Open Access
Volume 5 Issue 2
Research Article

Journal of Water Engineering and Management
ISSN: 2582-6298

Design, Development and Performance Evaluation of Manually Operated Groundnut Planter

Mohd Ahamad[1], Babban Yadav[1]

[1]Department of Farm Machinery and Power Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture, Technology & Sciences Prayagraj (U.P.), India

Article Info

Article History:
Received on: March 12, 2024
Revised on: July 28, 2024
Accepted on: September 25, 2024
Published on: September 30, 2024

Published by Academic Hope

Corresponding author: Babban Yadav
Email: babban.yadav@shuats.edu.in

How to Cite:
Ahamad, M. and Yadav, B. 2024. Design, Development and Performance Evaluation of Manually Operated Groundnut Planter, Journal of Water Engineering and Management 5(2):1-8. DOI:https://doi.org/10.47884/jweam.v5i2pp01-08

Abstract

Groundnut is one of the key food crops for human and animal consumption and raw materials in industries. In this work, a manually operated groundnut planter was designed to require less operating force to reduce the seed damage and missing rates. During the laboratory calibration, the average seed rate in the planter was 66.40 kg/ha. The mean percentage of seed damage assessed from the planter is 0.45%, indicating the gentleness of the seeds during its operation. Minimum and maximum variations in the seed spacing are 19.4 cm and 19.7 cm, respectively, which is considered reasonable spacing. In addition, the missing index, which is a measure of the percentage hills where seed was missing, was 2.7% and 4.3% respectively for 1.5 km/h and 2.5 km/h forward speed, which gave better performance at lower operating speeds. Field testing of the manual groundnut planter showed satisfactory performances. Its mean seed rate was 65.08 kg/ha, while the missing index was 3.67%. The theoretical and actual field capacities recorded were 0.09 ha/h and 0.077 ha/h, respectively, with a field efficiency of 86.57%. The depth of seed placement, which fell within 4.1 cm, is appropriate for planting groundnut. It was also found that use of this equipment was easy, both for males and females, which shows its practical utility for smallholder farmers. A manually operated groundnut planter has been fabricated with locally available materials; hence, it was relatively inexpensive and simple to construct. Its lightweight and ergonomic design means the planter requires very little effort to operate, and a single person can handle it comfortably. This also means the simplicity of its mechanism will be easy to use, maintain, and suitable to be used by a small-scale farmer. Overall, the planter offers an affordable and practical solution aimed at improving sowing efficiency in groundnut cultivation.

Keywords: Groundnut seeds: Groundnut planter: Seed metering plate: Field efficiency.

Introduction

Groundnuts (Arachis hypogea), sometimes referred to as peanuts or earthnuts, are a valuable source of protein for diets when meat is not available. It is the third most widely grown oilseed worldwide, and it has contributed significantly to the economies of Nigeria and other African nations over the years. With Gujarat, Tamil Nadu, Andhra Pradesh, Maharashtra, Karnataka, and Rajasthan among the top producing states, groundnuts are essential to India's oil industry (ICAR, 2020). According to Patil and Ghewande (2011), groundnut kernels have 26% protein and 45% oil. After being harvested, the nuts are crushed to extract the kernels. While a greater portion of the kernels are used to make vegetable oil, some are eaten when roasted. In terms of metric tonnes produced, the oil ranks as the sixth most significant vegetable oil globally. Approximately 25% of the world's oil production, or 1,117,758 tonnes, came from Africa alone in 1997.

During designing and developing equipment for harvesting, handling, processing, and storage, the physical characteristics of groundnut seeds such as mass, size, shape, surface area, volume, aspect ratio, sphericity, true density, bulk density, porosity, and angle of repose are crucial considerations (Abioye et al., 2016). For sorting, grading, and other separation procedures, characteristics like mass, size, and shape are especially crucial (Zare et al., 2013). The angle of repose and the frictional characteristics between the seeds and bin wall materials affect structural load considerations in storage systems (Burubai and Amber, 2014).

Planting is among the most labor-intensive tasks in cultivating grains like maize, millet, and sorghum, as well as pulses such as groundnut, and soybean. Traditionally performed using basic tools or even by hand or heel planting is often done by women and children, many of whom may lack the skills for accurate seed placement and soil coverage. This manual process is inefficient, causes physical strain due to continuous bending, and ultimately reduces labor productivity. Manually operated planters are essential for smallholder farmers who often face financial limitations and have restricted access to mechanized equipment. These affordable, user-friendly tools improve planting accuracy, reduce labor demands, and support sustainable agriculture by operating without external power. Typically, lightweight and made from locally available materials, they combine seed metering, soil opening, and covering in one operation. Features like adjustable seed rates and ergonomic handles enhance usability and adaptability (Chukwu and Iwueke, 2020).

Accurate control over planting depth, ideal row spacing between seeds, and uniform germination conditions for all seeds are all components of precision planting. It minimizes seed bounce within the furrow, guarantees uniform seed distribution, and stops overuse and scattering of seeds. For smallholder farmers who have limited access to mechanized equipment, the manually operated planter is an affordable tool. By combining seed placement, soil opening, and covering in a single operation, it increases efficiency, decreases labor and physical strain, and improves planting accuracy. Better crop establishment is encouraged, and small-scale, sustainable farming is supported. Muhammad et al. (2015) investigated the design and optimization of machinery for handling, processing, and storing groundnuts. Numerous other studies have been conducted on manually operated seed-cum-fertilizer soybean planters (Kumar and Tripathi, 2017), multi-crop inclined plate planters (Nandini et al., 2018), and manually controlled single and two row multi-crop planters (Khan et al., 2015; Sedara et al., 2020; Singh and Moses, 2021; Karunyaa et al., 2024). In light of these, the current study aims to investigate the physical characteristics of groundnut seeds that are pertinent to planter design as well as the creation, advancement, and performance assessment of manually operated groundnut planters.

Materials and Methods

The Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture, Technology, and Sciences, Prayagraj, Uttar Pradesh, Department of Farm Machinery and Power Engineering, conducted tests on the developed planter. Measurements were made of the groundnut seeds' length, width, and thickness as well as their physical characteristics, including size, shape, sphericity, surface area, bulk density, true density, porosity, angle of repose, and coefficient of static friction, in order to design the manual planter. The calculation of sphericity, which measures how closely a seed's shape resembles that of a sphere, was done by considering the seed to be a tri-axial ellipsoid with axes for length (l), width (b), and thickness (t). The diameter of the circumscribing sphere was taken as the largest axis.

Degree of sphericity $(\varphi) = {D_g}/{L}$ (1)

D_g= Geometric mean diameter

The inclined plane method was used to calculate the coefficient of static fraction of groundnut seeds on a mild steel surface. On a level surface with a steadily rising slope, the seed was kept apart. The angle at which the items started to slip was noted. The following formula was used to calculate the static friction coefficient.

Coefficient of static friction (μ) = tan Φ (2)

Φ = Angle of static friction, degrees.

The average value Φ for the seed was calculated independently after the process was repeated three times. A test weight of 1,000 groundnut seeds was weighed using an electronic digital weighing balance. Using the oven-drying method, the moisture content of groundnut seeds was ascertained. The initial weights of the samples were measured using an electronic balance. After being dried for 24 hours at 105°C in a hot air oven in triplicate, the samples were weighed every 6 hours until they reached a consistent weight. The formula was used to determine the moisture content on a wet basis.

$$MC(\%) = \frac{W_w - W_d}{W_w} \times 100 \quad (3)$$

MC = Moisture Content
W_w = Weight of wet sample
W_d = Weight after drying

Design, and Development of Manually Operated Planter

The manually operated planter was designed to perform four key field operations: furrow opening, seed metering, seed placement in hills, and covering and compacting soil over the seeds. These functions ensure accurate seed spacing, proper depth, and good soil–seed contact for better germination and uniformity of crop establishment. The planter was designed with simplicity, safety, and affordability in mind. All its components were made in the most basic way to facilitate easy construction, use, and maintenance. It was also made safe for operation and user-friendly so it could be handled without discomfort by both male and female farmers, especially in rural settings. Materials used were selected on the basis of local availability and cost for making the machine practical and economical for small-scale agricultural purposes.

The planting mechanism consists of a vertical seed plate with spoons, driven by the ground wheel through a chain and sprocket system. During operation, one person pulls the planter with a rope from a hook, while another guide using the handle. The forward travel of the planter rotates the ground wheel, which in turn transmits the motion to a vertical plate inside the seed hopper. The spoons revolving with the plate pick up the seeds and drop them into a small hopper connected to the furrow opener with a delivery tube. The seeds fall into the furrow opened by the opener. Plant-to-plant spacing is varied by changing the number of spoons on the vertical plate. Interchangeable spoons for peas, groundnut, sunflower, maize, and soybean are available.

The expression given by Campbell et al. (1990) can be used to estimate the power of useful work delivered by a human operator.

$$HP = 0.35 - 0.092 \log(t) \quad (4)$$

where, t = Time in minutes

Now, to operate the manually operated planter for 3-4 hours continuous work the power developed by the operator would be 0.10-0.13 hp (0.11hp). We also know that

$$HP = \frac{Push(kgf) \times speed(m/s)}{75} \quad (5)$$

Let the operating speed of machine be 0.8 m/s i.e. about 2.9 km/h

Push (kgf) = (HP x 75)/speed (m/s) =0.11 × 75/0.8 = 10.5 kgf.

In order to select the size of manually operated seed planter, we use following formula.

$$Z = D / d$$

Z = number of furrow openers in the planter
D = draft of planter, kgf (12-15 kgf for shallow depth)
d = draft of each row, kgf

Working width of the machine would be

$$W = Z \times A$$

W = Working width of machine, cm
Z = Number of furrow openers in the planter, and
A = Row to row distance, cm (depends on type of crop sown)

Trapezoidal shape of seed boxes is generally used in the machine for free flow of seed in hopper bottoms (Sharma and Mukesh, 2013).

Volume of seed box, $V_b = 1.1V_s$ and $V_s = W_s/\gamma_s$

V_b = Volume of seed box, cm^3
V_s = Volume of seed, cm^3
W_s = Weight of seed in the box, g
γ_s = Bulk density of seed g / cm^3

Using above dimension of box, its volume will $V_A + V_B$, where V_A = Volume of section 'A' of box and V_B = Volume of section 'B' of box

Seed metering roller (having triangular cells) are used for the machine (Sharma and Mukesh, 2013). Number of cells in the roller is calculated by

$$N = \pi D / I \times X \quad (6)$$

N = Number of cells on roller
D = Diameter of ground wheel, cm
I = Gear ratio (1:1)
X = Seed to seed spacing, cm (20 cm, groundnut crop)

Diameter of seed roller is determined by the following equations.

$$d_r = V_r / \pi N_r \quad (7)$$

d_r = Diameter of seed roller, cm
V_r = peripheral velocity of roller (16.5 m / min. assumed for minimum seed breakage)
N_r = RPM of the roller (50-60 rpm)

The chain length is calculated by following equation.

$$m = 2C / p + (Z_1 + Z_2) / 2 + (Z_1 - Z_2)^2 / 2 \pi p \quad (8)$$

m = number of chain links
C = center to center distance b /w two sprocket, mm
Z_1 = number of teeth in driver pulley
Z_2 = number of teeth in driven pulley
P = chain pitch, mm

A standard light weight M.S. 27.5 mm outside diameter conduit pipe is used for handle of the tool carrier. Length of handle is calculated based on average standing elbow height of female operators (Sharma and Mukesh, 2013).

Average standing elbow height of women workers = 100 cm.
Distance of wheel center from the operator (for operator height of 95 – 105 cm) in operating condition = 115 cm.
Therefore, angle of inclination (θ_h) with the horizontal

$$\tan(\theta_h) = 80 / 115 = 0.696$$
$$(\theta_h) = 34.82^0 \text{ say } 35^0$$
$$\sin(\theta_h) = 80 / l_h$$

l_h = length of handle
$l_h = 80 / \sin 35^0 = 80 / 0.5735 = 139.49$ cm or 140.0 cm.
So, in order to accommodate 5 – 95 % of operator, a 27.5 mm outer diameter conduit pipes of 140 cm long are used for handle whose operating height can be adjusted from 95 cm to 105 cm from the ground. A plastic handgrip of 27.5 mm outer diameter, 215 mm long is fitted at the end of conduit pipes for easy grip and operation of the machine.
Distance of draft application on furrow opener tyne,

$$a = h / 3$$

Moment arm length = (h - a)
Bending moment in tyne = D. (h - a)
Take factor of safety = 2
Therefore, maximum bending moment in tyne = B.M × F.O.S
M.S. flat tyne is used in planter ($f_b = 56$ N / mm^2 for mild steel)
Section modulus of tyne (Z) = M_b / f_b

$$Z = (1 / 6)\, t\, b^2 \text{ (for rectangular section)}$$

Testing of Developed Manually Operated Groundnut Planter

The performance of the developed manual groundnut planter, depicted in Figure 1, was assessed using the Indian Standard test codes IS: 11271-1985 and IS: 6316-1993. The following tests were part of the evaluation process to determine the manually operated groundnut sowing planter's field applicability and functional efficiency. The test was carried out at SHUATS, Prayagraj, in the Department of Farm Machinery and Power Engineering (FMPE) laboratory. Following the creation of the manually operated groundnut planter, the accuracy of all specifications was confirmed. Each component's materials are displayed in Fig. 5.
Additionally, the planter was visually inspected and modified as needed. The planter was set up in a level spot. Under the frame, bricks were placed so that the ground wheels could spin freely. For the purpose of collecting seeds, the lower end of the seed tube was marked with a poly bag. The ground drive wheel rotated 50 times and had a chalk mark at one spot. A fictitious calculation was made to determine the area covered by the groundnut in 50 revolutions. At the VIAET farm machinery and power engineering laboratory in SHUATS, Prayagraj, the quantity of seed gathered in the tagged bag was weighed using an electronic digital balance.
The number of revolutions was calculated to cover one ha land. Seed rate was calculated as follows:
Seed Rate (kg/ha) = Wt. of collected seeds (g) in 50 rev. × No. of rev. of drive wheel required to cover 1 ha / 50 × 1000. During the calibration process, the metered seed was taken in five replications, labeled five samples for the assessment of damaged seed, and weighed using a digital balance. Every sample was manually inspected and selected to check for obvious seed damage.

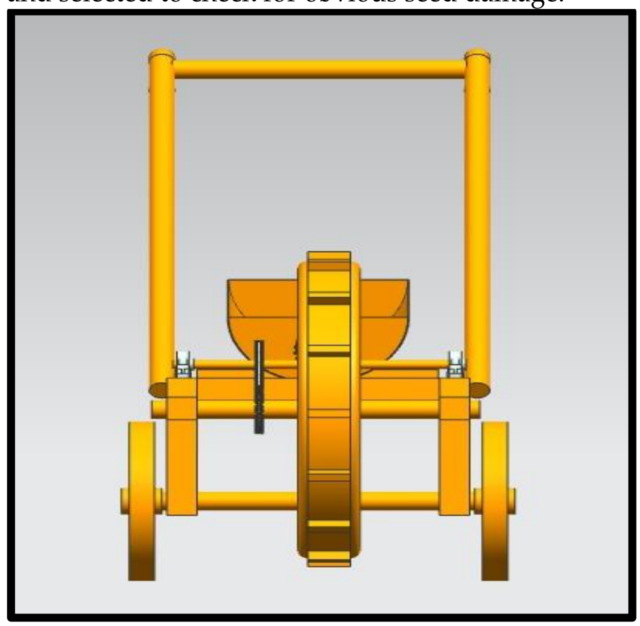

Fig. 1 3D Design Front view of planter

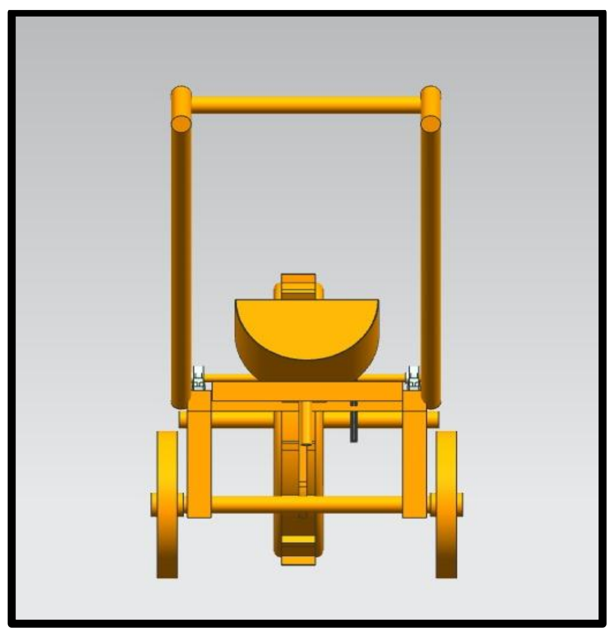

Fig 2. 3D Design Back view of planter

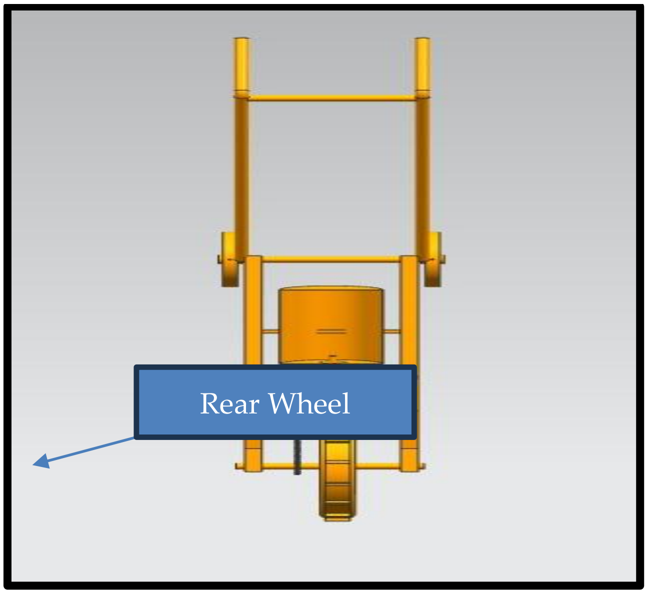

Fig. 3 3D Design Top view of planter

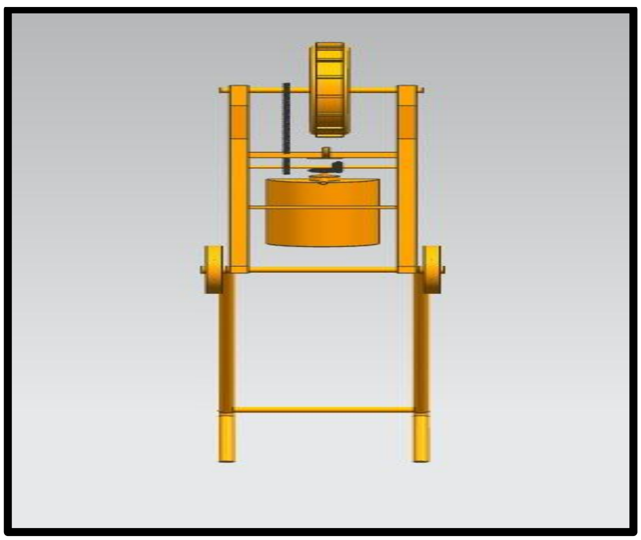

Fig. 4 3D Design Bottom view of planter

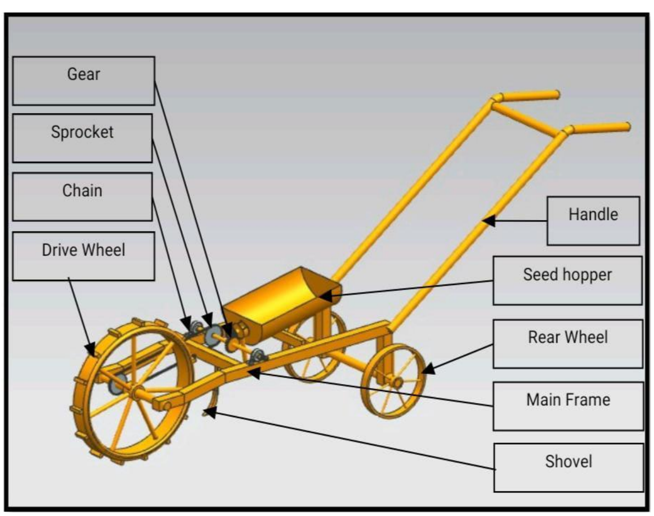

Fig. 5 3D Design Isometric view of planter

After being removed from the seed tube for obvious damage, the damaged seeds were also weighed on a digital balance. The groundnut seed was the subject of the test.

$$Seed\ damage\ percent = \frac{Weight\ of\ damaged\ seeds, g}{Total\ weight\ of\ seed\ sample\ after\ calibration, g} \times 100$$

The purpose of this test was to verify that the seed's metering was consistent. The sand bed method was employed for this. An artificially leveled fine sand bed measuring 25 cm in depth, 10 revolutions of ground drive wheel length, and 1.5 meters in width was prepared. With seed tubes or furrow openers lowered as close to the top surface of the bed as feasible, the planter was permitted to pass over this bed. For every meter of bed length, the average distance between two seeds as well as the quantity of seeds dropped were recorded. Five iterations of the test were conducted. To calculate the number of missing seeds, the precise number of seeds that fell within the experimental area during the test was noted. The missing index, %, is calculated by the following equation.

Missing Index (%) = (N / M) × 100

N = Actual number of seeds missing in length of strip travelled in 10 revolutions

M = Theoretical number of seeds dropped by the metering plate in 10 revolution length of strip

The planter must undergo field testing at a speed of 1.5 to 2.5 km/h after undergoing sufficient laboratory testing to ensure proper operation. A prepared field requires two rotavator runs to become nearly flat under a conventional tillage method. The groundnut seed was planted in the testing field, which measured 10 m by 5 m in length and width. For better operation, the planter's speed is essential. Higher speeds harm the seeds more and shorten the distance between seeds in the row; conversely, lower speeds automatically result in less efficiency from the planter. So, for improved performance, regular walking was recommended. The theoretical field capacity of the developed planter was calculated based on its effective coverage width and the average operating speed. The following formula, as described by Hossain (2014), was used:

TFC (ha/hr) = W × S / 10

W = Width of operation, m and S = Speed of operation, km/h

The effective field capacity is the actual rate of area coverage with respect to time. The effective field capacity comprises the time lost in filling hopper and turning at the end of the row.

EFC (ha/hr) = A / T

A = Actual Field coverage, ha and T = Actual time of operation, hr

The field efficiency is the ratio of effective field capacity and theoretical field capacity stated in percentage. The field efficiency is determined by the following equation.
FE (%) = EFC / TFC × 100
EFC = Effective field capacity, ha/hr and
TFC = Theoretical field capacity, ha/hr

Results and Discussion

Observation of Physical Properties of Groundnut Seeds

The design of the metering wheel and seed hopper was supported by measurements of the physical characteristics of groundnut seeds, such as size, shape, bulk and true density, volume, porosity, angle of repose, and coefficient of static friction. In order to ensure smooth seed flow, the hopper slope was chosen based on the seed's angle of repose and friction properties, while the seed dimensions directly influenced the cell size on the metering plate (Table 1).

The seeds' moisture content ranged from 7.2% to 8.0%, with an average of 7.6% (wb). With lengths ranging from 11 to 14 mm and widths from 6 to 7.5 mm, the average seed dimensions were 12.20 mm in length and 6.90 mm in width. The mean sphericity was 71.16%, and the mean roundness was 61.94%. With coefficients of variation of 9.41% and 13.61%, the average bulk density was 0.65 g/cm^3 (0.58–0.72 g/cm^3), while the true density averaged 1.01 g/cm^3 (0.84–1.14 g/cm^3). The coefficient of static friction averaged 0.41 (0.35–0.49) and the angle of repose averaged 27.72° (26.64–28.66°). In order to facilitate unhindered seed flow, the hopper slope and pan angle were maintained higher than these values. The average groundnut seed weight was 560.40 g.

Table 1 Physical properties of groundnut seed

S. N.	Properties		Average Value
1	Moisture Content	Wet Basis (%)	7.60
		Dry basis (%)	8.23
2	Size	Length (mm)	12.20
		Width (mm)	6.90
		Thickness (mm)	7.70
		Arithmetic Mean Diameter (mm)	8.93
		Geometric Mean Diameter (mm)	8.65
3	Shape	Roundness (%)	61.94
		Sphericity (%)	71.16
		Surface Area (mm2)	235.55
4	Density	Bulk density (g/cm3)	0.65
		True density (g/cm3)	1.01
5	Frictional properties	Angle of Repose (degree)	27.72
		Static Coefficient of Friction	0.41
6	Test weight of seed	Weight of 1000 seeds, g	560.40

Calibration of Manually Operated Planter in the Laboratory

The manually operated groundnut planter was calibrated in the Farm Machinery and Power Engineering Laboratory at SHUATS. One hectare requires 20,220 revolutions of the drive wheel, as the average area covered in 50 revolutions was 0.002473 ha. The average weight of the seeds dropped in 50 revolutions was 164.2 g, with a range of 164 to 164.5 g. Based on this, the calibrated seed rate was determined to be 66.40 kg/ha, which is less than broadcasting and within the advised range of 60–80 kg/ha. With an average mechanical damage of 0.45%, seed damage during calibration was negligible. An 11-meter sticky belt was used to measure the uniformity of seed spacing at walking speeds ranging from 1.5 to 2.5 km/h. Due to sporadic misses, the planter only planted 57–59 seeds instead of the anticipated 60. The recommended seed-to-seed spacing of 15–20 cm was followed, with a range of 19.4–20 cm. The metering plate's uneven rotation and variations in the operator's walking speed caused a slight variation in spacing.

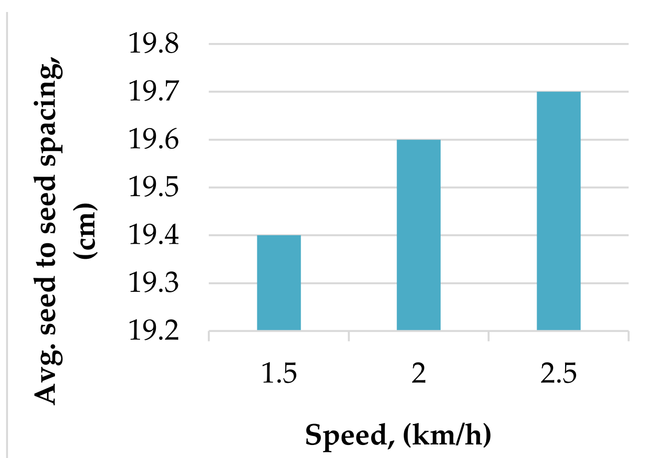

Fig. 6 Avg. seed to seed spacing in the laboratory

As the planter was being operated in a laboratory-prepared artificial sticky belt, the number of seeds that were actually dropped in ten ground wheel revolutions was counted. The actual number of seeds was then tallied. The variation of the missing index across five replications is displayed in Fig. 7. During field operation of the manually operated planter, it was found that the missing rate fluctuates because of vibration and jerk. At a speed of 1.5 km/h, the average missing index was 2.7%. At a speed of 2.5 km/h, the average missing index was 4.3%.

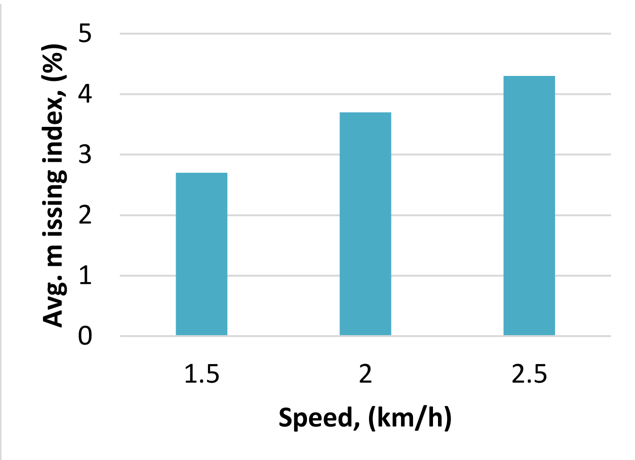

Fig. 7 Avg. seed missing index (%) in the laboratory

Field Evaluation of Manually Operated Planter for Groundnut Seeds

The length and width of testing field was 10m × 5m for groundnut seeds. The average value of field evaluation parameters is presented in the Table 2. The four observations were taken and range of speed were found as 1.5-2.5 km/h and average speed was found as 2.0 km/h.

Table 2 Field evaluation parameters of planter for groundnut seed

S.N.	Parameter	Average value
1	Plot size, m^2	50
2	Speed, km/h	2.0
3	Theoretical field capacity, ha/h	0.09
4	Effective field capacity, ha/h	0.077
5	Field efficiency, %	86.57
6	Seed placement depth, cm	4.1
7	Seed rate, kg/ha	65.08

The operating speed was determined to be 1.5 km/h at the minimum and 2.5 km/h at the maximum. An estimated 2.0 km/h was the average operating speed. The speed of operation in the field, using a 45 cm planter, was used to evaluate theoretical field capacity. It was found that as operating speed increased, so did the theoretical field capacity. The theoretical field capacity was found to be 0.09 ha/h on average, with minimum and maximum values of 0.0675 ha/h and 0.1125 ha/h, respectively. Actual field capacity was evaluated on the basis of actual time taken to cover the experimental area. The actual field capacity was determined to be 0.064 ha/h at the minimum and 0.088 ha/h at the maximum.

The planter's effective field capacity and theoretical field capacity were the determinants of its field efficiency. It can be defined as the ratio of theoretical field capacity to effective field capacity. For groundnuts, the average theoretical field capacity of a manually operated planter was 0.09 ha/h, and the highest field efficiency recorded was 94.81 percent. The lowest field efficiency recorded was 78.22 percent, and the average field efficiency was 86.57 percent. After the groundnut seed was sown in the field, the experiment was carried out. The four locations were chosen in order to gauge how deeply the seed penetrated the soil. It was discovered that the average depth of seed placement was 4.1 cm. The basis of seed dropped in the given area, the five replications were taken and the average seed rate was found as 65.08 kg/ha.

Conclusions

Because it allowed for timely, consistent, and accurate sowing a crucial component of increasing crop productivity the manually operated groundnut planter that was developed proved to be effective and ideal for small-scale farming. Accurate seed handling and placement were guaranteed by the inclined-plate metering mechanism, which was designed based on important physical characteristics of groundnut seeds. In both laboratory and field tests, the small device (840 × 450 × 310 mm) with a metering plate of 10.5 cm in diameter that had six cells powered by a 370-mm ground wheel operated dependably. At walking speeds of 1.5 to 2.5 km/h, the calibration results demonstrated a seed rate of 66.40 kg/ha with consistent seed spacing between 19.4 and 19.7 cm. Efficient metering was confirmed by very low seed damage (0.45%) and few missing indices (2.7–4.3%). The planter achieved an overall field efficiency of 86.57% by delivering a theoretical field capacity of 0.09 ha/h and an effective field capacity of 0.064–0.088 ha/h (average 0.077 ha/h).

Agronomic standards for groundnut sowing were satisfied by the average placement depth of 4.1 cm.

All things considered, this manually operated planter provides small and marginal farmers with an affordable, easy-to-use, and gender-inclusive solution. It offers significant potential to boost productivity and facilitate sustainable, accurate groundnut cultivation in resource-constrained farming systems by lowering labor costs, increasing seed placement accuracy, and guaranteeing when to sow.

Data Availability Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

This research received no external funding.

References

Abioye, A. O., Adekunle, A. A. and Agbasi-Ebere, V. 2016. Some moisture-dependent physical and thermal properties of Bambara groundnut. *IOSR* Journal of Environmental Science, Toxicology and Food Technology, 10(10): 65–74.

Burubai, W. and Amber, B. 2014. Some physical properties and proximate composition of Ngologolo fruits. Journal of Food Process Technology, 6(5): 331.

Chukwu, O. and Iwueke, C. N. 2020. Design and performance evaluation of a manually operated groundnut planter. Journal of Agricultural Engineering and Technology, 28(2): 45–54.

ICAR-Directorate of Groundnut Research. 2020. Annual report 2019–20. Indian Council of Agricultural Research.

Karunyaa, T., Dhayaneswaran, P. and Siva Shanker, A. 2024. Design and development of a manual groundnut planter for smallholder farmers. MATEC Web of Conferences, 400, 01009. https://doi.org/10.1051/matecconf/202440001009

Khan, K., Moses, S. C. and Kumar, A. 2015. The design and fabrication of a manually operated single row multi-crops planter. *IOSR* Journal of Agriculture and Veterinary Science, 8(10): 147–158.

Kumar, D. and Tripathi, A. 2017. Performance evaluation of a manually operated seed-cum-fertiliser soybean planter. Journal of Agricultural Engineering, 53(2): 134–142.

Muhammad, A. I., Isiaka, M., Fagge, A. A., Attanda, M. L., Lawan, I. and Dangora, N. D. 2015. Some engineering properties of three varieties of groundnut pods and kernels. Arid Zone Journal of Engineering, Technology & Environment, 11: 62–76.

Nandini, Y., Moses, S. C. and Aalam, R. N. 2018. Design of manually operated multi-crop inclined plate planter for farm women. International Journal of Current Microbiology and Applied Sciences, 7(6): 931–940.

Patil, B. S. and Ghewande, M. P. 2011. Groundnut production and future strategies. Directorate of Groundnut Research.

Sedara, A., Lanwo, R. and Sedara, O. 2020. Development of a low-cost two-row groundnut planter. *Turkish Journal of* Agricultural Engineering Research, 1(2): 324–338.

Sharma, D. N. and Mukesh, S. 2013. Farm machinery design: Principles and problems (3rd rev. ed.). Jain Brothers.

Singh, U. V. and Moses, S. C. 2021. Development and testing of manually operated single-row planter for groundnut seeds. International Journal of Farm Sciences, 11(1–2): 93–101. https://doi.org/10.5958/2250-0499.2021.00018.5

Zare, D., Bakhshipour, A. and Chen, A. 2013. Physical properties of cumin and caraway seeds. International Agrophysics, *27*: 491–494.