



Mechanization Enhancement in Maize Cultivation for Small Holder Farming Community

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Power tiller operated machines may play vital role in maize cultivation for small scale farming system as the average holding size is close to 1 ha and more than 86% of India's farming community are small and marginal farmers. Present efforts were carried out for the development and testing of power tiller operated strip-till multi-crop planter for the mechanization of maize cultivation in small holder farming community. With increasing the level of mechanization by adopting appropriate matching implements for maize cultivation in small farming community, the production and productivity could be increased by reducing cost of cultivation and increasing input use efficiency. Efforts are being made to adopt conservation tillage practices with power tiller operated matching implements for small holder farming focusing on maize cultivation. The developed planter was tested under three different tillage practices as conventional tillage (CT), strip tillage (ST) and zero tillage (ZT). Three types of rotary blades viz. L-type, J-type and C-type were used in strip-tilling operation. The developed machine was evaluated in terms of field

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capacity, fuel consumption, draft, seed germination and crop yield. Average maize yield in ST was maximum (3.32 t ha^{-1}) followed by ZT (3.26 t ha^{-1}) and CT (3.23 t ha^{-1}). The cost of cultivation was maximum for CT followed by ZT and ST.

Keywords: Maize; mechanization; small holder; power tiller; conservation tillage; strip tillage; zero tillage.

1. INTRODUCTION

Maize (*Zea mays* L) is one of the most important food crops in the world with the greatest global production, and contributes to satiating the demands for human food, animal feed, and biofuels (Wang et al., 2022). It is considered as 'queen of cereals' because of its highest genetic yield potential among cereals and wider adaptability to different soil and climatic conditions (Parihar et al., 2018). To minimize the considerable yield gap, the conventional system could be reoriented to conservation agriculture-based tillage practices, as it improves soil physico-chemical and biological properties (Biswakarma et al., 2020).

In India, maize is the third most important food crops after rice and wheat. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. India ranks 4th and 7th in global maize acreage and production, contributing to 4.6% and 2.4%, respectively (Likhitha and Permual, 2025). In India, maize is cultivated over an area of 10.04 million hectares, producing 33.62 million tonnes with an average yield of 3.35 t ha^{-1} (Meena et al., 2025).

About 47% of maize produced in India is consumed in feed industry, while 13% as animal feed. Starch industry consumes around 14% of maize and other industries use maize as a primary raw material, including starch, oil, protein, alcoholic drinks, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. (Prakash and Venkataramana, 2023). Maize has attained an important position as industrial crop because 83% of its produce is used in starch and feed industries (Patel et al., 2024).

Mechanization for maize cultivation is done for different farm operations right from seed bed preparation to harvesting and threshing by using various tractor drawn implements. Marginal and

small land holders are not able to use mechanization due to lack of appropriate power tiller matching implements and also lack of awareness to use power tillers effectively. Kumar and Karmakar, (2024) studied the performance of various power tiller operated matching implements for different farm operations in conservation agriculture for various crops. Power tiller and matching implements may play vital role for the mechanization of small holder farming community as about 86% farmers belong to small and marginal category (Kumar and Karmakar, 2025a).

Nirala, (2011) developed a 3-row animal drawn multi-crop inclined plate planter and its performance was evaluated for maize. The seed rate was found as 20.60 kg ha^{-1} and fertilizer rate was varied from 9.3 to 124.3 kg ha^{-1} . The wheel slip was recorded as 4.53%. The field capacity, field efficiency and plant population were 0.23 ha h^{-1} , 51.1% and 11 plants m^{-2} . The operating cost was 3.5 times economical than traditional method.

Hoque and Karim, (2015) developed power tiller operated inclined plate planter for one pass tillage and seeding operation. Field test was conducted for maize, wheat and mungbean. Effective field capacity and field efficiency were 0.17 ha h^{-1} and 75%, respectively. Coefficient of seed distribution uniformity and coefficient of planting depth uniformity were 97 and 94%, respectively. Time and cost saving to complete land preparation and planting of maize by the planter were 90 and 86%, respectively. Norris et al., (2016) studied that strip tillage cultivation of maize improves arthropod community structure and biodiversity through a reduction in the area disturbed by cultivation and increased non-crop. They found that improving above and below ground arthropod biodiversity can support other important ecosystem services.

Sahu et al., (2017) developed a five-row tractor drawn multi-crop inclined plate planter. The seed rate was found as 20.13 kg ha^{-1} for maize and fertilizer rate was varied from 9.24 to $124.43 \text{ kg ha}^{-1}$. The field capacity and field efficiency were 0.70 ha h^{-1} and 80%, respectively. Nandini et al.,

(2018) developed manually operated multi crop inclined plate planter and its performance was evaluated for planting maize, pigeon-pea, bengal gram and green gram. The average depth of maize, pigeon-pea, bengal gram and green gram was 4.6, 3.83, 4.17 and 4.21 cm, respectively and seed to seed spacing was 22.7, 19.2, 12.6 and 11.47 cm, respectively at an average forward speed of 2.7 km h⁻¹.

Parihar et al., (2018) conducted an experiment to evaluate the performance of maize with permanent bed, zero tillage and conventional tillage. Maize yield (4589 kg ha⁻¹) including cobs per m² (7.8), cob length (0.183 m), grain rows per cob (13.8), and grains per row (35.6), were significantly higher under zero tillage than permanent bed and conventional tillage. Baral et al., (2019) developed a tractor drawn electronic multi crop planter cum fertilizer applicator for sowing maize, pigeon-pea, soybean and groundnut. The seed rate was controlled easily with the rpm controller and could be used for a variety of seeds with the change in seed metering plates.

Abubakar et al., (2020) developed a manually operated two row maize planter and its performance was evaluated. The results showed that field efficiency, field capacity, seed damage and missing were 68.18%, 0.16 ha h⁻¹, 13.3% and 17.5%, respectively. Bisen et al., (2020) developed a three-row animal drawn multi-crop planter cum herbicide applicator and its performance was evaluated for soybean, green gram and maize. The average seed rates for soybean, green gram and maize were found to be 77.85, 17.66 and 42.86 kg ha⁻¹, respectively. The average field capacity and field efficiency were 0.143 ha h⁻¹ and 73.8%, respectively. Adetola et al., (2020) developed a self-propelled maize planter and its performance was evaluated. The field capacity, field efficiency and seed damage were found as 0.3 ha h⁻¹, 73.7% and 8.33%, respectively. The depth of sowing was varied from 2.47 to 2.60 cm. Soyoye, (2020) developed an electrically powered maize planter and its performance was evaluated. Light reflecting optoelectronic field counter capable of detecting free falling seeds was designed and built to monitor seed drop on the planter. The device accurately counted the falling seeds with the planter forward speed of 1.38 m s⁻¹ and seed delivery tube of 24 mm. The average number of seeds discharged per hole was two.

Singh et al., (2020) conducted an experiment to evaluate a power tiller operated seed drill for

sowing maize. The average depth of sowing, row-row spacing and seed rate were 4.5 cm, 50 cm and 18 kg ha⁻¹, respectively. Kumar and Karmakar, (2025) conducted an experiment to find the engineering properties of maize, groundnut and paddy seeds for the design of seed metering mechanism of multi-crop planter.

Manjulatha et al., (2021) conducted an experiment to study the comparative economics of maize cultivation under conventional and mechanization method. They found that the total cultivation costs under conventional and mechanization methods were Rs.117794 ha⁻¹ and Rs.104137 ha⁻¹, respectively with 12% saving under mechanized method. Yadav and Meena, (2024) studied the production process of sweet corn in mechanized way.

2. MATERIALS AND METHODS

2.1 Development of Strip-till Multi-crop Planter

Power tiller operated strip-till multi-crop planter was developed which consists of furrow opener, seed and fertilizer boxes, seed metering mechanisms, seed and fertilizer tubes, ground drive wheel, furrow covering unit, strip-tilling unit, chain & sprockets, set of bevel gears etc. The power tiller VST Shakti 130DI was used as the prime mover.

2.2 Performance Evaluation of the Developed Multi-crop Planter

The performance of the developed strip-till multi-crop planter was evaluated in the laboratory as well as in the field with maize of variety Hybrid: Yuvraj Gold.

2.2.1 Experimental site

Field investigations were carried out during the cropping season of 2022-23 at Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya (BCKV), Nadia, West Bengal, India. The research work was a part of the PhD research project named "Power Tiller Operated Strip-till Multi-crop Planter for Conservation Agriculture". The homogeneous soil of the field was clay loam type. The design of experiment was split plot with three replications and the whole experiments were carried out in accordance to the design. The crop was cultivated according to three different tillage methods viz. conventional tillage (CT), strip tillage (ST) and zero tillage (ZT).

2.2.2 Experimental details

The entire field of area 26 x 62 m² was divided equally into three main plots of 8 x 62 m² area comprising of 3 different tillage practices as conventional tillage (CT), strip tillage (ST) and zero tillage (ZT). The maize (Hybrid: Yuvraj Gold) was sown in Kharif season. For field preparation, various tractor drawn tillage implements were used in CT and ST whereas no tillage was done in case of ZT. The crop was sown with the developed power tiller operated strip-till multi-crop planter.

2.2.3 Crop establishment technique

The developed power tiller operated strip-till multi-crop planter was used for sowing of maize in CT and ZT without strip tilling and in ST with strip tilling. The VST Shakti 130DI was selected as the matching prime mover for the development of strip-till multi-crop planter. The row to row and plant to plant spacing were 60 cm and 20 cm, respectively. Inclined plate type seed metering mechanism was used to maintain seed to seed spacing of the crop. The metering plates were designed on the basis of engineering properties of maize (Hybrid: Yuvraj Gold) seeds. Separate seed boxes were used for rows and row to row spacing was adjustable. The number of rows of the power tiller operated multi-crop planter for maize was two. The multi-crop planter was calibrated before sowing operation in the field. The inclined type seed metering plates with cells made on the periphery of the circular plates was used for maize seeds. The seed rate was found as 20 kg ha⁻¹.

The recommended dose of fertilizer (RDF, kg ha⁻¹) was (N: P₂O₅:K₂O) 120:60:40 for maize. Urea (46 % N), Di-ammonium Phosphate (DAP) (18 % N and 46 % P₂O₅) and Muriate of Potash (MOP) (60 % K₂O) were used to apply to meet N: P₂O₅:K₂O dose. The amount of nitrogen (N) was calculated from Urea (46 % N) and DAP (18 % N) to meet out required dose. The amount of P₂O₅ and K₂O were calculated from DAP (46 % P₂O₅) and MOP (60 % K₂O), respectively to meet out the required dose.

3. RESULTS AND DISCUSSION

The performance of the developed power tiller operated strip-till multi-crop planter was evaluated in both laboratory and field conditions with maize (Hybrid: Yuvraj Gold) seeds. The machine was calibrated five times with a fixed number of revolutions of ground drive wheel

(5, 10, 15, 20, and 25). The average seed rate was found to be 19.15 kg ha⁻¹.

The sand bed method was used to evaluate the performance of the machine in the laboratory. The average seed to seed spacing, number of multiples, missing hills and visible damage were found as 19.25 cm, 4.67%, 2.67% and 1.33%, respectively.

The field performance of the developed planter was undertaken in terms of field capacity, draft, fuel consumption, seed germination and crop yields.

3.1 Effective Field Capacity

The average EFC at 1.5 km h⁻¹ forward speed for maize sowing was 0.11 ha h⁻¹. And when forward speed increased to 2.5 km h⁻¹, the average EFC increased to 0.172 ha h⁻¹ as shown in Fig. 1(a). The percent increase in EFC from 1.5 km h⁻¹ to 2.5 km h⁻¹ forward speed was 56.36%. With the increase in operating depth, the average EFC was maximum at 5 cm operating depth for C-type rotary blade and minimum at 6 cm operating depth for L-type rotary blade as illustrated in Fig. 1(b).

3.2 Fuel Consumption

It was observed that the fuel consumption decreases with increase in forward speed of the machine for all types of rotary blades used in strip-tilling. The fuel consumptions at 1.5 km h⁻¹ forward speed for maize were 11.85, 12.69 and 12.69 L ha⁻¹ for L-type, J-type and C-type rotary blades, respectively. With increase in forward speed to 2.5 km h⁻¹, the fuel consumptions were 11.13, 10.95 and 12.21 L ha⁻¹ for L-type, J-type and C-type rotary blades, respectively as shown in Fig. 2(a). The average fuel consumption at 1.5 km h⁻¹ forward speed was 12.41 L ha⁻¹. With increase in forward speed to 2.5 km h⁻¹, the average fuel consumption decreased to 11.33 L ha⁻¹. The percentage decrease in fuel consumption with increase in forward speed from 1.5 to 2.5 km h⁻¹ was 8.7%. It was observed that with increase in operating depth from 4 to 6 cm, the average fuel consumption was increased for L-type and J-type rotary blades and for C-type rotary blade, it was minimum at 5 cm operating depth as illustrated in Fig 2(b).

3.3 Wheel Slip

It was observed that the average slip percentage of power tiller wheel was 7.8±1.87% in maize

cultivation. The slip percentage was decreased with increase in forward speed as shown in Fig. 3(a). The average slips at 1.5 km h⁻¹ forward speed were 8.45% for maize sowing. At 2.5 km h⁻¹ forward speed, the average slip percentage was 6.62%. When the forward speed increased from 1.5 km h⁻¹ to 2.5 km h⁻¹, the slip percentage was decreased by 21.66%. It was found that there is no any perfect relationship between the slip percentage of power tiller wheel and operating depth of strip tilling operation as illustrated in Fig 3(b).

However, the average slip percentage at 4 cm operating depth was 7.84%. At 6cm operating depth, the average slip percentage was 7.17%. It was seen that the maximum slip percentage was for L-type rotary blade. The slip percentage for L-type blade was 9.72%. The minimum slip percentage was 6.04% for C-type blade at 5 cm operating depth.

3.4 Draft

The draft of the machine was increased with increase in operating depth and forward speed for all types of rotary blades as illustrated in Fig. 4 (a & b). The drafts at 1.5 km h⁻¹ forward speed were 127, 130 and 128 N for L-type, J-type and C-type rotary blades, respectively. With increase in forward speed to 2.5 km h⁻¹, the drafts were 177, 220 and 182 N for L-type, J-type and C-type rotary blades, respectively. With increase in operating depth from 4 cm to 6 cm, the draft increases for all types of rotary blades used. The maximum draft (277 N) was found at 6 cm operating depth for J-type rotary blade and

minimum draft (98 N) was found at 4 cm operating depth for L-type rotary blade.

3.5 Germination of Seeds

The average germination of maize seeds was observed for strip tillage operation with different input parameters as illustrated in Fig. 5 (a & b). It was observed that the average seed germination of maize was 82.89±3.32%, 83.02±2.76% and 83.67±2.09% for L-type, J-type and C-type rotary blade tilled plots, respectively.

It was seen from the Fig. 5(a) that with increase in forward speed from 1.5 km h⁻¹ to 2.5 km h⁻¹, the seed germination was more or less same for all rotary blades. With increase in operating depth from 4 cm to 6 cm, the seed germination was almost same at 4 cm and 6 cm operating depth for all types of rotary blade but at 5 cm operating depth, the seed germination was minimum for all types of rotary blade as shown in Fig 5(b).

3.6 Yield of Maize

The average yield variation of maize under strip tillage (ST) plots with forward speeds and operating depths are presented in Fig. 6 (a & b). It was observed from the Fig. 6(a) that the maize yield slightly decreased with increase in forward speed from 1.5 to 2.5 km h⁻¹. The average yield of maize was maximum (3463 kg ha⁻¹) under strip tilled plot operated by L-type rotary blade at 1.5 km h⁻¹ forward speed and minimum (3061 kg ha⁻¹) operated by C-type rotary blade at 2.5 km h⁻¹ forward speed.

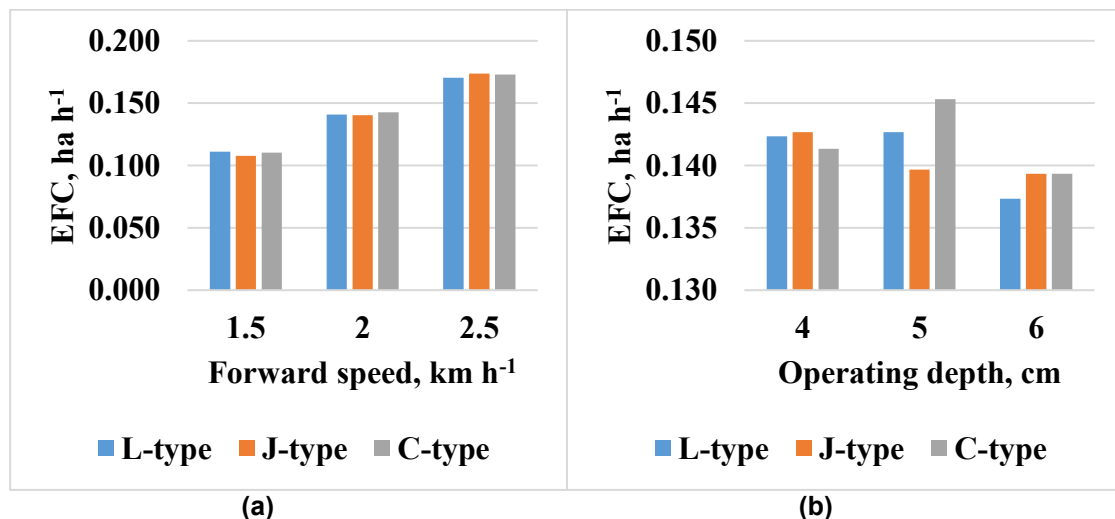


Fig. 1. Effective field capacity at different forward speed and operating depth for different rotary blades

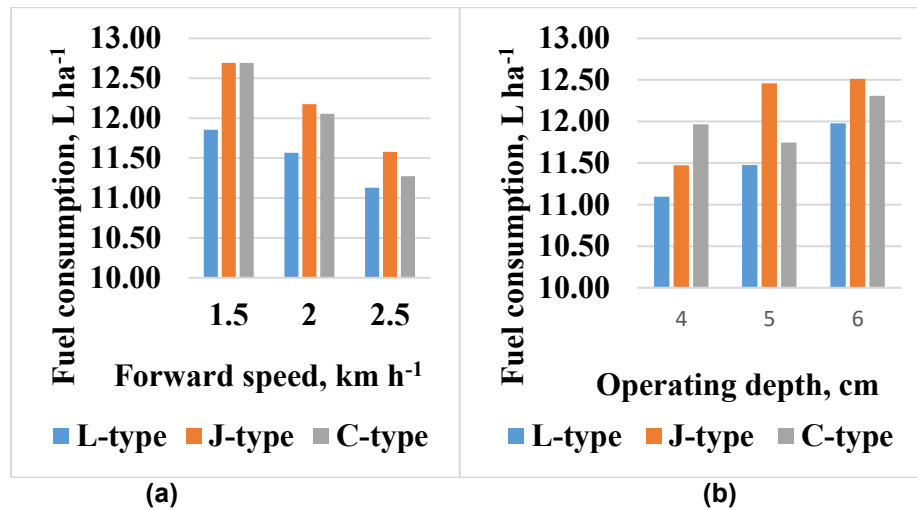


Fig. 2. Fuel consumption of the machine at different forward speed and operating depth for different rotary blades

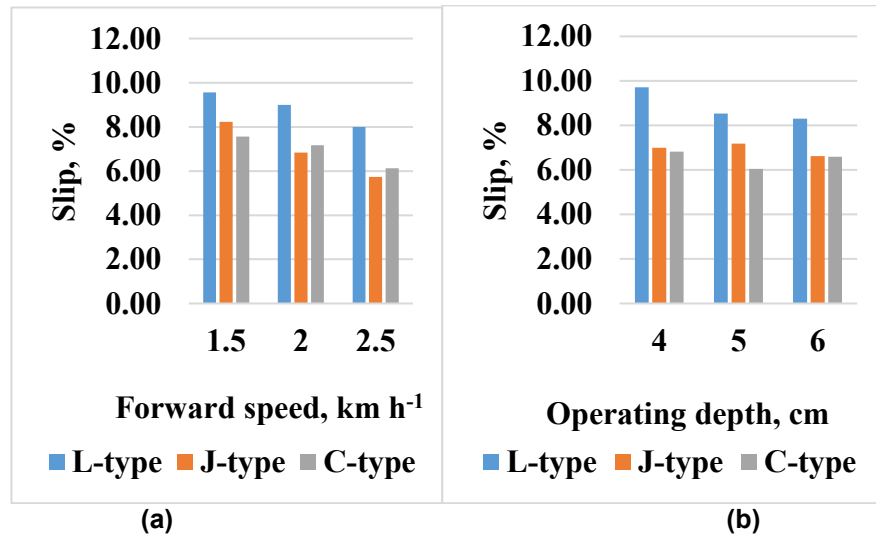


Fig. 3. Slip at different forward speed and operating depth for different rotary blades

From the Fig. 6(b), it has been seen that the average yield of maize was maximum (3376 kg ha⁻¹) under strip tilled plot operated by L-type rotary blade at 4 cm operating depth and minimum (2971 kg ha⁻¹) operated by C-type rotary blade at 5 cm operating depth.

The average yield of maize under strip tillage operation for various input parameters and the yield under conventional tillage and zero tillage are presented in Fig. 7. It has been seen from the Fig. 7(a); the average maize yield of all the strip tilled plots operated at 1.5 km h⁻¹ forward speed was maximum (3327 kg ha⁻¹) followed by zero tilled plots (3260 kg ha⁻¹) and conventional tilled plot (3234 kg ha⁻¹).

From the Fig. 7(b), it was observed that the average maize yield of all the strip tilled plots

operated at 6 cm operating depth was maximum (3315 kg ha⁻¹) followed by 4 cm (3274 kg ha⁻¹) and 5 cm (3177 kg ha⁻¹) operating depth.

Similarly, from the Fig 7(c), it was seen that the average maize yields of all the strip tilled plots operated by L-type and J-type rotary blades at different forward speeds and operating depths were 3318 and 3352 kg ha⁻¹, respectively followed by C-type (3096 kg ha⁻¹) rotary blade.

3.7 Cost of Production for Maize

From Fig. 8, it is observed that the cost of cultivation of maize was maximum (63410 INR ha⁻¹) for conventional tillage followed by zero tillage (59762 INR ha⁻¹) and strip tillage (58930 INR ha⁻¹). Similarly, the gross return and net

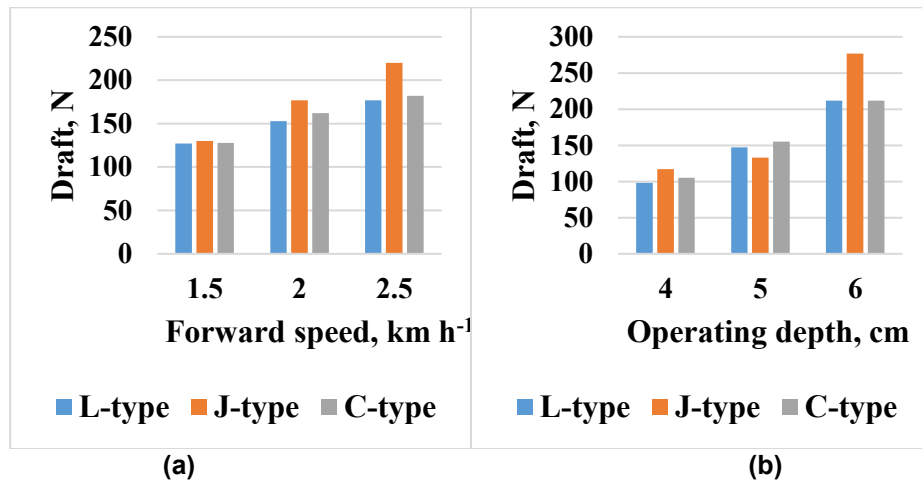


Fig. 4. Draft of the machine at different forward speed and operating depth for different rotary blades

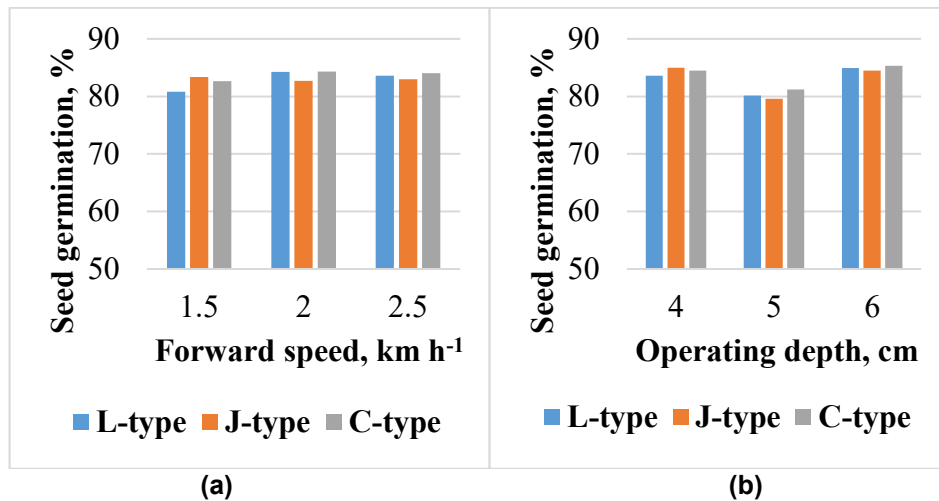


Fig. 5. Seed germination at different forward speed and operating depth for three types of rotary blades

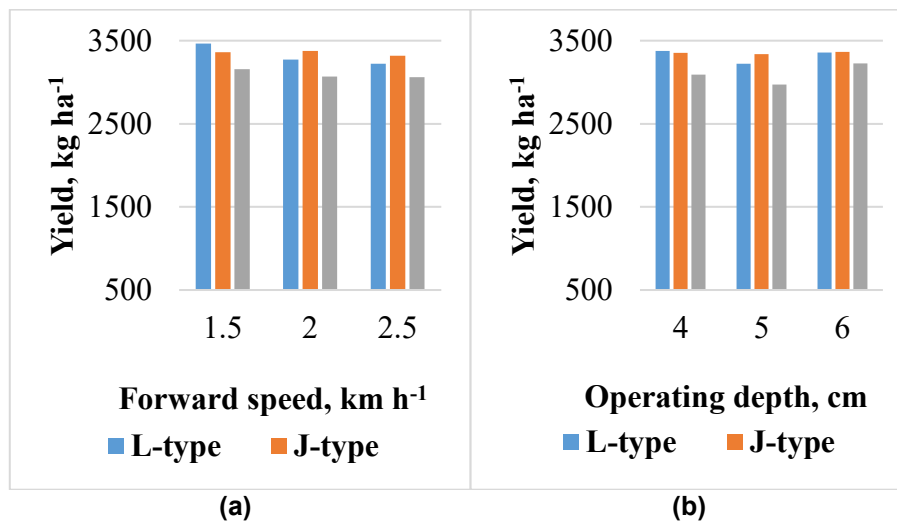


Fig. 6. Maize yield variation with (a) forward speed and (b) operating depth for different rotary blades

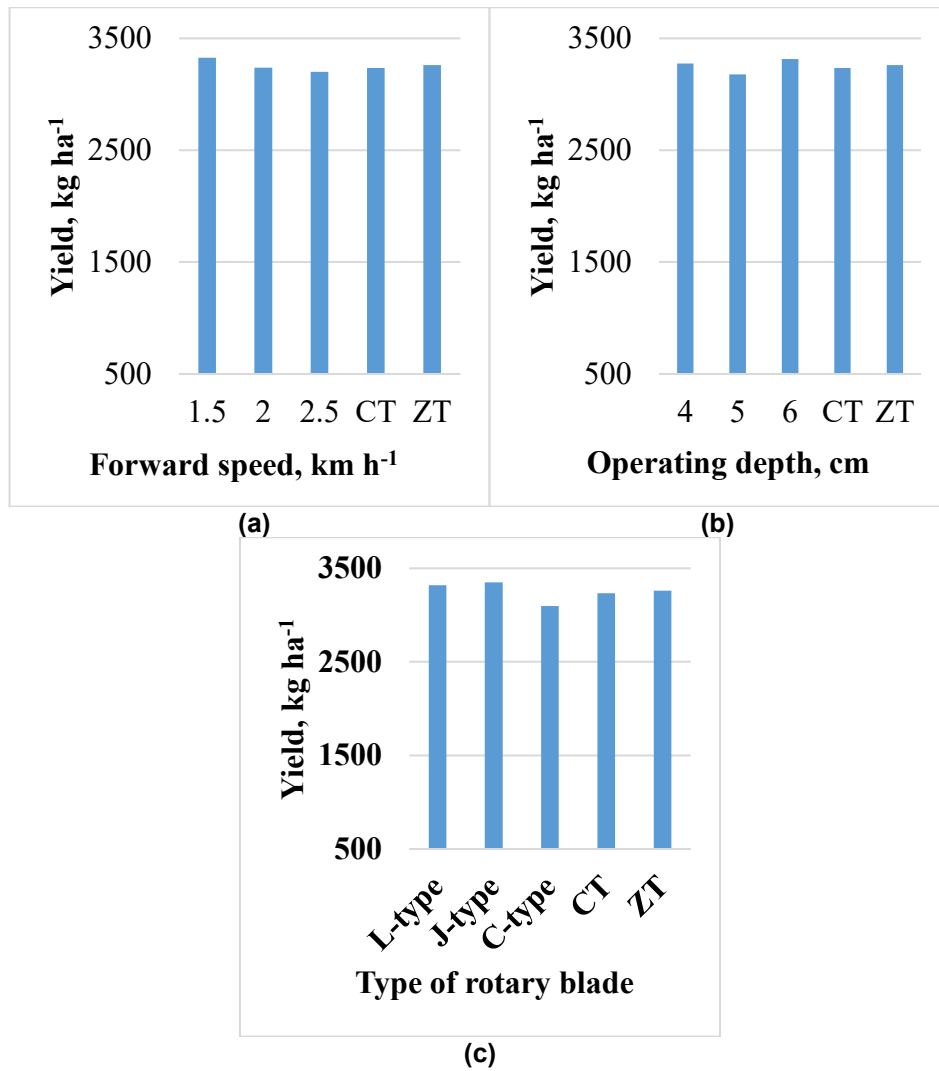


Fig. 7. Maize yield variation of strip tilled plot with (a) forward speed (b) operating depth and (c) type of rotary blade and comparison with yield under zero tillage and conventional tillage

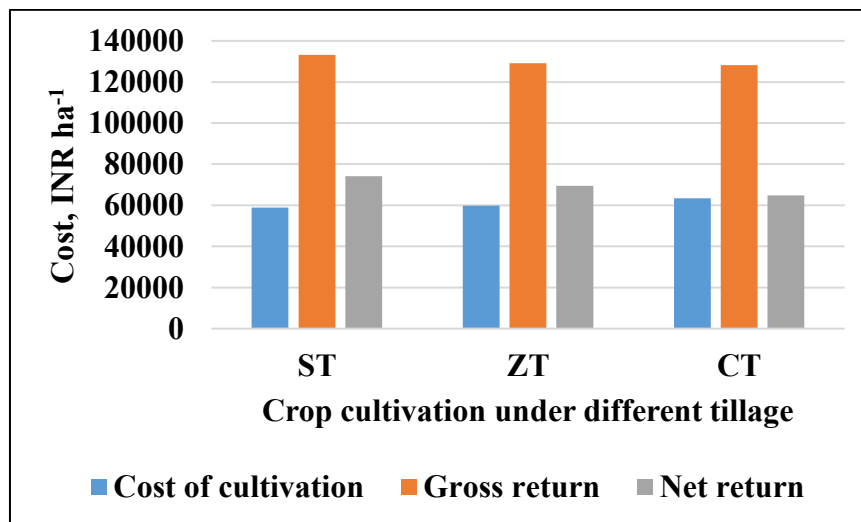


Fig. 8. Cost of cultivation and returns under different tillage practices for maize

Table 1. Cost of cultivation and returns under different tillage practices

Crop	Tillage	Cost of cultivation, INR ha ⁻¹	Gross return, INR ha ⁻¹	Net return, INR ha ⁻¹	B:C ratio
Maize (Hybrid: Yuvraj Gold)	ST	58929.51	133159.01	74229.50	1.26
	ZT	59761.59	129185.78	69424.19	1.16
	CT	63409.63	128155.46	64745.83	1.02

return were maximum for ST (133159 and 74230 INR ha⁻¹) followed by ZT (129186 and 69424 INR ha⁻¹) and CT (128155 and 64746 INR ha⁻¹). The cultivation cost under CT was maximum due to higher operational charge and electricity charge used during irrigation. On the other hand, the gross return and net return were maximum under strip tillage because of lower input resources used for cultivation and higher crop production. The B:C ratio was observed as 1.26, 1.16 and 1.02 for ST, ZT and CT respectively (Table 1) (Parihar et al., 2011).

4. CONCLUSIONS

Sowing of seeds is a very crucial and time bound farm operation for better crop production and productivity. With the considerations of small and marginal farm holders, and the advantages of strip tillage (ST) over conventional tillage (CT) and zero tillage (ZT), the present work was carried out to develop a power tiller operated strip-till multi-crop planter for conservation agriculture. Conventional tillage requires large amount of energy as well as high operating cost. The operating time from tillage to sowing is also high in CT as compared to combined tillage and ZT. The loss of natural resources from CT could be minimized with the adoption of reduced tillage or combined tillage. The study shows that power tiller operated strip-till multi-crop planter can be used effectively to compensate conventional and zero tillage practices especially for small and marginal farm holdings.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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