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DESIGN AND DEVELOPMENT OF TWO-ROW POWER TILLER-MOUNTED DIRECT SEEDER FOR CABBAGE CULTIVATION

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A two-row upland seeder for cabbage was designed, developed, and tested to improve sowing efficiency and crop establishment in small-scale farming. It featured precision seeding and was evaluated with and without press wheels. Seed delivery rates decreased as ground speed increased, with the highest rate of 0.267 kg·ha^{-1} achieved at 0.6 m·s^{-1}; faster speeds lowered accuracy. Slippage tests at 10 RPM showed stable traction with an average slippage of 3.92%. Field trials revealed that press wheels significantly enhanced seeding performance, providing more consistent sowing depths (mean 6.6 mm), higher germination rates (61%), and fewer missing hills than without press wheels. Statistical analysis (ANOVA, Tukey's HSD) confirmed that press wheels had significant effects on sowing depth, germination rate, and seedling count (p <0.05). Despite some issues like seed clogging and hopper damage, the seeder was user-friendly and effective. The study highlights the need for optimal speeds and press wheels to improve planting precision and crop establishment.

Keywords: upland seeder; sowing efficiency; small-scale farming; press wheels; cabbage

Mauritius faces growing climate challenges, positioning sustainable agriculture as a national priority. Although agriculture contributes only 4.6% to GDP, it supports over 30,900 jobs and generates USD 71.94 million in exports (Guerrero et al., 2022). Advancing sustainability enhances resilience, food security, and long-term economic development (FAO, 2021). Most local farmers sow small vegetable seeds manually, with 55% farming less than one acre and 30% on one-to-two-acre plots (Ramphul et al., 2016; Betchoo, 2015). For these smallholders, affordable and low-cost mechanisation is most appropriate (Sims and Kienzle, 2016). However, adoption is hindered by factors such as imperfect information, risk, and inadequate infrastructure (Gadekar et al., 2016). Precision agriculture offers efficient resource use and waste reduction (Zhang et al., 2002). To encourage innovation, the Ministry of Agro-Industry and Food Security of Mauritius provides advisory services, equipment access, and field demonstrations to promote technology adoption (Idemudia et al., 2022; Kienzle et al., 2013). These efforts help bridge the gap between innovation and on-field adoption. They form part of a wider strategy to accelerate technology transfer and integrate modern practices into daily farming (Rodrigues, 2002; Joyce and Cartwright, 2020). Over USD 1.09 million has been allocated to climate-resilient agricultural projects, including the Belle Mare Climate-Smart Agriculture Village, which targets food security and poverty alleviation (Agromoris, 2024). Collaborative efforts between the government and private sector have improved self-sufficiency in leafy vegetables (Dudin et al., 2019), supported by incentives, input access, and training (Ijaz et al., 2019; Jayne et al., 2018; Obayelu et al., 2021; Benin et al., 2015). Within this context, this study aims to design a simple, integrated, low-cost, two-row power tiller-mounted seeder for cabbage, optimised for small to medium-scale farms (Olorunnisola, 2021; Singh and Kanna, 2021; Nag et al., 2020).

Material and Methods

The cabbage seeder prototype was tested for seed spacing, depth, and consistency; field performance with press wheels for seed-to-soil contact and emergence; and assembly strength and usability (Parish, 2005).

Design of seeder

Design parameters for cabbage seeder

The targeted seeder includes essential components for accurate seed placement: a drive wheel transmits power through a shared shaft on a robust frame, and a floating hitch links it to the tractor (Wang and Zhang, 2019). A major design challenge in the sowing unit is the selection of parameters that allow for safe and efficient turning at the headland (Findura et al., 2024). Seeds move from the hopper through a metering roller into a furrow opened by a trenching tool, then are covered and pressed by a wheel to promote germination. Table 1 lists the initial design assumptions.

The average seed delivery rate was 0.1673 kg·ha^{-1} (SD = 0.0669 kg·ha^{-1}), with the highest (0.267 kg·ha^{-1}) at 0.6 m·s^{-1}, the optimal speed to minimise seed loss. Ground

Table 1 Design parameters for cabbage seeder

No.	Parameters	Assumed values
1	seed variety (cabbage)	Kagayaki-Kanran
2	average diameter (cabbage seeds being round)	1.8 to 2 mm
3	hill distance	40 cm
4	row spacing	60 cm
5	sowing depth	5 to 7 mm
6	weight of 100 seeds	0.45 g
7	diameter of metering roller	60 mm
8	number of holes to be bored on roller	2 units
9	recommended sowing rate (seeds·10a)	4000 seeds per 1000 m^2
	in $kg \cdot ha^{-1}$ (calculation)	4000 seeds × (10,000 m^2/1000 m^2) (0.45 g/100 seeds) = 0.18 $kg \cdot ha^{-1}$
10	actual sowing rate for above hill distance and row spacing	
	row spacing (m) × hill distance (m) × 10,000 m^2	0.6 × 0.4 × 10,000 = 41,667 seeds
	in $kg \cdot ha^{-1}$ (calculation)	100 × 0.45 × 41,667 = 0.187 $kg \cdot ha^{-1}$

wheel slippage averaged 3.92%, indicating good traction. The seeder, built from accessible materials, is suitable for small-scale farmers and adaptable to other crops. Shallower sowing improved germination, while deeper sowing reduced emergence. Press wheels improved seed-to-soil contact and sowing depth uniformity but had no effect on seed count or spacing, highlighting their role in enhancing seeding precision.

$$\frac{\pi d}{n} = H \tag{1}$$

Equation (1) relates the drive wheel diameter (d), hill distance (H = 40 cm), and number of holes on the metering roller (n = 2). Substituting into $= \frac{\pi d}{2} = 40$, gives: $d = \frac{(40)(2)}{\pi} = 25.5$ cm.

Construction and assembly of seeder components

Steel plates were added to the drive wheel for better traction and spacing. The frame, built from four bolted angle irons, supported the hopper, roller, and other components. A 16 mm × 850 mm shaft held the metering rollers and

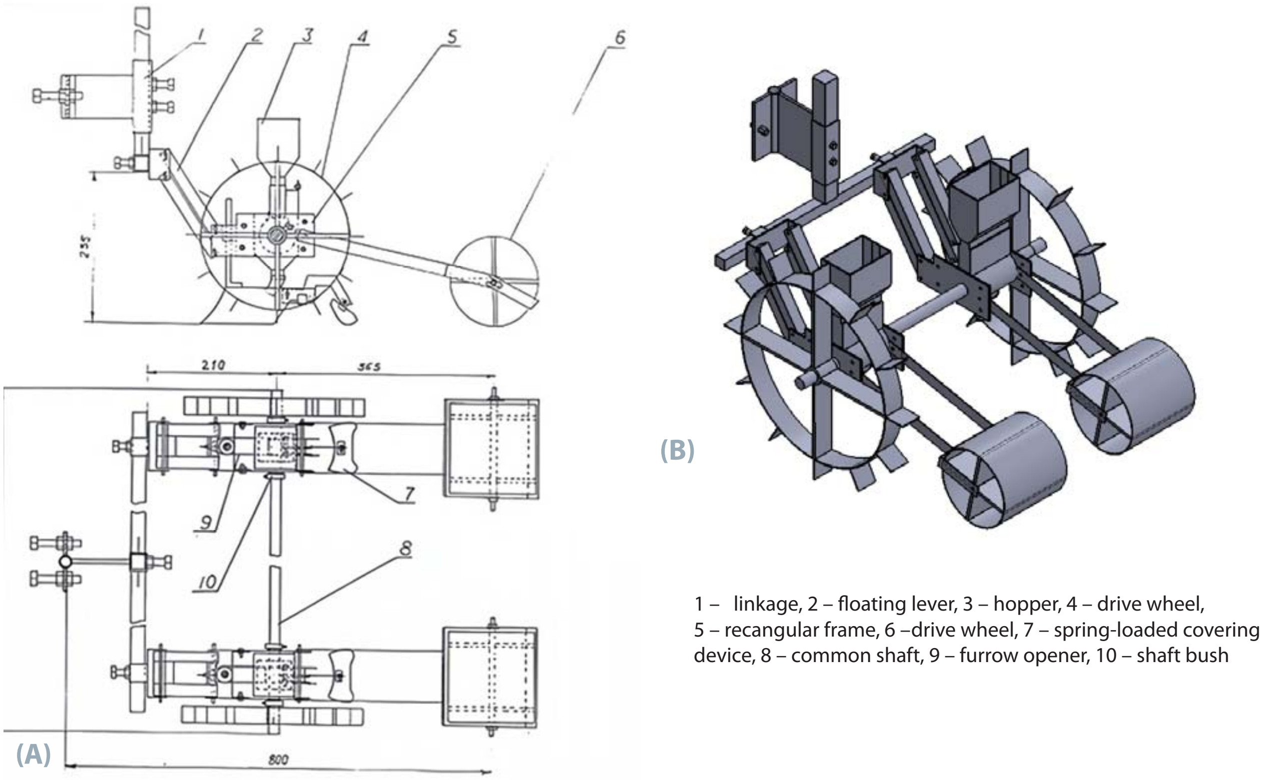

Fig. 1 (A) Seeder assembly drawing (scale 1 : 7); (B) Three-dimensional view of the seeder

Table 2 Component specifications of the seeder

Components		Dimensions (mm)					Material	Quantity
		L	W	H	T	W		
1	drive wheel	-	30	-	3	250	mild steel (MS) sheet	2
1.1	wheel lugs	50	30	-	1.3	-	MS sheet	24
1.2	wheel spokes	100	-	-	-	13	MS rod	8
1.3	wheel bushes	-	30	-	-	30	MS rod	2
2	frame	455	80	-	3	-	MS rod	10
3	common shaft	850	-	-	-	16	MS rod	1
4	floating lever	160	20	-	-	-	angle iron bar	1
5	linkage	700	25	-	-	2.5	MS box section	1
5.1	adjustable part of linkage	230	75	-	6	-	MS sheet	1
6	hopper	70	60	100	0.8	-	MS sheet	
7	hopper bottom	20	20	50	-	-	MS sheet	2
8	furrow opener	250	60	-	2	-	box section MS bar	4
9	covering device	150	100	-	2	-	MS sheet	
10	press wheel	150	-	-	1.5	150	MS sheet	2
10.1	wheel spokes	65	-	-	-	8	MS rod	16
10.2	wheel bushes	200	-	-	-	12	MS pipe	2
10.3	wheel scraper	360	22	-	3	-	MS sheet	2
11	metering roller	45	-	-	-	60	PVC	2
12	lock plate for floating lever	150	60	-	1.8	-	MS sheet	2
13	bushes for common shaft	12	-	-	-	30	MS rod	4

Overall dimensions of seeder (length × width × height = 800 × 853 × 400 mm)
L – length; W – width; H – height; T – thickness; D – diameter

drive wheels. At the front, a 2 mm steel furrow opener and spring-loaded coverer guided seed placement. Seeds passed through a PVC tube into the furrow. Press wheels (150 mm diameter and width), with scrapers and a floating link, ensured firm soil contact. A floating hitch maintained uniform depth and vertical movement (up to 25 cm). The hopper, with a curved base, contained a durable PVC metering roller. Table 2 and Fig. 1 provide technical and visual details.

Laboratory test

A laboratory test evaluated the metering mechanism, seed calibration (Fig. 2), and optimal power tiller speed. Calibration followed the Japanese National Test Code.

Shaft speeds from 0.5 to 1.2 m·s^{-1} were tested to assess performance under varying conditions. The shaft's rotational speed (*n*, in RPM) was calculated using the following equation:

$$n = \frac{60V}{\pi} \tag{2}$$

where: V – speed of shaft, m·s^{-1}

Seed delivery rate:

$$q = \frac{10L}{60VR} \tag{3}$$

where: L – seeds discharged in one minute; R – row distance (m) ($R = 0.6$ m)

Field test

Field experiments were conducted on dry Tsukuba volcanic ash soil without pre-irrigation or moisture control, reflecting typical small-scale farming conditions, though potentially affecting germination. Prior to testing, power tiller slippage with the cabbage seeder was measured on concrete and field surfaces using an 8 × 8 m plot. Six rows were sown with press wheels and seven without, under similar conditions.

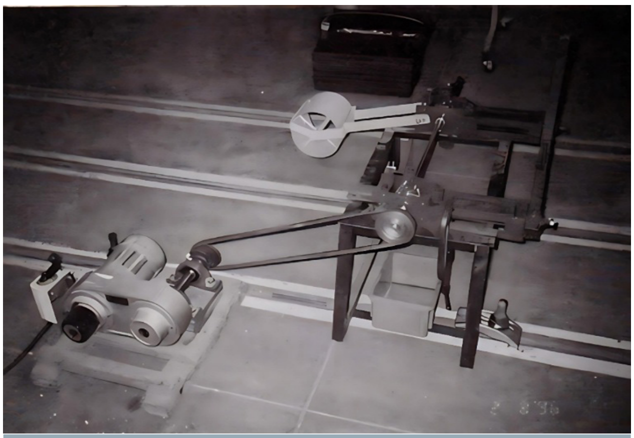

Fig. 2 Laboratory calibration test of the seeder

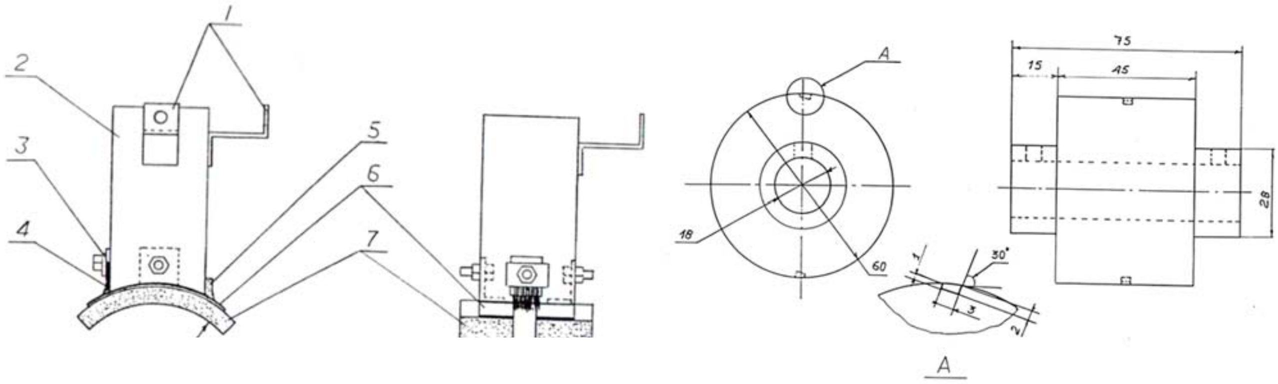

Fig. 3 Assembly drawing of the cabbage seeder, featuring a PVC metering roller for seed dispensing
A – two holes drilled as shown in part A; B – roller fixed on shaft by 2 lock screws, diameter 6 mm
1 – mild steel plates, 1 mm thickness (bolted to frame); 2 – 25 × 25 mm steel box section, approx. height 50 mm ; 3 – fixing plate; 4 – plastic bristles, diameter 0.13 mm; 5 – sponge (glued to box section); 6 – aluminium plate 10 × 40 mm, thickness 1 mm; 7 – sponge 15 × 45 mm, thickness 5 mm (glued to bottom part of 6)

Data collection ended two weeks after sowing due to logistical limits. Slippage (%) was calculated as:

$$slippage\ (\%) = \frac{L_1 - L_2}{L_1}(100) \qquad (4)$$

where: L_1 – theoretical distance travelled; L_2 – actual distance travelled.

Zolotukhin et al. (2025) analysed field tests of a drill seeder equipped with a seed metering control unit. Their results indicate that the seeder meets agrotechnical performance standards. It offers smooth adjustment capabilities, time savings, and supports variable-rate seeding for precision agriculture applications.

Figure 3 shows the seeder assembly and the detailed PVC metering roller schematic.

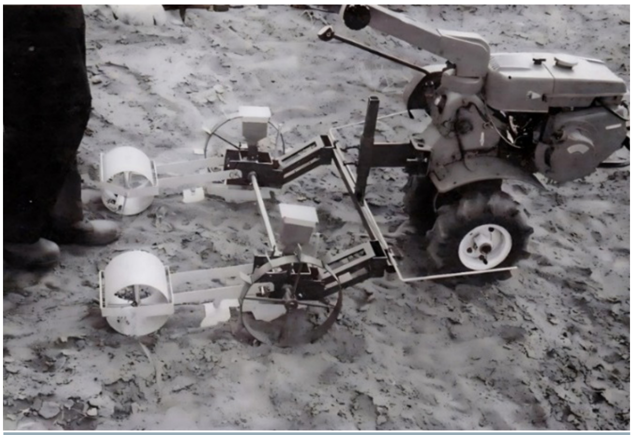

Fig. 4 Two-row direct seeder for cabbage cultivation

Results and Discussion

Figure 4 shows a two-row cabbage seeder mounted on a walk-behind tractor. It features two identical seeding units, each with a hopper, metering mechanism, furrow opener, seed tube, and press wheel to ensure uniform spacing, planting depth, and good seed-to-soil contact. Speed delivery tests showed that operating speed significantly affects seed distribution. At 45 RPM, the delivery rate was 0.26 kg·ha^{-1}, dropping to 0.07 kg·ha^{-1} at 95 RPM. The average rate was 0.1673 kg·ha^{-1} (SD = 0.0669), ranging from 0.0690 to 0.2670 kg·ha^{-1}. The optimal rate (0.267 kg·ha^{-1}) occurred at 0.6 m·s^{-1} and was chosen for field trials to reduce seed loss. As noted by Zhong et al. (2024) and Reddy et al. (2012), gravity-fed rollers require sufficient dwell time in the pick-up zone, which decreases at higher speeds, leading to under-delivery. Pareek et al. (2025) also reported poor seed spacing in traditional planters due to ground wheel skidding and vibration. A slightly lower rate (0.202 kg·ha^{-1}) at 0.7 m·s^{-1} confirmed better accuracy at lower speeds, supported by the roller's dual inclined-hole design. The optimal speed was achieved using a Kubota T30 tiller in the 3rd gear at low throttle.

Traction tests at 10 RPM (Fig. 5) showed 3.92% average slippage, confirming reliable traction and seed placement in field conditions. Traction was evaluated by measuring slippage at 10 RPM ground wheel speed. Slippage was calculated by comparing travel distances on concrete (9.384 m) and field soil (9.016 m) across five trials. Slippage ranged from 3.73% to 4.25%, averaging 3.92%, indicating reliable traction and accurate seed spacing under field conditions.

Table 3 Tukey's HSD test results for pairwise comparisons of slippage data

Source	SS	*df*	MS	F	Prob >*F*
Groups	93.6189	2	46.8094	2885.9	7.9763e-17
Error	0.1946	12	0.0162		
Total	93.8135	14			

HSD – honestly significant difference; SS – sum of squares; dF – degrees of freedom; MS – mean square; F – Fisher statistic

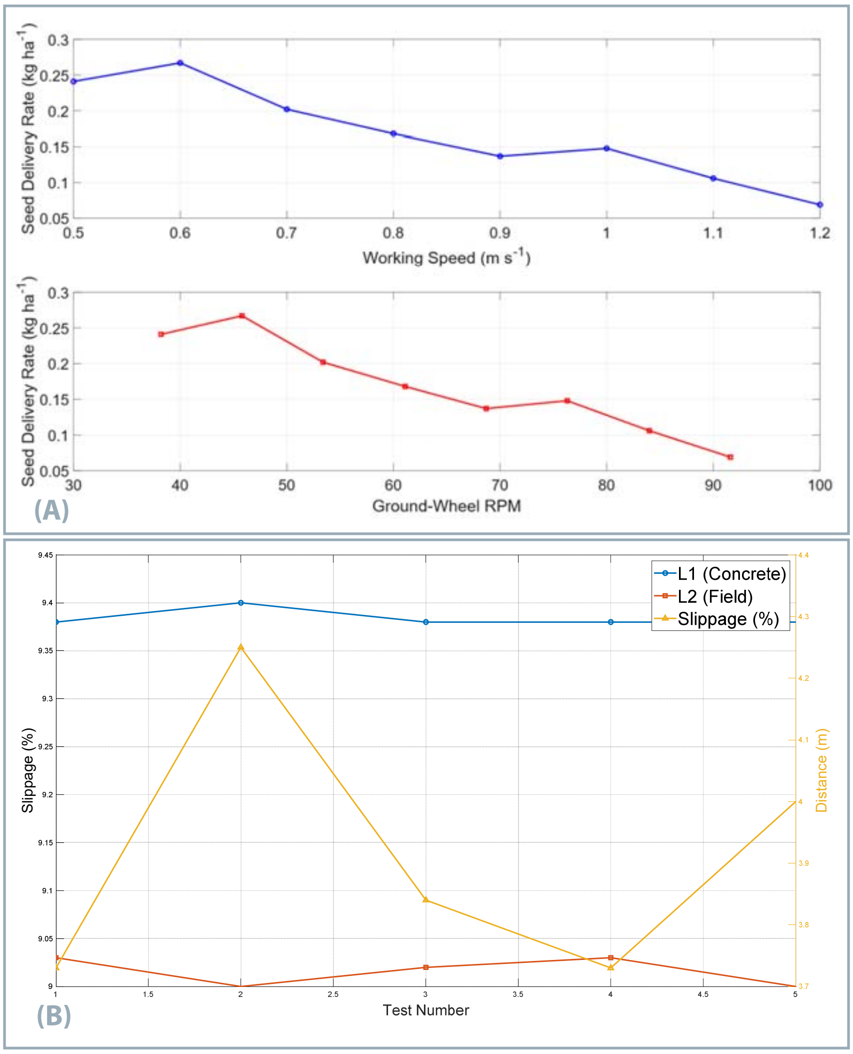

Fig. 5 (A) Seed delivery rate as a function of working speed and ground-wheel RPM; (B) Comparison of travelling distances and slippage rate for the ground wheel at 10 RPM

Table 3 shows ANOVA results comparing distances and slippage, with a highly significant F-value of 2885.9 and p-value of 7.98×10^{-17}, confirming that surface conditions significantly affect machine performance.

Table 4 summarises pairwise analyses, revealing significant differences between distances on concrete (L_1) and field (L_2) (p = 0.0017), as well as between both L_1 and slippage, and L_2 and slippage (p <0.0001). These findings confirm that surface conditions significantly impact travel distance, traction, and machine mobility.

The machine showed efficient traction with an average slippage of 3.92%, well below the 5% limit recommended by RNAM (1991). Steel lugs on the drive wheels enhanced traction, and no slippage on concrete confirmed its reliability as a baseline. The cabbage seeder with press wheels (Fig. 6) maintained a consistent sowing depth of 6.6 mm and an average germination rate of 61% (Table 5). Row 4 had the highest germination (85%), while Row 2, sown deeper at 8.3 mm, had the lowest (30%), demonstrating the effect of sowing depth on emergence. Despite some mechanical issues like seed lodging and tube misalignment, the seeder was user-friendly and suitable for small-scale farming. Similar problems noted by Younis et al. (2020) could be addressed

Table 4 Tukey's HSD test results for pairwise comparisons of slippage data

Group 1	Group 2	Difference	Lower limit	Upper limit	*p*-value
1 (L1)	2 (L2)	0.1531	0.3680	0.5829	0.0017
1 (L1)	3 (slippage)	5.2591	5.4740	5.6889	0.0000
2 (L2)	3 (slippage)	4.8911	5.1060	5.3209	0.0000

HSD – honestly significant difference

Table 5 Field test results (with press wheels)

Row number	Number of germinated seeds	Number of missing hills	Germination (%)	Sowing depth (mm)	Hill distance (cm)	Plant height (mm)
1	14	6	70	6.3	48.1	51.0
2	6	14	30	8.3	48.2	42.0
3	12	8	60	5.3	48.3	41.0
4	17	3	85	6.0	44.4	44.4
5	13	7	65	6.7	46.4	42.2
6	11	9	55	7.0	48.6	44.2
Average	12.0	8.0	61.0	6.6	47.3	44.1
SD	3.34	3.34	16.69	0.93	1.49	3.30

Fig. 6 Field test comparison with and without press wheels installed

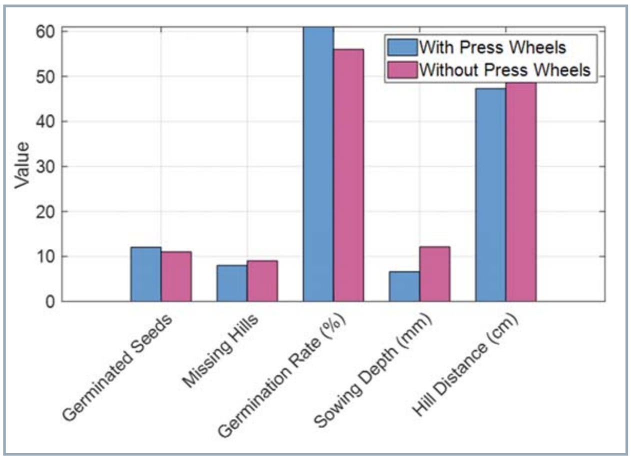

Fig. 7 Comparison of seeder performance with and without press wheels

by adding hopper vibrators or improving the seed drop guide.

Field tests showed that press wheels (Fig. 7) enhanced seeder performance, achieving 61% germination and a consistent sowing depth of 6.6 mm, which improved early growth. Without press wheels (Table 6), germination dropped to 56%, sowing depth rose to 12.1 mm, and plant height decreased, underscoring their importance for small-scale farming. De Mello Prado et al. (2001) reported that increased soil compaction led to higher seedling emergence rates, with a press wheel load of 147.10 N producing greater vigour than sowing without compaction.

ANOVA results (Table 7) indicate sowing depth is significantly influenced by experimental conditions ($p = 1.5 \cdot 10^{-7}$). However, germination rate, missing hills, and plant height showed no significant differences (p >0.05). This highlights the critical role of sowing depth calibration, while other factors like hill spacing and growth are less affected.

Tukey's post hoc test revealed significant differences between treatments with and without press wheels in germination rate (p = 0.032), sowing depth (p = 0.015), and number of germinated seeds (p = 0.024) (Table 8). No significant differences were found in hill distance (p = 0.432) or plant height (p = 0.080). Press wheels enhanced seeder performance by improving germination, reducing missing hills, and ensuring shallower sowing depths.

ANOVA results in Table 9 show significant differences (p <0.05) among treatments for all variables: germinated seeds (p = 0.024), missing hills (p = 0.037), germination rate (p = 0.001), sowing depth (p <0.001), and hill distance (p <0.001). This indicates at least one treatment group differs significantly for each variable.

Table 6 Field test results (without press wheels)

Row number	Number of germinated seeds	Number of missing hills	Germination (%)	Sowing depth (mm)	Hill distance (cm)	Plant height (mm)
7	10	10	50	9.3	46.0	49.2
8	15	5	75	12.3	48.5	38.0
9	13	7	65	13.3	47.1	38.0
10	10	10	50	12.7	51.6	41.4
11	9	11	45	13.5	49.0	40.4
12	11	9	55	12.3	50.2	34.2
13	10	10	50	11.3	48.2	39.0
Average	11.0	9.0	56.0	12.1	48.6	40.0
SD	1.96	1.96	9.79	1.33	1.73	4.29

Table 7 ANOVA results for various planting parameters and their statistical significance

Dependent variable	*F*-statistic	*p*-value	Significant difference (p <0.05)
Number of germinated seeds	0.6	0.45	no
Number of missing hills	0.38	0.55	no
Germination (%)	0.49	0.5	no
Sowing depth (mm)	106.8	$1.5 \times 10–7$	yes
Hill distance (cm)	2.36	0.15	no
Plant height (mm)	3.58	0.09	no

Table 8 Tukey's post hoc test results for field test (with press wheels vs without press wheels)

Parameter	Comparison	p-value	Significance ($\alpha = 0.05$)
Germination rate (%)	with press wheels vs without press wheels	0.032	significant
Sowing depth (mm)	with press wheels vs without press wheels	0.015	significant
Number of germinated seeds	with press wheels vs without press wheels	0.024	significant
Hill distance (cm)	with press wheels vs without press wheels	0.432	not significant
Plant height (mm)	with press wheels vs without press wheels	0.080	not significant

Table 9 ANOVA results for variables related to sowing ($\alpha = 0.05$)

Variable	*p*-value	Significance
Germinated seeds	0.024	significant
Missing hills	0.037	significant
Germination rate (%)	0.001	significant

Conclusion

The average seed delivery rate was 0.1673 kg·ha^{-1} (SD = 0.0669), ranging from 0.0690 to 0.2670 kg·ha^{-1}, with half the data within a 0.1000 kg·ha^{-1} range, showing consistency. The highest rate (0.267 kg·ha^{-1}) occurred at 0.6 m·s^{-1}, the chosen field speed to reduce seed loss, while higher speeds decreased delivery. Ground wheel slippage averaged 3.92%, indicating good traction. Made from readily available materials, the seeder suits small-scale farmers and can be adapted to other crops via simple roller changes. Shallower sowing improved germination (Rows 1–6), whereas variability in Rows 7–13 underscores the need for precise depth and moisture control. Press wheels enhanced germination and depth uniformity but did not affect seed count, hill spacing, or germination frequency.

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