



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(3): 196-200
Received: 11-12-2025
Accepted: 17-01-2026

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Performance evaluation of bullock drawn five row seed cum fertilizer drill

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i3Sc.5106>

Abstract

Seed sowing is a critical operation influencing crop establishment and yield. In Odisha, smallholder farmers largely depend on traditional broadcasting methods, which often result in non-uniform seed distribution, improper seeding depth, and excessive seed rates, leading to poor crop stands. Bullock-drawn seed drills provide an appropriate alternative for small and fragmented landholdings due to their low cost, fuel-free operation, and lightweight design that minimizes soil compaction and preserves soil health. This study evaluated the field performance of a bullock-drawn five-row seed cum fertilizer drill. The implement achieved an actual field capacity of 0.212 ha h⁻¹ at an average operating speed of 2.172 km h⁻¹, with an average seed placement depth of 2.53 cm. Field efficiency was recorded as 78.08%, with a power requirement of 0.4 hp and a seed rate of 41.67 kg ha⁻¹. The standard deviation of seed distribution among seed tubes was 2.177, indicating satisfactory uniformity. The results confirm that bullock-drawn seed cum fertilizer drills offer an efficient and sustainable solution for improving sowing precision in small-scale farming systems of Odisha.

Keywords: Bullock drawn seed drill, actual field capacity, field efficiency, seed distribution

Introduction

Seed drills are important agricultural implements that deliver uniform seed metering, precise placement at desired depths, and optimal spacing, improves germination rates, crop establishment, and yields. In tribal areas of Odisha, hilly, and rainfed regions, small and marginal farmers with fragmented, irregular landholdings depend heavily on bullock-drawn seed drills. Tractor-operated alternatives prove impractical due to uneven terrain, poor road access, and high costs, while traditional broadcasting and manual sowing remain labour-intensive, yielding uneven distribution and poor fertilizer efficiency. The animate power usage has declined from 92.3% in 1960–61 to 11.8% in 2013–14, bullock-drawn tools persist as lightweight, economical options well-suited to these constraints.

Commercially available mechanized seed-cum-fertilizer drills are not affordable and adaptable for small fields, and existing bullock-drawn models typically single-row without fertilizer mechanisms less efficiency and adoption. In this study efforts were made to develop and evaluate a multi-crop, five-row bullock-drawn seed-cum-fertilizer drill to enable simultaneous sowing and fertilization, enhancing input use, reducing drudgery, and fitting animal draught limits.

The scope involves comprehensive laboratory calibration to optimize metering mechanisms, furrow openers, and seed tubes under controlled conditions, followed by rigorous field trials diverse soils. Performance evaluation will quantify seed and fertilizer placement, operational metrics like theoretical and effective field capacity, draft requirements, slippage, and fuel-equivalent animal energy use, alongside adaptability in wet/dry conditions. Additionally ergonomic factors evaluation such as ease of operation, labour hours per hectare compared to manual methods, maintenance simplicity, and economic feasibility through cost-benefit analysis done, including payback period and net returns for smallholders tilling 0.5–2 ha.

Klocke (1979) [8] tested experimental planters with varied coulters under moist soils; Kumar *et al.* (1986) developed animal-drawn attachments with high capacity and low damage; Gupta and

Herwanto (1992) ^[4] achieved efficient paddy seeding for soaked grains; Ladeinde and Verma (1994) ^[9] reduced fatigue via improved designs; Molin and D'Agostin (1996) ^[10] enhanced accuracy in tough terrains with rolling planters; Bamgboye and Mofolasayo (2006) ^[2] reported strong efficiency in two-row manual models; and Shelke (2011) ^[15], Raut *et al.* (2013) ^[13], Ramesh and Kumar (2014) ^[12], and Sawalakhe *et al.* (2015) ^[14] advocated precision mechanization amid labor shortages. Despite these, research on multi-row bullock-drawn seed-cum-fertilizer drills remains sparse, particularly for multi-crop versatility (e.g., paddy, pulses, millets), performance in rain-fed hilly zones, lightweight durable materials, and integration of fertilizer bands without exceeding bullock draught (typically 200–400 kg). This study addresses these voids by evaluating a five-row prototype tailored to Odisha's smallholder systems, fostering sustainable mechanization, input conservation, and productivity gains.

Review of Literatures

Previous research has demonstrated continuous efforts to improve the design and performance of seed sowing equipment. Klocke (1979) ^[8] evaluated experimental planters with different coulter designs and reported satisfactory performance under adequate soil moisture conditions. Kumar *et al.* (1986) developed an animal-drawn seeding attachment that showed good field capacity and minimal seed damage. Gupta and Herwanto (1992) ^[4] designed a direct paddy seeder with high field capacity and negligible seed damage for soaked seeds, while Ladeinde and Verma (1994) ^[9] reported reduced operator fatigue when using improved planters compared to traditional methods. Molin and D'Agostin (1996) ^[10] demonstrated improved planting accuracy and reduced labor requirements using rolling planters in difficult field conditions. Bamgboye and Mofolasayo (2006) ^[2] observed satisfactory field efficiency and

low seed damage in a manually operated two-row planter. Shelke (2011) ^[15] emphasized the growing importance of bullock-drawn planters due to labor shortages, while Raut *et al.* (2013) ^[13] highlighted the role of mechanization in enhancing productivity through precision and input conservation. Reviews by Ramesh and Kumar (2014) ^[12] and Sawalakhe *et al.* (2015) ^[14] further emphasized the need for efficient, crop-specific, and sustainable sowing technologies.

Materials and Methods

The seed drill consisted of a main frame fabricated from galvanised iron, designed to withstand operational loads and support all functional components, including the ground wheel and beam. The seed metering mechanism was powered by the ground wheel through a chain and sprocket arrangement and employed a cup-type, poly-vinyl chloride metering device to ensure uniform seed delivery. Rotary motion was transmitted to the sowing shaft inside the fibre-reinforced plastic seed box, which had a rectangular cross-section and a mild steel cover, allowing adjustable seed discharge as crop requirement. A ground wheel of 46cm diameter fitted with twelve mild steel pegs of 10cm height provided drive to the metering system. Seeds were conveyed through transparent, flexible PVC seed tubes (45 mm diameter and 3 mm thickness) to hoe-type furrow openers made of high-carbon steel (0.5% carbon, 4mm thickness), with adjustable row spacing. Two adjustable transport wheels mounted on the axle facilitated movement and controlled seeding depth, ensuring uniform seed placement under varying soil conditions. A centrally mounted hitching unit fabricated from mild steel hollow pipes allowed adjustment of the angle of pull according to bullock height, while a handle was provided to lift the ground wheels during transport and to cut off seed flow during headland turns, thereby preventing seed wastage.



Fig 1: Calibration of seed drill



Fig 2: Field testing of seed drill

Table 1: Specification of five-row bullock drawn seed drill

Sl. no.	Components	Dimensions/Size/Type
1	Overall dimensions	
	Length, mm	3100
	Width, mm	1500
	Height, mm	1500
2	Number of furrow openers:	5
3	Type of furrow openers:	Hoe type
4	Seed metering mechanism:	Cup type
5	Row spacing, mm:	250
6	Details of ground wheel	
	Diameter, mm	460
	Number of spokes	12
	Peg height	100
	Fabricated material	Mild steel
7	Detail of seed box	
	Material used for seed metering disc	Fibre reinforced plastic
	Type of seed delivery box	Gravity type
	Number of boxes	1+1(Seed & fertilizer)
	Shape	Rectangular
	Dimension, mm	290×280
	Disc spacing, mm	50
8	Chain	
	Length, mm	1680
	Pitch, mm	13
	Sprocket	
	Number of sprockets	2
	a. Sprocket 1	18
	b. Sprocket 2	12
9	Gear:	4
10	Total seed box capacity, cm ³ :	6,000
11	Weight, Kg:	70
12	Power source, hp:	1 pair of bullocks

Results and Discussions

Laboratory calibration of the five-row bullock-drawn seed-cum-fertilizer drill was conducted to determine the precise seed rate and metering accuracy under controlled conditions. The nominal width of coverage was calculated as the product of row spacing ($s=0.25$ m) and number of rows ($n=5$), $s \times n=1.25$ m. The drive wheel circumference (CC) was derived from its effective diameter ($D = 0.36$ m) as $C = \pi \times D = 1.131$ m.

To dispense seeds equivalent to 1/100th of a hectare (100 m²), the required wheel revolutions (N) were computed using the formula:

$$N = \frac{1000}{C \times s \times n \times 100} = 70.734 \approx 71 \text{ revolutions}$$

Accounting for 10%-wheel skid, the adjusted revolutions (N1) became

$$N1 = 71 - (0.1 \times 71) = 63.9 \approx 64 \text{ revolutions}$$

For N1 revolutions, the total seed weight collected (W1) across all tubes was 460.58 g (0.46058 kg), corresponding to an observed seed rate (R) of:

$$R = 100 \times W10.01 = 100 \times 0.46058 = 46.058 \text{ kg/ha}$$

Seeds were individually collected from each of the five seed tubes to assess metering uniformity, with detailed observations presented in Table 2.

Table 2: Uniformity of seed dropping

Seed tube no.	Weight of seed collected, (g)	Deviation
1	10.89	2.07
2	9.80	3.16
3	15.06	2.10
4	14.29	1.33
5	14.76	1.80
Total	64.80	
Average	12.96	

Standard deviation = 2.177

The variation in quantity dropped per hectare and quantity specified to be dropped at a particular setting shall be not more than 7 for seeds (IS code: 6316-1993) [5]. Thus, setting up of the five-row seed drill was found to be acceptable according to IS code.

For a distance of 10 m considering the average speed of bullock as 2 km/h, the following data were recorded in table-3.

Table 3: Calibration data

Trial No.	Time, (s)	Weight, (g)
1	22	66.6
2	19	65.6
3	21	64
4	18	64.8
5	17	63

Average time = 19.4 s; Average weight = 64.8 g;

Data collected during the test of bullock drawn seed drill in the field is shown in the following table-4.

Table 4: Field test data

Pass no.	Time interval, (s)	Distance, (m)	Speed of operation, (m/s)	Width covered in one lap, (m)	Depth of furrow, (cm)
1	52	30	0.58	1.25	2.3
2	50	30	0.6	0.92	2.8
3	45	30	0.67	0.95	3
4	49	30	0.61	0.98	2.1
5	53	30	0.57	0.97	2.6
6	51	30	0.59	1.10	2.4

Field trials for the five-row bullock-drawn seed-cum-fertilizer drill were performed on a rectangular plot measuring 30 m in length and 20 m in width, covering an area of 600 m² (0.06 ha). The test run commenced at 9:30 AM and concluded at 9:47 AM, totalling 17 minutes (0.283 h) of operation. The implement operated at an average speed of 0.603 m/s (equivalent to 2.172 km/h), achieving a seed sowing depth of 2.53 cm with the dynamometer inclined at 8°. Performance metrics, including theoretical field capacity (TFC), effective field capacity (EFC), field efficiency, power requirement, and seed rate, were calculated as follows.

Theoretical field capacity (TFC) = (WS)/10 = (1.25×2.172)/10 = 0.2715 ha/h;

Effective field capacity (EFC) = A/T = 0.06/0.283 = 0.212 ha/h;

Field efficiency (%) = (EFC/TFC) × 100 = (0.212/0.2715) × 100 = 78.08%;

Power requirement (P) = (Draft × Speed)/75 = (50 × cos 8° × 0.603)/75 = 0.4 hp;

Seed rate (kg/ha) = Weight of seed sown / Area = 2.5/0.06 = 41.67 kg/ha.

The laboratory calibration indicated an observed seed rate of 46.058 kg/ha, aligning with the recommended 40–60 kg/ha range, while distribution uniformity was confirmed by a standard deviation of 2.177, keeping variation within the IS 6316-1993 permissible limit of 7%. Field trials demonstrated a field efficiency of 78.08% at an average speed of 2.172 km/h, though this efficiency may naturally decline in larger fields due to animal fatigue. The implement achieved an optimal sowing depth of 2.53 cm for direct-seeded paddy with a power requirement of 0.4 hp, well within the draft capacity of a bullock pair, although the actual field seed rate slightly decreased to 41.67 kg/ha due to slippage and varying soil resistance. While the drill proves beneficial for sustainable, zero-till farming by eliminating fossil fuel dependency and reducing soil compaction, operational challenges such as clogging in moist, weedy conditions and tine breakage in stony soils highlight the need for design improvements, including the adoption of disc openers and boron steel components. Furthermore, the absence of a furrow closer resulted in exposed seeds, necessitating the addition of a covering mechanism to prevent predation and ensure uniform crop establishment.

Conclusion

Laboratory calibration of the five-row bullock-drawn seed-cum-fertilizer drill observed seed rate of 46.058 kg/ha, which falls within the recommended range of 40–60 kg/ha for target crops, while field trials registered an actual rate of 41.67 kg/ha owing to variables such as soil moisture, wheel slip, and operational speed. Seed distribution uniformity across rows demonstrated compliance with IS 6316-1993 standards, exhibiting a standard deviation of 2.177 g and variance of 4.74% (less than 7% variation), confirming reliable metering performance under both controlled and real-world conditions. The implement delivered a field efficiency of 78.08% (effective field capacity: 0.212 ha/h; theoretical field capacity: 0.2715 ha/h) at an average forward speed of 2.172 km/h optimal for bullock traction without

excessive fatigue while achieving a consistent sowing depth of 2.53 cm suitable for paddy establishment. Power demand remained modest at 0.4 hp, well within the capacity of a single bullock pair (~1 hp), underscoring the drill's lightweight design and economic viability for smallholders. Particularly well-adapted to sandy soils and zero-till systems, the prototype promotes soil conservation, residue retention, and reduced emissions; however, operational challenges including weed interference, clogging in wet soils, and tine wear in rocky terrains could be resolved through upgraded materials like boron steel tines or heat-treated components.

Acknowledgement

The authors acknowledge the financial, technical, and research facilities provided by ICAR- All India Coordinate Research Project on Mechanization of Animal Husbandry (AICRP on MAH) and Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India for the successful completion of the research study.

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