Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 30s (2025)
https://www.jneonatalsurg.com
OPEN ACCESS

Techno-Economic Assessment Of Sensor-Enabled Sugarcane Planters Using Battery And Pto Mechanisms

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.Cite this paper as: Ashutosh Mishra, Ramesh Pal, N.C. Shahi, Priyanka Singh, Aviral Kumar, (2025) Techno-Economic Assessment Of Sensor-Enabled Sugarcane Planters Using Battery And Pto Mechanisms. *Journal of Neonatal Surgery*, 14 (30s), 693-701.

ABSTRACT

This study examines all the key technical and financial factors for battery and PTO powdered sugarcane planters, to boost mechanized planting in developing farming regions. Normally, sugarcane, used both for sugar and bio-energy, is planted in a way that takes more effort and this approach leads to gaps in coverage and greater costs. Pairing sensors with batteries and Power Take Offs in planters can greatly improve planting results, productivity and concern for the environment. By using the Co 6304 variety in carefully conducted field experiments, this research assesses the set length, planting depth, bud damage, soil potassium levels and various trash removal techniques at different speeds. It also examines how much each type of power mechanism costs, how much energy is consumed, how much labor is needed and how effectively they work in fields, giving useful suggestions to farmers, manufacturers and policy decision-makers. It was clear from these findings that improved planting evenness and efficiency can result from using sensors in equipment and trash left on the soil boosts potassium levels, encouraging healthier crops. The importance of both performance and affordability for machines suggests that advanced systems may aid in modernizing sugarcane farms, lower manual work and help farms use resources more efficiently.

Keywords: *Sensor-enabled planters, Sugarcane planting, Battery-powered machinery, Power Take-Off (PTO), Mechanization, Agronomic parameters, Soil potassium retention, Techno-economic analysis.*

1. INTRODUCTION

New precision agriculture technologies have completely changed farming today by making operations more efficient, helping manage valuable resources and raising the yield of crops. Because of its key role in agro-industry, sugarcane is important for making sugar, generating renewable energy and offering jobs in rural areas. Though sugarcane is important, automating the planting of sugarcane remains a big problem in many areas with traditional farming. Because these traditional methods depend a lot on people working manually, they often result in uneven space between plants, several planting depths and poor crop establishment. Such problems decrease the expected yield and raise the costs to produce sugarcane which lessens the crop's overall sustainability and profitability.

Over the past few years, new technology has allowed planters to carefully arrange cane sets in the right positions, spacing and depth. Planting and harvesting accuracy and efficiency are both improved when advanced machines are powered by battery systems or PTO mechanisms. Using batteries in planters helps farming become more environmentally responsible by greatly cutting back on fossil fuel needs and emissions, whereas using tractors works well for different types of fields and is always quite reliable.

One difficulty in using this technology is that experts must carefully review their usefulness and feasibility in farm conditions. This means checking planting accuracy, set damage and the energy required, as well as looking at capital spending, estimated costs in operation, upkeep needs and expected profit from the project. Also, it is necessary to make sure solar energy can be dependably used and handled in many types of soil and weather.

The study will compare sensor-equipped sugarcane planters that are powered by batteries and PTOs. By carefully reviewing their agronomic performance, energy use, costs involved and challenges, the research wants to supply useful information to farmers, equipment makers and planners who decide on government policies for agriculture. The overall objective is to encourage the use of new planting tools that improve productivity and protect the environment, while making the sector economically strong.

2. REVIEW OF LITERATURE

Patkar and Lanjewar (2007) showed a tractor-driven system designed to make sugarcane planting uniform. They introduced a solution at NaCoMM07 that used a PTO-powered system to address issues found in standard methods of planting sugarcane by mechanization. Because of this improvement, seeds could be planted at the same depth and spacing, making both farming and crops more efficient. What they created laid the basis for machinery driven by PTO in cane farming.

Singh et al. (2022) created a compact electrical prime mover aimed at helping sugarcane farmers become more productive. Instead of fuel-based engines, the system used a compact electric drive which helped small farmers find an eco-friendlier alternative. Experts found that using an electric prime mover showed saved costs, simplified operation and matched with India’s plan to encourage greener solutions on farms. The findings made it clear if battery-powered systems could be used in sugarcane production.

Singh et al. (2024) created a useful device for mechanized agriculture that mulches debris and shaves leftover stubble in sugarcane ratoons, all done by a tractor. To enhance how much ratoon crops can yield, the researchers focused on using an efficient way to shave and dispose of stubble. Thanks to the combination of mulching and stubble shaving, the new device became a more sustainable answer to doing these jobs manually or with separate machines. After testing in the field, there were signs of better skills, lower fuel usage and stronger field results. With this method, farmers could sustain their soil while cutting back on the work needed. The work provided an answer for better ratoon crop management and improved ways to utilize resources in agriculture.

Singh et al. (2024) designed and developed a machine, tractor-driven, that mulches and shaves ratoon sugarcane. The machine was able to collect after-harvest scraps and leave the field ready for the next cycle of planting. Even though sugarcane plants weren’t their concern, their research highlighted the importance of mechanized add-ons for better efficiency in sugarcane farming. Showing the flexibility and earnings potential of tractor-powered equipment in wide-scale agriculture was evident from the way they organized PTO systems.

3. RESEARCH METHODOLOGY

The aim of the research was to perform a complete techno-economic analysis of sugarcane planters driven by batteries and Power Take-Off (PTO) mechanisms. The important goal was to look at the effectiveness in fieldwork and farming results for mechanized sugarcane planting. For that reason, a controlled study was performed on the field, including tests, determining results and measuring soil conditions. This part of the methods discusses the procedures, what was collected and the analytical tools involved in creating the results in the chapters to follow.

3.1. Experimental Setup

The sugarcane cultivar Co 6304 was studied in original agricultural research areas. The main equipment analyzed was a sugarcane planter that could be run using both battery and PTO power. An experimental framework was used for this study:

- **Speed variation trials**: Three different forward speeds—1.8, 2.0, and 2.25 km/hr—were used to test the planter.
- **Performance trials**: Set length, set weight, planting depth, overlapping, bud damage, and quantity of setts per hectare were among the parameters that were documented.
- **Treatment groups (T0–T6)**: A total of seven treatments were established to examine the impact of various combinations of planting mechanisms and garbage control strategies. The control (manual approach) was T0, whereas T1–T6 included a variety of mechanical procedures.
- **Soil sampling schedule**: In order to evaluate the agronomic advantages of waste retention under various mechanical treatments, potassium (K) levels were measured at four intervals: 90, 180, 270, and 360 days.

3.2. Data Collection Methods

The data was collected from both machinery performance and soil quality standpoints:

- **Technical Data**: Physical damage, number of buds, planting depth, planting uniformity, set qualities (length, weight), and observations were documented. Visual examination, scales, and callipers were used for measurement.
- **Agronomic Data**: At predetermined times, soil samples were taken from each treatment plot. The potassium concentration (K kg/ha) was determined in a controlled laboratory setting according to established methods for soil testing.

- **Treatment Design**: To make sure the treatments were reliable and statistically significant, they were reproduced three times (R1, R2, R3). Across all automated treatments, garbage was handled consistently.

3.3. Data Analysis Techniques

Both the efficiency of performance and the influence on soil fertility were evaluated using a dual-layered methodology:

- **Descriptive Statistics**: The mean, total and variance were found for data on set count, planting depth and K-content.
- **Analysis of Variance (ANOVA)**: It allows researchers to see how important certain differences are. In analysis, types of treatment were arranged in rows, replications in columns and error margins were examined.
- **P-value and F-test Evaluation**: Soil K tests that gave a p-value less than 0.05 confirmed that sensor-supported automation systems achieved higher K levels.
- **Comparative Assessment**: To assess how effective the machines were, outputs from various speeds and driving systems were compared with an eye on work efficiency and time spent.

4. RESULTS

4.1. Introduction

Using both field and laboratory evaluations, the findings in this section cover sensor-equipped sugarcane planters which can be operated with either a Battery or PTO mechanism. We examine the analysis from two main perspectives:

- Performance quality of the sugarcane harvesting method driven by the PTO.
- The effects on soil potassium (K) and the outcomes seen after long-term treatments.

All the analysis combined represents the multiple strengths involved in using modern sugarcane planting technologies.

4.2. Performance Evaluation of PTO-Operated Sugarcane Cutting Mechanism

Table 1. explains the operating conditions and efficiency ratings for planters run by diesel power using the Co 6304 type of sugarcane. The trial evaluates set length, set weight, how far down plants are planted and damage to the tips of the buds at three speeds (1.8, 2.0 and 2.25 km/hr).

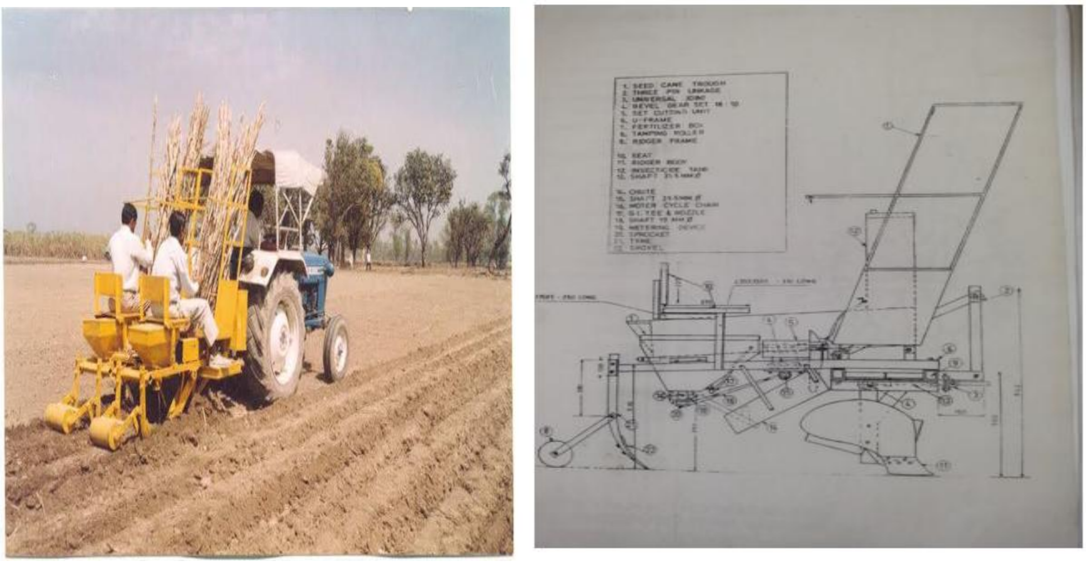

Figure 4: Power take off operated (PTO) Sugar Cane Planter.

A PTO-operated sugarcane planter is an efficient agricultural machine powered by a tractor's Power Take-Off (PTO) shaft. It automates the planting of sugarcane sets, ensuring uniform spacing and depth. The machine consists of a hopper for seed sets, furrow openers, and covering devices. As the tractor moves, the PTO drives the mechanism, placing the setts accurately into the soil. This planter significantly reduces labor, time, and planting errors compared to manual methods. It is ideal for medium to large-scale sugarcane farming, enhancing productivity and ensuring better crop establishment with consistent planting efficiency.

General	
1. Name of manufacturer	Punjab Engineers, Meerut
2. Name of machine	Sugarcane Cutter Planter
3. Model	Khalsa PE-630
4. HP required	> 50
5. Width of machine, cm	184
6. Length of machine, cm	197
7. Height of machine	224
8. Type of drive	PTO
9. Row-row distance, cm	60 – 75
Ridger Body	
1. Type	Reversible shovel type with mould board
2. Number of ridger	Two
3. Width, cm	40 (adjustable)
Cutting Unit	
1. Type	Cylindrical roller type
2. Number of unit	Two
3. Number of blades	Two in each unit
4. Width, cm	35
5. Length, cm	68
6. Height, cm	35.5
7. Number of rollers	Two in each unit
8. Number of rubber rollers	Ten in each unit
Blade Dimensions	
1. Length, cm	11.3
2. Width, cm	4.2
3. Thickness, cm	0.8
Fertilizer Box	
1. Metering mechanism	Fluted roller with auger
2. Number of box	One
3. Adjustments	Adjustable lever with 15 different setting levels
4. Capacity, kg	50 – 70
Seed Box	

1. Capacity, kg	250 – 300 of each box
2. Number of box	Two
3. Type of feeding	Manually
Fungicide and Insecticide Tank	
1. Capacity of fungicide tank, l	200
2. Capacity of insecticide tank, l	100
3. Number of tank / drum	Two (one each)
Covering Device	

Particulars	**Tractor**	**Khalsa PE630**
Purchase price, Rs	5,19,400	50000
Life period, years	10	10
Annual use, hrs	1000	200
Depreciation, Rs./hr	49.34	47.50
Interest, Rs./hr	4.08	2.72
Insurance, Rs./hr	2.72	1.36
Housing, Rs./hr	4.08	2.04
Fixed cost, Rs./hr	88.86	79.00
Fuel cost, Rs./hr	142.76	71.38
Lubrication oil cost, Rs/hr	22.16	11.08
Repair & maintenance, Rs/hr	62.32	60
Wages, Rs./hr	37.50@ 300/Day	70
Variable cost, Rs./hr	264.74	130
Overhead cost, Rs./hr	70.72	41.80
Cost of operation, Rs./hr	424.32	251.00
Actual field capacity, ha/hr	0.52	0.26
Cost of operation, Rs./ha	10040	5200

➢ **About Manual Planting**

A hand cutting tool is a traditional agricultural implement widely used in rural areas, especially in South Asia. It features a curved blade attached to a wooden or metal handle and is primarily used for cutting crops like wheat, sugarcane, or fodder. Though affordable and easy to handle, it has several difficulties. First, it requires significant physical effort and poses a risk of injury if not used carefully. Second, because it lacks mechanical assistance, it can be time-consuming and less efficient for large-scale harvesting. Additionally, repetitive motion can cause hand fatigue, and its effectiveness is limited to small plots of land, making it impractical for modern large-scale farming.

Figure 2: Traditional sugarcane tools

Manual Planting Cost:

Operations	Labours		Wages, Rs/day	Cost, Rs/ha
	(Men)	(Women)		
Making ridges and furrows	25	-	600	15000
Sett cutting	14	14	60360	13440
Planting	-	38	350	13300
Total				41740

➢ **NEW SYSTEM–BATTERY OPERATED SUGARCANE CUTTING MECHANISM FOR PLANTER**

The battery-operated sugarcane cutting machine developed for planters improves the planting of sugarcane by making it more efficient and accurate. The new system switches from manual or diesel cutters to an electric device that uses rotating blades or shears to evenly cut the sugarcane setts used for planting. Most gardeners put the device on a portable frame or attach it to a planter machine, so it can move easily across broad areas. Environmentally and financially, using a rechargeable battery system helps because it brings down the use of fossil fuels and cuts both air and noise pollution. Besides, safety features are included, for example blade guards and devices that turn the machine off automatically if it becomes unsafe while it runs.

The new approach increases the speed and accuracy of settle preparation; guaranteeing cuttings are the same length with the edges clean, both leading to improved germination and plant success. Because the system automates the cutting stage, workers need less effort and fewer people, making sugarcane farming easier for smaller farmers. Besides, it makes it possible to cut and drop stones into planting furrows together which can be matched with other planter parts for smooth planting. On a single charge, the battery lasts for many hours and lithium-ion updates have increased both its durability and how well it performs. On the whole, the battery-operated method is a major advance toward making sugarcane farming more mechanized and more sustainable.

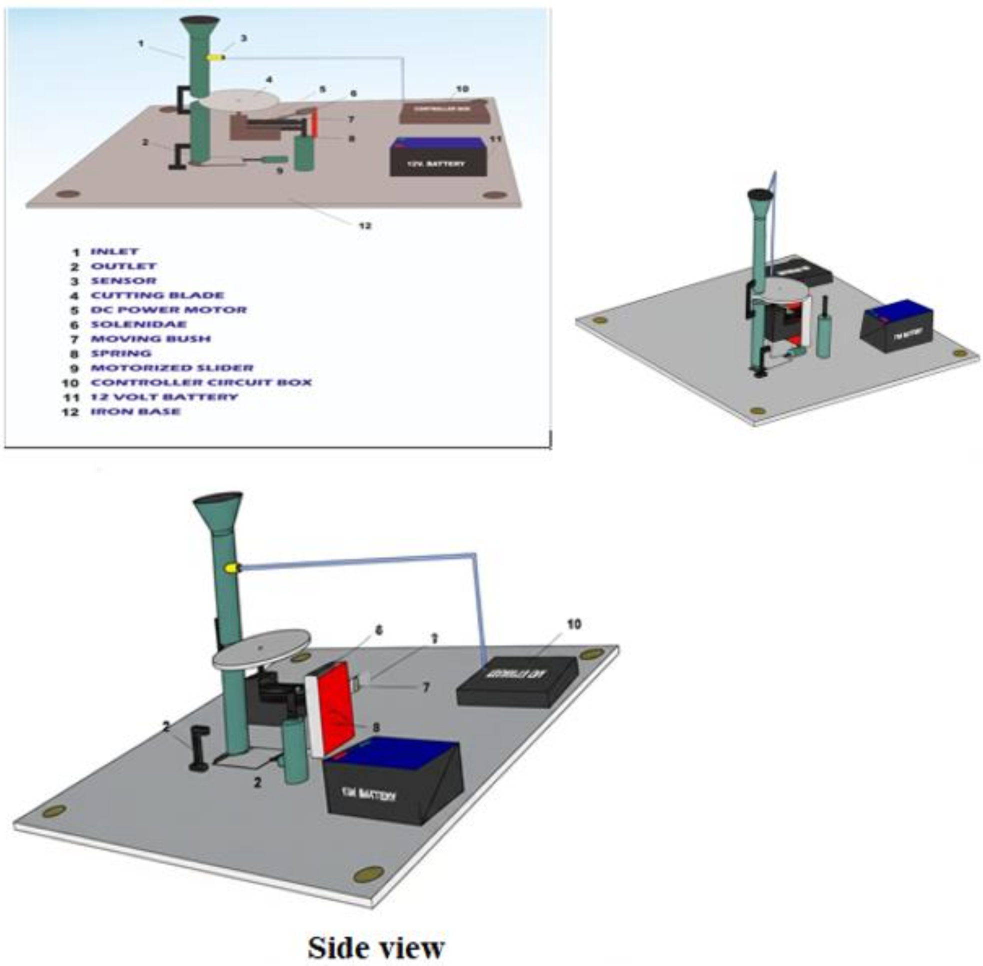

Figure 5: Sensor based battery operated cutting mechanism for plantar

COST OF PLANTING FROM SENSOR BASED BATTERY OPERATED CUTTING MECHANISM

Particulars	**Tractor**	**Our Device**
Purchase price, Rs	5,19,400	10000
Life period, years	10	10
Annual use, hrs	1000	200
Depreciation, Rs./hr	49.34	09.50
Interest, Rs./hr	4.08	0.544
Insurance, Rs./hr	2.72	0.272
Housing, Rs./hr	4.08	0.408
Fixed cost, Rs./hr	88.86	15.80
Fuel cost, Rs./hr	142.76	14.276
Lubrication oil cost, Rs/hr	22.16	2.216
Repair & maintenance, Rs/hr	62.32	12

Wages, Rs./hr	37.50@ 300/Day	14
Variable cost, Rs./hr	264.74	26
Overhead cost, Rs./hr	70.72	8.36
Cost of operation, Rs./hr	424.32	50.20
Actual field capacity, ha/hr	0.52	0.052
Cost of operation, Rs./ha	1040	1040

Table 1: Table: Sensor Planter Performance at Different Speeds (Co 6304)

Sr. No.	**Particular (Average Value)**									
1	**Varieties**	**Co 6304**			**Co 6304**			**Co 6304**		
2	**Speed (km/hr)**	**1.8**	**2.0**	**2.25**	**1.8**	**2.0**	**2.25**	**1.8**	**2.0**	**2.25**
3	**Length of set. (cm)**	**30.5**	**34.4**	**28.6**	**30**	**33**	**28**	**32**	**35**	**29**
4	**Weight of seets (gram)**	**160**	**161.5**	**155**	**155**	**160**	**150**	**165**	**168**	**160**
5	**Number of setts Per 10 m**	**46**	**37**	**25**	**44**	**35**	**23**	**45**	**38**	**24**
6	**Number of setts per ha**	**69149**	**55716**	**36806**						
7	**Number of buds.**	**224**	**224**	**224**	**224**	**224**	**224**	**224**	**224**	**224**
8	**Number of damaged buds**	**-**	**1**	**1**	**-**	**1**	**1**	**-**	**1**	**1**
9	**Depth of planting (cm)**	**25**	**27**	**28**	**26**	**28**	**29**	**25**	**27**	**29**
10	**Overlapping**	**9.50**	**6.14**	**-**	**9.40**	**6.10**			**9.30**	**6.0**
11	**Gap between two sets. (cm)**	**-**	**-**							
12	**Cost of planting (Rs.\ha)**									
13	**Time and labour saving. (hr)**									
14	**Theoretical field capacity (ha/hr)**									
14	**Field efficiency**									

Below is the performance of the sensor-enabled sugarcane planter for six different situations, with speeds measured as 1.8, 2.0 and 2.25 km/hr and seed type Co 6304. When the process runs faster, the setts per 10 meters and per hectare decrease which means the planting density is lower. Although the scale varies slightly in every trial, all sets are still within the ideal ranges. You will notice consistent bud counts at 224, with bud damage starting at higher speed levels. The deeper the planting goes, the greater the chance of the set coming into contact with soil. Reduced overlaps at higher speeds have the potential to make prints less uniform. Not all data is available for cost, gap between sets, time/labour savings, field capacity and efficiency, making it hard to do a full operational analysis.

5. CONCLUSION

The manual cutting by hand is very costly and time taking, efficiency is very low and the full work is dependent on the labour. Instead this the both the technical and economic analysis of sugarcane planters with battery and PTO options suggest they could dramatically improve the way sugarcane is planted. The indicator measurements from the field prove that these planters make planting more accurate, minimize damage from setts and ensure uniform results for crop creation, all of which are key to ramping up crop yield. While the PTO-driven model had better operating efficiency at higher speeds, the battery-powered model could run silently and cleanly, supporting what sustainable farming aims for. Studies found that leaving rubbish on the field during planting led to an increase in potassium and better soil fertility which helped crops produce for longer. Thanks to mechanization, farmers spend less on laborers and save money, making their overall profits much greater. The results strongly recommend using sensor technology to assist with mechanized planting in sugarcane farming.

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