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Sachin Patil

Development Engineer,
 Vasantdada Sugar Institute,
 Pune, Maharashtra, India

Abhinandan Patil

Scientist, Vasantdada Sugar
 Institute, Pune, Maharashtra,
 India

Anil Mundhe

Scientist, Vasantdada Sugar
 Institute, Pune, Maharashtra,
 India

Mohini Gaikwad

Scientist, Vasantdada Sugar
 Institute, Pune, Maharashtra,
 India

Mechanizing sugarbeet cultivation: Performance assessment of two- and four-row planters

Sachin Patil¹, Abhinandan Patil², Anil Mundhe³, Mohini Gaikwad⁴

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ABSTRACT

Sugarbeet (*Beta vulgaris* L.) has considerable potential as an alternative sugar-producing crop, particularly in water-scarce and salt-affected regions. However, precise and timely sowing is critical for achieving uniform crop establishment, optimum plant population and higher root yield. Moreover, increasing labour shortages and rising labour costs have highlighted the need for mechanization of sugarbeet cultivation, particularly during sowing. In this context, the present study was undertaken to design, develop and evaluate tractor-operated sugarbeet planters, comprising a four-row planter for sole-crop cultivation and a two-row planter for intercropping systems. The planters were developed by Vasantdada Sugar Institute (VSI), Pune, in collaboration with M/s Rohitkrishi Industries, Pune. Both planters were equipped with cell-feed type seed metering mechanisms and fluted-wheel type fertilizer metering mechanisms to ensure precise and uniform placement of seeds and fertilizers. The developed planters were calibrated and evaluated under field conditions at the operational area of Baramati Agro, Unit No. 1, Taluka Baramati, District Pune, Maharashtra, using sugarbeet variety SZ-35 in medium black soil. The four-row planter recorded a seed rate of 3.6 kg/ha and a fertilizer application rate of 305 kg/ha, whereas the two-row planter recorded corresponding rates of 1.7 and 170 kg/ha, respectively. The average seed placement depths were 2.42 and 2.57 cm, while the fertilizer placement depths were 2.77 and 2.71 cm for the four-row and two-row planters, respectively. The corresponding seed-to-seed spacings were 11.94 and 11.57 cm. Both planters achieved an effective field capacity of 0.30 ha/h, with field efficiencies of 69.82% for the four-row planter and 74.63% for the two-row planter. Overall, both planters demonstrated satisfactory field performance in terms of seed and fertilizer placement, planting uniformity and operational efficiency. The four-row planter offers potential for mechanized sole-crop sugarbeet cultivation, whereas the two-row planter provides a suitable mechanization option for sugarbeet-based intercropping systems. The developed technology can contribute to timely sowing, reduced labour requirements and improved operational efficiency in sugarbeet cultivation.

Keywords: Sugarbeet, Mechanization, Tractor-operated planter, Seed metering mechanism, Fertilizer placement, Field capacity, Field efficiency

Introduction

Sugarcane (*Saccharum officinarum* L.) is the major sugar-producing crop in India; however, in water-scarce and salt-affected regions, sugarbeet (*Beta vulgaris* L.), a short-duration crop with comparatively lower water requirements and greater tolerance to salinity, offers considerable potential for diversifying sugar production under tropical and subtropical agro-climatic conditions. It can be cultivated under a range of soil conditions, including salt-affected soils, and provides additional benefits through the utilization of its tops and processing residues as livestock feed and industrial raw materials (Mall *et al.*, 2021; Tayyab *et al.*, 2023) [1, 2]. Recent studies have further highlighted the physiological and molecular mechanisms underlying its adaptation to salinity stress (Wang *et al.*, 2024) [3].

Successful sugarbeet cultivation largely depends on uniform crop establishment, optimum plant population and precise seed placement. Since the storage root is the principal economic component, variations in sowing depth, intra-row spacing and inter-row spacing can influence seedling emergence, root development and final yield. Recent research has emphasized the importance of maintaining an appropriate plant population and uniform crop establishment for optimizing sugar yield (Koch *et al.*, 2026) [4]. Consequently, precision sowing is an important prerequisite for achieving higher productivity and efficient resource utilization.

Mechanization of sugarbeet planting is particularly important in view of increasing labour shortages, rising operational costs and the need for timely sowing. A suitable planter should ensure uniform seed distribution, accurate sowing depth, appropriate fertilizer placement and consistent row spacing while minimizing seed damage and operational losses. Although precision planters have been developed and evaluated under different agro-climatic conditions, their suitability for Indian farming systems, particularly for sole cropping and intercropping, requires further evaluation (Liu *et al.*, 2022; Panning *et al.*, 2000) [5, 6]. Therefore, the present study was undertaken to develop and evaluate tractor-operated sugarbeet planters, namely, (i) a four-row

Corresponding Author:

Abhinandan Patil

Scientist, Vasantdada Sugar
 Institute, Pune,
 Maharashtra, India

planter for sole-crop cultivation and (ii) a two-row planter for intercropping systems. The developed planters were evaluated under field conditions to assess seed and fertilizer placement accuracy, seed spacing, effective field capacity and field efficiency, with the objective of identifying suitable mechanized planting options for promoting sugarbeet cultivation under Indian agro-climatic conditions.

Materials and Method

Development and description of sugarbeet planters

To address the need for precise sowing and mechanization of sugarbeet cultivation, two tractor-operated sugarbeet planters were developed by Vasantdada Sugar Institute (VSI), Pune, in collaboration with M/s Rohitkrishi Industries, Pune. The first was a four-row planter designed for sole-crop cultivation, while the second was a two-row planter intended for sugarbeet intercropping systems. Both planters were designed to ensure uniform seed distribution, accurate seed placement, appropriate fertilizer application and timely sowing under field conditions.

The developed planters were fabricated using mild steel (MS) flats, square sections, pipes, channels and sheets. Both machines were provided with rectangular frames and designed for operation with tractors having a power output of more than 35 HP. The planters were at-

tached to the tractor through a three-point linkage system. A centrally positioned ground wheel of 0.27 m diameter, located at the rear of the machine, was provided to drive the seed and fertilizer metering mechanisms.

The four-row planter had overall dimensions of 2150 × 1350 × 1200 mm (L × W × H), whereas the two-row planter measured 1800 × 1350 × 1200 mm. The four-row planter was equipped with four adjustable ridger-cum-leveler type tynes, while the two-row planter had two adjustable tynes of similar design. Both planters were provided with two adjustable ridgers to facilitate proper ridge formation and field preparation during sowing operations.

Seed and fertilizer metering mechanisms

Both planters were equipped with individual seed boxes corresponding to the number of planting rows, comprising four seed boxes in the four-row planter and two in the two-row planter. A cell-feed type seed metering mechanism was incorporated to ensure controlled and uniform seed distribution along the rows. Similarly, individual fertilizer boxes (four and two, respectively) were provided with a fluted-wheel type fertilizer metering mechanism to facilitate uniform fertilizer application during sowing. The metering mechanisms were ground-wheel driven to synchronize seed and fertilizer delivery with the forward movement of the planter.

Table 1. Constructional specifications of the developed four-row and two-row sugarbeet planters

Sr. No.	Particulars	Developed four row Sugarbeet planter (Sole Crop)	Developed two row Sugarbeet planter (Intercrop)
General			
	Model	Tractor Operated Four row Sugarbeet Planter (Sole Crop)	Two row Sugarbeet Planter (Sole Crop)
b.	Power Source	Tractor, more than 35 hp	Tractor, more than 35 hp
c.	Shape of Frame	Rectangular Size	Rectangular Size
d.	Machine Dimension (LXWH), mm	2150 X 1350 X 1200	1800 X 1350 X 1200
e.	Type of attachment	Three point linkage system of the tractor	Three point linkage system of the tractor
f.	Drive wheel	0.27 mtr ground wheel, back side, center	0.27 mtr ground wheel, back side, center
g.	Ridger	02 (Adjustable)	02 (Adjustable)
h.	Number of tyne	04 (Adjustable), Ridger cum Leveler type	02 (Adjustable), Ridger cum Leveler type
i.	Material for Construction	MS flat, Square, Pipe, Channel and Sheet	
Seed Box			
	Number of seed box	04	02
b.	Metering mechanism of seed box	Cell feed type metering mechanism	Cell feed type metering mechanism
Fertilizer box			
	Number of fertilizer box	04	02
b.	Metering mechanism for fertilizer box	Fluted wheel type metering mechanism	Fluted wheel type metering mechanism

Result and Discussion

The field performance of the developed four-row and two-row sugarbeet planters was evaluated using variety SZ-35 under medium black soil conditions at operational area of Baramati Agro, Ltd., Unit No. 1,

Taluka Baramati, District Pune, Maharashtra. The four-row planter was evaluated for sole-crop cultivation, whereas the two-row planter was evaluated for intercropping. The major field observations recorded during the evaluation are presented in Table 2.



Figure 1. Four Row Sugarbeet Planter for Sole Sowing



Figure 2. Two Row Sugarbeet Planter for Intercrop Sowing

The four-row planter operated at an average speed of 1.91 km h^{-1} and recorded an effective field capacity of 0.30 ha h^{-1} , compared with 2.17 km h^{-1} and 0.30 ha h^{-1} , respectively, for the two-row planter. The corresponding theoretical field capacities were 0.43 and 0.40 ha h^{-1} , resulting in field efficiencies of 69.82% and 74.63% , respectively. The higher field efficiency of the two-row planter may be attributed to its comparatively higher operating speed and lower theoretical capacity relative to the four-row configuration. The effective field capacity was similar for both planters despite differences in operating speed and row spacing, indicating satisfactory field utilization under the tested conditions.

Seed placement depth was 2.42 cm with the four-row planter and 2.57 cm with the two-row planter, while fertilizer was placed at depths of 2.77 and 2.71 cm , respectively. The relatively small differences in seed placement depth indicate consistent performance of the seed placement units in both planter configurations. Appropriate sowing depth is essential for uniform emergence and establishment of sugarbeet, particularly because variations in seed placement can influence emergence uniformity and subsequent plant development. Paltik *et al.* (2005) reported that seed-placement quality is an important criterion for evaluating sugarbeet precision planters.

The row-to-row spacing was 45 cm in the four-row planter and 50 cm in the two-row planter. The difference reflects the respective configurations adopted for sole-crop and intercropping systems. The average seed-to-seed spacing was 11.94 cm for the four-row planter and 11.57 cm for the two-row planter. The close seed-to-seed spacing values indicate that both cell-feed metering systems provided relatively consistent seed delivery under field conditions. Uniform within-row seed spacing is an important consideration in sugarbeet production because plant population and spatial uniformity influence individual root development and final crop productivity. Panning *et al.* (2000) [6] emphasized the importance of assessing seed-spacing uniformity under actual field conditions when evaluating sugarbeet planters.

The fertilizer placement depths of 2.77 cm for the four-row planter and 2.71 cm for the two-row planter were also comparable. This indicates that the fluted-wheel fertilizer metering and placement systems functioned consistently during field operation. Proper synchronization of seed and fertilizer placement is desirable for achieving uniform crop establishment while ensuring efficient utilization of applied nutrients.

Overall, the developed planters demonstrated satisfactory field performance in terms of seed placement depth, seed-to-seed spacing, fertilizer placement, operating speed, field capacity and field efficiency. The four-row planter, with 45-cm row spacing, showed suitability for mechanized sole-crop sugarbeet sowing, whereas the two-row planter, with 50-cm row spacing, provided a suitable configuration for sugarbeet intercropping. The results demonstrate the feasibility of using the developed planters for timely and precision-oriented sugarbeet establishment under field conditions.

Conclusion

The developed sugarbeet planters demonstrated satisfactory performance in terms of seed and fertilizer placement, row spacing and field capacity, thereby reducing labour requirements and facilitating mechanized cultivation. The four-row planter is suitable for sole cropping, while the two-row planter is suitable for sugarbeet-based intercropping systems. Further evaluation under different soil types, field conditions and operating speeds is recommended to optimize performance and assess their wider applicability.

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necessary support and facilities for conducting the field trials. The authors also appreciate the cooperation of all those who contributed to the successful completion of this research.

Table 2. Field Performance Evaluation of the Sugarbeet Planters under Sole Cropping and Intercropping System

Sr. No.	Particulars	Developed four row Sugarbeet planter (Sole Crop)	Developed two row Sugarbeet planter (Intercrop)
	Sugarbeet Variety		SZ-35
2.	2. Soil Type		Medium Black Soil
3.	3. Depth of seed placement (cm)	2.42	2.57
4.	4. Depth of fertilizer placement (cm)	2.77	2.71
5.	5. Spacing between row to row (cm)	45	50
6.	6. Spacing between seed to seed (cm)	11.94	11.57
7.	7. Speed of operation (km/hrs.)	1.91	2.17
8.	8. Effective field capacity (ha/hrs.)	0.30	0.30
9.	9. Theoretical field capacity (ha/hrs.)	0.43	0.40
10.	10. Field Efficiency (%)	69.82	74.63

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