker costs around $7,25,000). Unfortunately, expensive cotton pickers are stored under the shed for more than nine months a year, waiting to harvest for only three months. Also, the machines weigh more than 33 tons, causing soil compaction, which reduces land productivity. The maintenance of such machines is also expensive and complicated. Breakdowns in the field can take days to repair, reducing operating efficiency and exposing bolls to further weather-related quality degradation. Most cotton harvesting technologies are either "stripper" or "spindle" picker.

Only the open bolls of seed cotton are picked by the "spindle" picker, while green, unopened bolls are left on the plant to grow for subsequent harvest. The "spindle" grabs the seed-cotton from the plant by using barbed spindles that rotate at a high velocity. Then, a counter-rotating doffer is used to strip the seed-cotton from the spindles. "Stripper" is a non-selective herbicide that kills both opening and unopened bolls on the same plant. The "stripper" grabs the lint from the plant and some amount of plant matter. Later, the lint is separated from the plant matter by dropping the heavy plant matter while leaving the lint behind, which is directed to the basket at the back of the machine. Cotton is only picked entirely by machine in Australia, Israel and the United States, with picking prices varying substantially between countries.

Human labour is nearly entirely used to pick cotton in India. This is a time-consuming and arduous operation. Hand picking is known to take up more of a cultivator's man-day in the production of a cotton crop. Due to posture, load of picked cotton and abrasion of fingers from sharp points of dried bracts, manual picking includes low to moderate drudgery. Cotton picking by hand is time-consuming, requiring 1565 man-hours per hectare (Selvan *et al*., 2012).

Due to scarcity of labour and higher cost of manual picking, need for mechanization of cotton harvesting is being realized. In India cotton is grown by farmers having small land holdings beside cultivated on large farms. Because of the cultural and agronomic techniques, as well as the staggered flowering characteristics of Indian cotton plants, mechanical cotton pickers available in industrialized countries are not deemed ideal for Indian conditions which lead to selective picking methods. As the biological scientists are gearing upto develop suitable plant type amenable to mechanical picking, it is high time to develop suitable technology and equipment for mechanized cotton harvesting system in India.

Material and Methods

To increase the maneuverability and reduce the drudgery, picking mechanism for knapsack cotton picker was developed. The components were similarly optimized and the dimensions were arrived. The components are:

Prime mover :

The knapsack cotton picker used a 0.9 kW air-cooled, petrol run engine that was sufficient for picking of cotton from a boll.

Picking mechanism :

Aspirator :

Aspirators are a type of fluid machine that has the ability to transfer energy between a continuous stream of fluid and a rotating element around a fixed axis. It is a machine that generates heads via the dynamic action of a rotating piece called the rotor. The rotor's motion alters the energy level of a constantly moving fluid. The fluid enters axially and is discharged by the rotor into a static collecting system casing and then into a discharge pipe in each of these systems. The main components of an aspirator are the impeller, which has a rotational motion and transfers energy and the stationary part casing, which transforms energy. Casing determines the system's size and pressure rise.

Impeller

Because its performance inadvertently dictates the aspirator's performance, the impeller is the most crucial portion of the aspirator. In an aspirator, an impeller is a disk-shaped component with vanes that creates the actual suction. The impeller is always mounted directly on the prime mover's shaft, causing it to spin at a rapid rate. The impacts of centrifugal force on the rotating air inside the impeller create suction. The spinning air travels outward away from the hub as the impeller turns, generating a partial vacuum that allows additional air to flow into the impeller (Von Cube and Steimle, 1981).

The open cotton bolls were easily sucked and conveyed to the collector using a curved vane closed type impeller with ten vanes. The view of impeller is shown in Fig. A.

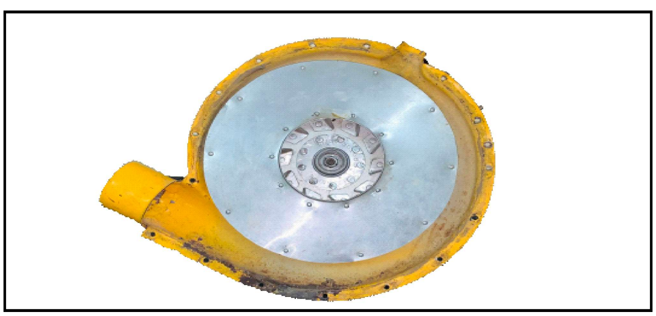


Fig. A : Curved vane close type impeller

Sucking assembly :

Flexible hose pipe was used as a suction pipe. One end of suction pipe was attached to collector and other end was attached to the picking spout. The length and diameter of the suction pipe were 1500 mm and 63 mm, respectively. The picking spout consisted of PVC nipple of alternative diameter 32, 40 and 50 mm having 300 mm length and connected to the flexible hose by reducer and clamp.

Cotton collector :

A polypropylene container of 40 litre capacity was selected as a collector (Fig. B), which was mounted on the frame. The bottom of the collector was attached to the eye of impeller with PVC pipe. A hole was made on side of collector to fasten suction pipe.

Fig. B : View of collector along with filter

Filter :

To prevent cotton from entering the aspirator and to allow only air to pass through with minimal resistance between the collector and the aspirator, a suitable filter screen is required. A circular filter constructed of nylon mesh with diameter of 63 mm and a height of 400 mm is attached vertically in the centre of the collector on a suitable flange to prevent cotton from entering the aspirator.

Mounting frame :

The frame of knapsack cotton picker was made up of 20 mm MS conduit pipe in L-shape. The vertical dimensions were 320 × 410 mm at the backrest side. The inner supports of 25 mm × 16 gauge MS plate were provided. The horizontal dimensions were 320 × 210 mm at the resting side to keep the machine in erect position. To absorb engine vibration, a 70 × 70 mm 16 gauge MS sheet plate was provided in an L-shape along the width of the frame.

Fig. C : Mounting frame

To allow the mounting of the sucking assembly and collector of the knapsack cotton picker the enlarged frame made of 22 gauge GI sheet with dimensions of 320 × 180 × 350 mm was attach at the backside. To attach the collector, another frame 320 × 370 mm consisting of 18 mm MS conduit pipe was welded at top of the existing frame. The cushion and belt of the backrest made carrying the cotton picker easy and safe.

Evaluation of picking mechanism for knapsack cotton picker :

The dimensions of various components were incorporated while fabricating picking mechanism for knapsack cotton picker. This mechanism was fabricated at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. Later, the evaluation was done in laboratory as well as under field condition. An independent variable is a variable that is manipulated to determine the value of dependent variables. In this experiment, there were two independent variables *i.e.*, picking spout diameter and speed of aspirator. Three types of picking spout diameters *viz.,* 32 mm, 40 mm and 50 mm were selected for the study. The optimum speed of aspirator for cotton picker ranges from 2200 to 5500 rpm (Rangasamy *et al*., 2006 and Selvan *et al*., 2004). Therefore, three speeds of aspirator 3000, 4000 and 5000 rpm were selected for the evaluation.

Field testing and evaluation :

The knapsack cotton picker with developed picking mechanism (Fig. D) was tested as per BIS test code for its working performance at Cotton Research Farm of Junagadh Agricultural University, Junagadh. During the field testing of the same, as previously discussed, the operating speed and the picking spout diameter were optimized through various picking capacity, picking efficiency, harvesting losses, trash content, the quality of machine-picked cotton and operation costs.

Fig. D: View of knapsack cotton picker with developed picking mechanism and collector

Harvesting losses :

The harvesting losses consist of seed cotton left on the plant during and after the passage of the machine. The left out cotton on the plants were picked manually after the operation of cotton picker. It was calculated by following formula:

$$\text{Harvesting losses (\%)} = W_c / W_d \times 100 \qquad ...(1)$$

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 is the seed cotton picked by the machine with respect to time. It was worked out by the following formula (Rangasamy *et al*., 2006).

$$C_p = W_p / t \qquad ...(2)$$

where,

C_p = Picking capacity, kg/h

W_p = Weight of cotton picked, kg
t = Time taken, h.

Picking efficiency :

The picking efficiency is the percentage of net seed cotton picked to the total yield including the pre-harvest losses and harvesting losses. It was determined by the following formula (Rangasamy *et al*., 2006).

$$n_p = W_p / W_t \times 100 \quad ...(3)$$

where,

n_p = Picking efficiency, %
W_p = Weight of cotton picked from plant, kg
W_t = Weight of total cotton on plant, kg.

Quality assessment of picked cotton :

In order to know the effect of machine picked cotton in comparison to the hand picked cotton, the assessment of quality was done by using the High Volume Instrument (HVI) as shown in Fig. E, in the laboratory of Cotton Research Station of Junagadh Agricultural University, Junagadh. In the HVI machine, various conventional instruments are integrated into a single compact operating system by using state-of-art technology in mechanics, optics and electronics. HVI system provides measurement of span length, uniformity ratio, fibre strength and trash content.

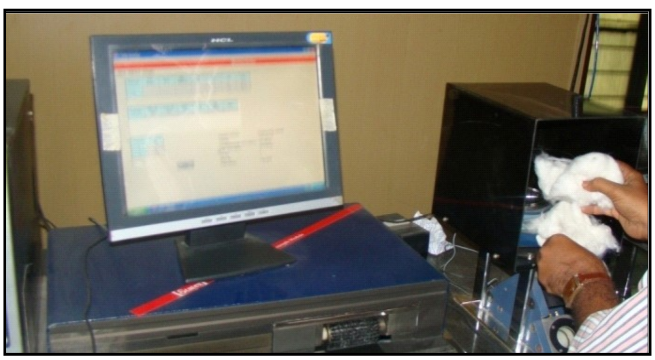


Fig. E : High volume instrument machine

The samples of machine picked and hand picked cotton were first fed to the Trash Separator (Fig. F) to remove trash content from the samples. Then, a fibre beard was prepared by using a fibro empler. The prepared fibre beard was then put into the HVI machine for analyzing the parameters. The following observations were taken and reported.

Fig. F : Cotton trash separator

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Optimization of picking spout diameter and aspirator speed :

The performance evaluation of knapsack cotton picker was conducted per research plan. The performance was evaluated in terms of air velocity, sucking pressure, picking capacity and picking efficiency. The statistical analysis (Factorial Completely Randomized Design) was followed to optimize the picking spout diameter and aspirator speed.

Effect of picking spout diameter :

The variation in picking spout diameter has a positive effect on the picking capacity. The maximum picking capacity was obtained with 40 mm diameter of picking spout as shown graphically in Fig. 1. From ANOVA (Analysis of Variance) for picking capacity and picking efficiency of knapsack cotton picker as presented in

Table 1: ANOVA for picking capacity (kg/h) of knapsack cotton picker

SV	d.f.	SS	MS	Fcal	TEST	S.E.±	C.D. (P=0.05)
D	2	12.48	6.24	136.03	*	0.07	0.21
S	2	4.77	2.39	52.06	*	0.07	0.21
D × S	4	0.93	0.23	5.05	*	0.12	0.37
Error	18	0.83	0.05				
Total	26	19.00				C.V.% =	3.63

Table 2: ANOVA for picking efficiency (%) of knapsack cotton picker

SV	d.f.	SS	MS	Fcal	TEST	S.E.±	C.D. (P=0.05)
D	2	76.90	38.45	100.53	*	0.21	0.61
S	2	28.34	14.17	37.05	*	0.21	0.61
D × S	4	9.15	2.29	5.98	*	0.36	1.06
Error	18	6.88	0.38				
Total	26	121.2				C.V.% =	0.66

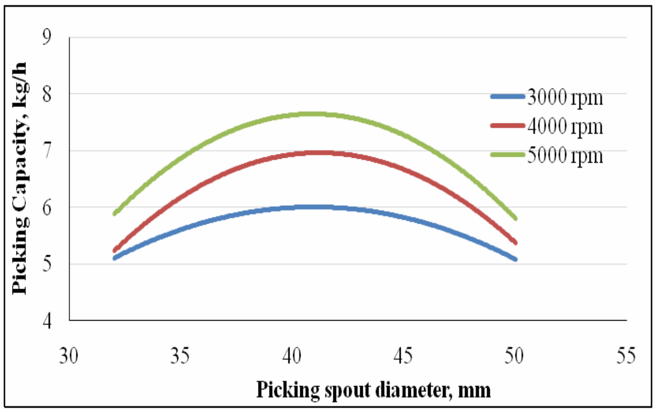


Fig. 1: Effect of picking spout diameter on picking capacity at various aspirator speeds

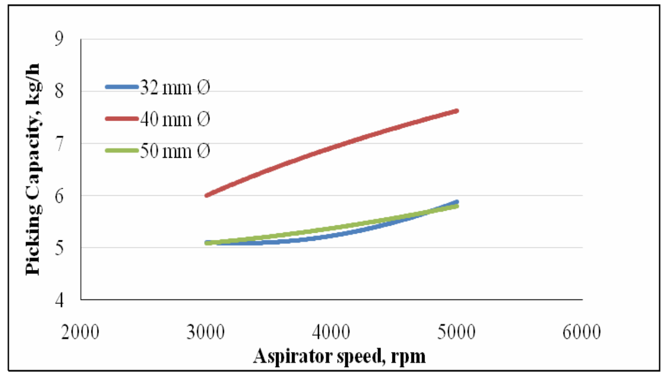


Fig. 2: Effect of aspirator speeds on picking capacity at various picking spout diameter

Table 1 and Table 2, respectively, it is concluded that the picking spout diameter and aspirator speed have an individual effect on the capacity and efficiency of picker. Also, there is interaction between both the parameters. The combination of 40 mm picking spout diameter with 5000 rpm aspirator speed was founded significant. In real action, the seed cotton is squeezed due to suction pressure on cotton. However, the picking spout diameter affects the entry of seed cotton inside. Sometimes, the blockage of spout occurs due to larger size bolls. Therefore, the picking spout diameter other than 32 mm was 40 mm which was considered optimum for further evaluation.

Effect of aspirator speed :

The aspirator speed has a positive effect on picking efficiency (Tables 3). This effect is presented graphically in Fig. 2. On increasing the aspirator speed, both picking capacity and picking efficiency increased as higher speed develops the higher sucking pressure. The pressure in the picking spout increased with increase in the speed and ultimately picking efficiency also increased. Thus, the optimum aspirator peed was found as 5000 rpm.

Field testing and evaluation of cotton picker :

The optimized size of picking spout as 40 mm and operating speed as 5000 rpm were considered for the field testing and evaluation of knapsack cotton picker.

Fig. 3 : Knapsack cotton picker in operation

Determination of performance parameters :

The performance parameters of knapsack cotton picker were determined as per BIS test code. Three replications were taken to get the appropriate value and average value was calculated.

Harvesting losses :

The harvesting losses were determined as 4.21% in case of knapsack cotton picker and 3.07% in manual picking.

Picking capacity :

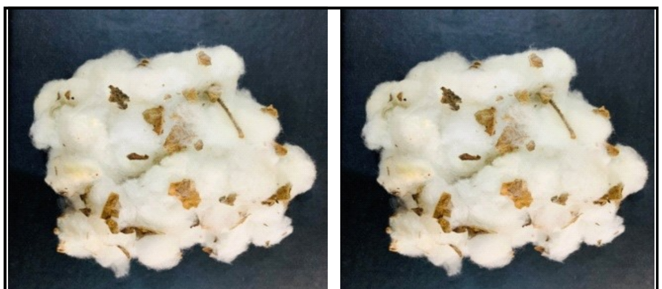
The picking capacity was observed as 7.62 kg/h (61.00 kg per day of 8 hours). In manual picking, it was observed as 3.72 kg/h (29.76 kg per day of 8 hours). Similar results were also reported by Goyal *et al*. (1979) and Rangasamy *et al*. (2006).

Picking efficiency :

The picking efficiency was determined as 95.79% in case of knapsack cotton picker and 96.93% in manual picking. The results are also supported by Asota (1996) and Rangasamy *et al*. (2006).

Trash content :

The machine picking incorporated more trash content in comparison with manual picking. It was determined as 8.13% in machine picked cotton and 3.59% in manually picked cotton. However, trash mainly consisted of dry leaves in the form of broken particles. It could be separated easily by shaking the mass of picked cotton and thereby its appearance can be maintained higher trash content was also observed by Asota (1996) and Rangasamy *et al*. (2006). Fig. 4 shows the view of samples of cotton picked by knapsack cotton picker and manual method.



a. Knapsack cotton picker **b. Manual picking**

Fig. 4 : View of trash content in picked cotton

Quality assessment :

For the quality of cotton fibre of machine picked cotton in comparison to the hand picked cotton, the samples were analyzed by using the High Volume Instrument (HVI) for its fibre properties *viz.,* span length, uniformity ratio, strength. It was observed that quality of cotton fiber was not affected by knapsack cotton picker.

Economical parameters :

The economical parameters (Fig. 5) in terms of time, energy and cost of operation were worked out for the developed picking mechanism for knapsack cotton picker and compared with manual picking method. It is found that total time required, energy consumed and cost of operation was 0.13 h/kg and 367.0 h/ha, 1.48 MJ/kg and 4144 MJ/ha and 9.98 /kg and 27941 /ha for the knapsack cotton picker, respectively. The picking cost by machine is about 16.96% of the market price of picked cotton. It is seen from result that total time required, energy consumed and cost of operation was 0.27 man-h/kg and 756 man-h/ha, 0.53 MJ/kg and 1484 MJ/ha and 11.72 / kg and 32816 /ha, respectively for the manual cotton picking.

Economical comparison of cotton picking methods:

It is evident from result that in using knapsack cotton picker, there was reduction in time about 51.44% over manual picking method of cotton. The picking cost could be lowered down by 14.86% as compared to manual picking. The similar finding was also reported by

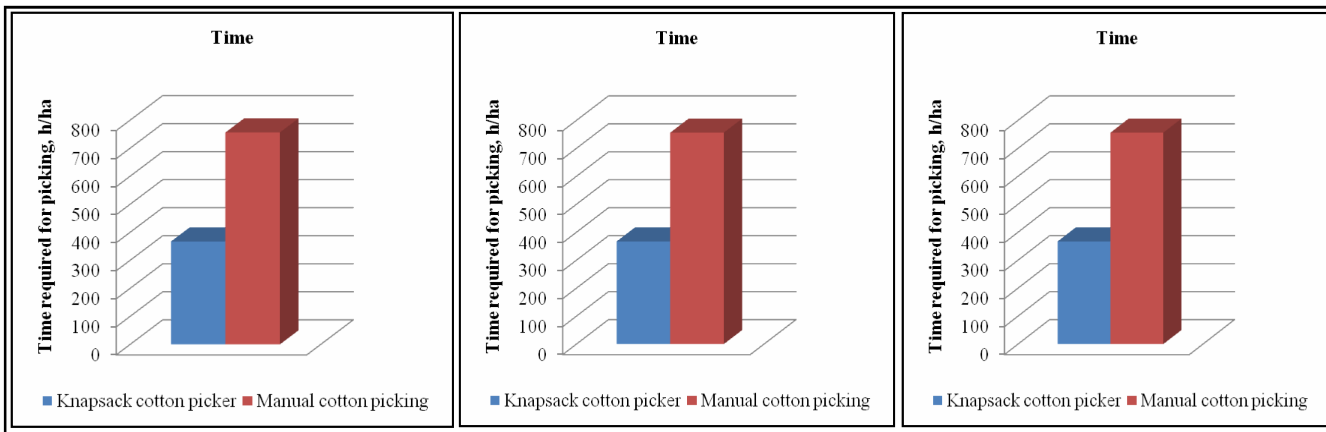


Fig. 4: Comparison of economical parameters in terms of time, energy and cost

Rangasamy *et al*. (2006).

Conclusion :

The optimization of diameter of picking spout (three levels) and speed aspirator (three levels) was done to decide the suitable dimensions. From working performance, the following conclusions could be drawn.

– Among three different diameter of picking spout tested, 40 mm diameter was found suitable to obtain higher picking capacity and picking efficiency.

– Both picking capacity and picking efficiency could be increased by increasing the speed of aspirator.

Based on the optimum diameter of picking spout and aspirator speed, the developed picking mechanism for knapsack cotton picker was tested in the field. Its performance evaluation leads to following conclusions.

– The design of main components such as sucking assembly, collecting sack and mounting frame were observed dimensionally suitable to the operator for cotton picking operation.

– The picking capacity of knapsack cotton picker was found as 7.62 kg/h (61 kg/day of 8 hours) whereas it was 3.72 kg/h (29.76 kg/day of 8 hours) in manual picking.

– The average picking efficiency was found as 95.79 and 96.93%, respectively in case of cotton picking by knapsack cotton picker and manual method.

– The fibre quality in terms of span length, uniformity ratio and strength was not affected by knapsack cotton picker.

– The mechanical cotton picking cost was found as 27941 /ha while in manual cotton picking it was 32816 / ha, thus, there was 14.86% reduction in cost over manual picking method.

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