Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 21(2) May-August 2023]

Pantnagar Journal of Research

(Formerly International Journal of Basic and Applied Agricultural Research ISSN : 2349-8765)

G.B. Pant University of Agriculture & Technology, Pantnagar

PANTNAGAR JOURNAL OF RESEARCH

Vol. 21(2) May-August, 2023

CONTENTS

Field evaluation of Tractor-Operated Pneumatic Planter for maize crop planting

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ABSTRACT: This research paper presents field evaluation of a tractor-operated pneumatic planter for maize crop planting, for enhancing agricultural productivity. Maize, a vital staple crop globally, demands efficient and accurate planting methods to meet growing demands and ensure food security. The study focuses on assessing the technical specifications and seed metering mechanism of the pneumatic planter, utilizing air suction for precise seed distribution. Laboratory evaluations revealed that the pneumatic planter achieved consistent and accurate seed picking for 20 cm (mean = 214 seeds) and 25 cm (mean = 166 seeds) plant spacings, with minimal variation (CV = 1.69% and 6.22%, respectively). Field trials demonstrated that the planter's field efficiency ranged from 75.83% to 88.33%, while mean seed spacing varied from 19.1 mm to 25.8 mm, depending on speed and plant spacing conditions. The results indicate that the pneumatic planter provides uniform and precise seed placement, with low miss and multiple indices, and consistently high-quality feed indices. These findings support the advancement of agricultural technology and underscore the significance of modern machinery in meeting the increasing demands for maize production while ensuring efficient and precise planting practices for enhanced crop yields and resource optimization.

Key words: Field efficiency, maize crop, tractor-operated pneumatic planter, seed metering, seed spacing accuracy, quality feed index

Maize (*Zea mays*) is one of the most important staple crops globally, providing vital sustenance for human and animal consumption and serving as a valuable raw material in various industries (Salunkhe and Deshpande, 2012). The major maize producers in the world are USA,

China, Brazil, Mexico and Argentina, which contribute to 70% maize output of the whole world (Ramirez-Cabral *et al.*, 2017). In India, maize cultivation covers a substantial area of approximately 9.02 million hectares during the period of 2018-2019. The country achieved a remarkable production of 27.71 million tonnes and a productivity of 3070 kilograms per hectare, highlighting the crop's significant importance and contribution to the agricultural sector (Erenstein *et al.*, 2022). To meet the increasing demand for maize and ensure food security, efficient and precise crop planting methods are essential. The use of modern agricultural machinery and equipment has significantly improved planting practices, leading to higher crop yields and resource optimization (Johansen *et al.*, 2012). Over the past few decades, advancements in seed quality have led to the assurance of higher germination percentages and emergence rates for maize seeds. Consequently, this progress has solidified precision planting as the primary approach for sowing maize.

In this context, the tractor-operated pneumatic planter emerges as a promising technology for maize crop planting (Singh *et al.*, 2018). The pneumatic planter is designed to accurately and uniformly distribute seeds in the field, reducing the manual labor and time required for planting. It offers advantages such as adjustable row-to-row spacing, consistent seed placement depth, and high planting efficiency, making it a preferred choice for modern farming operations (Liu *et al.*,2011).

In the regions of Kerala, maize planting machinery is accessible for farmers to use. Surprisingly, not many have adopted these mechanical planters, as a large portion of them still prefer to plant maize by hand (Meena *et al.*, 2015). These mechanical planters often miss planting some seeds, resulting in uneven spacing between plants and fewer plants overall when compared to manual planting. Among the various ways of planting, precise planting is the favorite due to its ability to maintain even distances between seeds. A different approach to planting is through pneumatic planters. These machines provide an accurate and precise way of placing seeds in the soil. The careful positioning of seeds in the ground offers several advantages (Wych, 1988). It not only saves money by using seeds more efficiently, but it also reduces the issue of thinning—where plants are too close together and need to be removed later. Additionally, crop yields are higher because each plant receives the optimal amount of sunlight, water, and nutrients (Singh *et al.*, 2018).

Given this backdrop, our study takes a closer look at the performance of pneumatic precision planters. We aim to understand how well these planters work in Kerala region, shedding light on their effectiveness in improving maize planting practices in these regions. The study focuses on assessing the planter's technical specifications and seed metering mechanism, which utilizes air suction for precise seed distribution. Additionally, the calibration process is conducted to determine the optimal gear combinations for achieving the desired seed rate and spacing. The research findings will provide valuable insights into the efficiency and accuracy of the tractor-operated pneumatic planter in maize crop planting. By understanding the planter's capabilities and limitations, farmers and agricultural practitioners can optimize their planting practices, leading to improved crop establishment, enhanced productivity, and sustainable agricultural practices.
Various studies were conducted to evaluate the performance of the pneumatic planting system. Ahmad *et al.* (2021) evaluated a bed-type pneumatic planter for maize seeding, noting significant effects on sowing uniformity and precision indices under different tillage levels and travel speeds. Study demonstrates the feasibility of achieving precise maize seeding using a bed-type pneumatic planter, particularly with appropriate seedbed preparation and operational parameters like speed of operation. Study, conducted by Vuajnk in 2017, investigated the impact of planting speed (7, 9, or 11 km/h) using a pneumatic vacuum planter on maize spacing, biomass, and grain yield. At 7 km/h, plant spacing aligned closely with the desired distance, while 9 km/h showed higher doubled and empty spaces. Singh *et al.* (2018) study focuses on resource-intensive paddy-wheat rotation in Punjab. Maize adoption as an alternative is explored, highlighting labor-efficient pneumatic planters. These planters enhance quality feed index, plant population, and yields compared to traditional methods. Notably, pneumatic planters also significantly reduce operational costs, promoting viable maize cultivation in Punjab.

The precision of sowing and the speed at which it occurs play crucial roles in effective crop establishment. Recognizing the significance of these factors, our research endeavors to comprehensively evaluate the performance of a pneumatic maize planter across various speed levels and different spacing between seed to seed.

MATERIALS AND METHODS

The pneumatic planter used for maize crop consists of a main frame, aspirator blower, disc with a cell-type metering plate, individual hopper, furrow openers, PTO-driven shaft, ground drive wheel, etc. The pneumatic planter's specifications are listed in Table 1.

Seed metering unit

The pneumatic seed metering system employed in the planter, as depicted in Figure 1, is driven by the

Table 1: Technical Specifications of the Pneumatic Planter

Parameters	Specifications
Power source	50 hp or higher tractor
Type	Mounted
Overall length	2.75 m
Overall width	3 m
Overall height	1.4 m
Overall weight	450 kg
Number of rows	4
Row to row spacing	Adjustable (0.45 to 0.85)
Metering mechanism	Pneumatic
PTO rpm required	540
Operating field speed	1.5-6 km/h
seed box capacity	34 L
Suction pressure	3-5 kPa

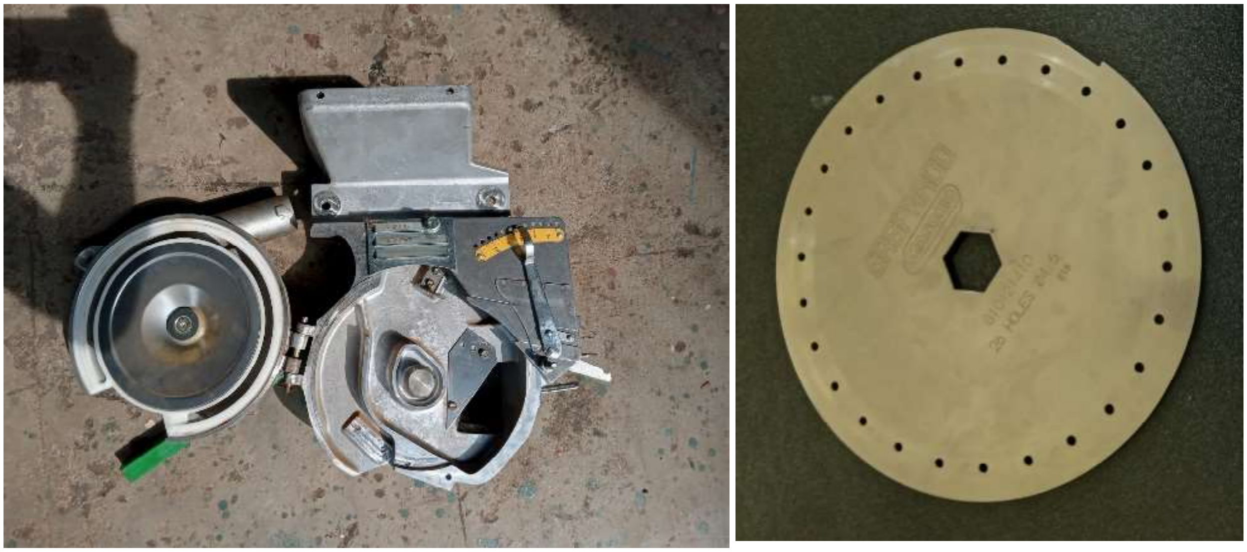

Fig. 1: Illustrates the seed metering mechanism and plate used in the planter

tractor's power take-off (PTO) with a speed range of 500-540 rpm. This system utilizes air suction, generated by the aspirator blower, to meter and distribute the seeds accurately. Each row of the planter has a pneumatic disc connected to the inlet chamber of the aspirator blower through a rubber tube. The seed metering disc contains 26 holes (4 mm in size) around its periphery, accommodating a single seed against each hole. When air suction is applied, the seeds adhere to the holes on the seed metering disc.

The ground wheel drives the seed discs, releasing the stuck seeds from the metering plate through a baffle cut positioned near the opener. The absence of suction at this point allows the seeds to drop into the small furrow created by a small opener placed below the bed shaper. To ensure precise plant-to-plant spacing, appropriate combinations of sprockets are used. The falling height of seeds into the furrow is kept minimal to minimize seed rolling and bouncing.

Power Transmission System of the Pneumatic Planter

The power transmission system of the pneumatic planter incorporates a series of gear arrangements, as illustrated in Figure 2. These gear arrangements

Fig 2: Transmission system of the planter to achieve different seed spacing

use different gear ratios to achieve the desired seed rate. The process begins with two gears, one with 16 teeth and the other with 23 teeth, mounted on the axle of the ground wheel. Power from the ground wheel is then transmitted through a chain to the primary driving shaft, which features gears with 16 and 23 teeth at each end. The system also includes a secondary driving shaft, equipped with seven gears with varying tooth counts: 23, 22, 21, 20, 19, 18, and 17 teeth, placed in the first to seventh positions, respectively.

To transfer power from the primary driving shaft to the secondary driving shaft, chain and idler gears are utilized. Eventually, the power is transmitted from the secondary driving shaft to the seed metering plate through the assistance of a bevel gear unit.

Calibration of planter

The objective was to determine various parameters such as tractor forward speed, effective diameter of the ground wheel, seed rate per hectare, and row to row and plant to plant distance. To determine the tractor forward speed, effective ground wheel diameter, and seed rate per hectare, the following steps were taken:

Effective Ground Wheel Diameter: The effective diameter of the ground wheel was measured and then circumference (À × d) of ground wheel was determined.

seed Rate Calculation: With the planter lifted using the tractor's hydraulic system and the PTO operating at 540 rpm, the ground wheel was rotated for 20 revolutions. seeds were collected from the tubes of four rows and weighed. This process was repeated three times, and the average seed weight per hectare was calculated.

The seed rate (Q) was then calculated using the formula given in Eq. 1 (Zaidi *et al.*, 2019):

$$Q = (L \times 10{,}000) / (\pi \times De \times n \times W) \quad \text{....... (1)}$$

Where:

Q = seed rate per hectare (kg/ha)

L = Distance covered by the ground wheel in 20 revolutions (meters)

De = Effective diameter of the ground wheel (meters)

n = Number of rows

W = Weight of seeds collected from the tubes (kg)

By following this calibration process, the planter's performance can be optimized to achieve accurate seed distribution and plantng distances in the field.

Performance Parameters Measured During Field Evaluation

The following performance parameters are measured during the field evaluation:

1. **Speed of operation:** The time taken (s) to cover a specific distance (m) during operation is determined using a stopwatch. The forward speed of the tractor (km/h) is calculated using the equation:

Forward speed of tractor =

$$S = \frac{\text{distance}}{\text{time}} \times 3.6 \quad \ldots (2)$$

2. **Theoretical field capacity:** The theoretical field capacity is calculated using the formula:

Theoretical field capacity (ha/h) = (Width of operation (m) × Travel speed (km/h)) /10 … (3)

3. **Actual field capacity**: The actual or effective field capacity (ha/h) is determined by considering time losses during various events, such as refilling seeds and fertilizer and turning:

Effective field capacity (ha/h) = Area covered (ha) / Total time taken (hr) … (4)

4. **Field efficiency (E_f)** is a measure of how effectively agricultural machinery is performing in the field. It's usually expressed as a percentage and can be calculated using the following formula:

Field efficiency (%) = (Effective field capacity / Theoretical field capacity) × 100 … (5)

5. **Miss Index (MI):** The Miss Index represents the percentage of spacings greater than 1.5 times the set spacing (X).

$$MI = (n_1 / N) \quad \ldots (7)$$

Where: MI = Miss Index; n_1 = Number of spacings greater than 1.5 times the set spacing (X).

6. **Multiple Index (DI):** The Multiple Index represents the percentage of spacings less than or equal to half of the set spacing (X).

$DI = (n_2 / N)$ … (8)

Where: DI = Multiple Index; n_2 = Number of spacings less than 0.5 times the set spacing (X).

7. **Quality of Feed Index (A):** The Quality of Feed Index combines the effect of misses and multiples and represents the percentage of spacings that are more than half but not more than 1.5 times the set spacing.

Quality of Feed Index = 100 - (Miss Index + Multiple Index) … (9)

These performance indices provide valuable insights into the planter's efficiency and accuracy in terms of seed spacing, helping to assess and improve its overall planting performance. (Kumar *et al.*, 2015; Ahmad *et al.*, 2021; Singh *et al.*, 2018)

Plan of experiment for accessing performance of Pneumatic planter

Parameters	Levels	Responses
Plant to plant distance	20 cm	•Theoretical field capacity, ha/h •Effective field capacity, ha/h
	25 cm	•Field efficiency, %
Speed of operation	2 km h^{-1}	•Miss index, % •Multiple index, %
	4 km h-1	•Quality feed index, %

The planter is powered by a 37.29 kW tractor, and the tractor is operated at different forward speed of 2 and 4 km/h during the field operations. The depth of operation of the furrow opener is set at 40 mm. The field operation of the pneumatic planter during actual field conditions is shown in Figure 3.

RESULTS AND DISCUSSION

The present study encompassed an assessment of the physical properties of maize seeds, including

Fig. 3: Pneumatic planter during actual field condition

measurements of size, geometric mean diameter, sphericity, surface area, and bulk density. These properties provide insights into the inherent characteristics of seeds, which play pivotal roles in the overall planting process.

Physical properties of seeds hold particular significance, especially when considering factors like hopper design and hole configuration on the disc. Additionally, these properties are of crucial importance when examining different settings provided within the metering mechanism (Singh *et al.*, 2005). For instance, a provision is integrated to ensure the presence of a singular seed within the metering mechanism. This is facilitated through the adjustment of the breaker near the hole using a lever with six adjustable levels. It is imperative to acknowledge that while physical properties of seeds indeed influence the planting process, our study was principally directed towards evaluating the pneumatic planter's inherent performance. Our investigation focused on the planter's functionality within the parameters and settings provided by the manufacturer. It is within this context that our assessment aimed to comprehensively understand the planter's capabilities.

In light of this, we acknowledge that the influence of seed physical properties can be crucial in certain contexts, particularly when fine-tuning the machine's design for varying seed types. Although not the primary focus of this study, future research could delve into the interplay between seed properties and machine design adjustments to accommodate diverse seeds. The physical properties of maize seeds were determined to better understand their characteristics, which are crucial for efficient planting by pneumatic planter and crop establishment. The table 2 presents essential data regarding the physical characteristics of different maize seed samples including length, width, thickness, geometric mean diameter, sphericity, surface area, and bulk density, are measured for each seed sample. The Table 2 presents the data and statistical analysis:

The length of the maize seeds varies from 9.40 mm to 11.15 mm, while the width ranges from 7.99 mm to 9.41 mm. Similarly, the thickness of the seeds spans from 3.63 mm to 5.5 mm. The geometric mean diameter, calculated for each sample, ranges from 6.78 mm to 7.83 mm, providing insights into the average size of the seeds. Sphericity, a dimensionless parameter indicating how closely each seed resembles a sphere, varies between 0.62 and 0.81, with higher values suggesting more spherical shapes. Similar findings were obtained be Tarighi *et al.*, 2011.

Additionally, the table showcases the surface area of the maize seeds, ranging from 144.43 mm^2 to 192.63 mm^2, providing information about the seeds outer area. The values of bulk density (kg m^{-3}) ranged from 775 kg m^{-3} to 826 kg m^{-3}. It indicates the mass of the seeds per unit volume. In conclusion, the table presents comprehensive information about the physical characteristics of maize seeds and their variation across different samples. This data is crucial for assessing the suitability of seeds for planting using a tractor-operated pneumatic planter and for optimizing the planting process to achieve maximum crop yield and efficiency. The results offer valuable insights into the singularity of seed pick-up through vacuum in the metering device, with a focus on selecting a suitable hole size in the metering device. By analyzing the physical characteristics of the maize seeds, we gain a better understanding of the optimal hole size required for efficient seed pick-up and metering. These properties are essential for efficient planting using the tractor-operated pneumatic planter. Understanding these characteristics helps to select the correct hole size plate and setting of metering mechanism.

The pneumatic planter for maize crop is tested both in the laboratory and under field conditions. After a thorough analysis of the physical and engineering properties of maize seeds, a hole size of 4 mm was meticulously chosen for the plate. Notably, the plate contains a total of 26 holes. Calibration data of maize planter for plant-to-plant spacings of 20 cm and 25 cm are presented in Table 3. The average effective ground wheel diameter was found to be 220 cm. The experiment was conducted in the laboratory with three replications for each plant spacing. The Table 3 shows the number of seeds picked in 20 revolutions of the ground wheel for individual rows, along with the mean, standard deviation (SD), and coefficient of variation (CV) for each replication. We kept lever for singulation at 3rd level for keeping singulation

Table 2: Physical Properties of Maize seeds

S. No	Size (mm)			Geometric mean, dia, (mm)	Sphericity	Surface area (mm^2)	Bulk density (kg m^{-3})
	Length	Width	Thickness				
1	11.15	7.99	3.88	7.01	0.62	154.4	790
2	9.88	9.41	3.7	7	0.7	153.96	785
3	9.4	8.52	3.9	6.78	0.72	144.43	802
4	10.34	8.54	4.6	7.4	0.71	172.06	810
5	10.5	8.6	4.2	7.23	0.68	164.24	820
6	9.7	8.8	4	6.98	0.72	153.08	814
7	10.8	9.3	4.4	7.61	0.7	181.96	775
8	9.55	9.14	5.5	7.83	0.81	192.63	826
9	10.4	9.41	3.63	7.08	0.68	157.5	789
10	9.62	9.09	4.55	7.35	0.76	169.74	815
Mean	10.13	8.88	4.236	7.227	0.71	164.40	802.6
S.D.	0.588	0.468	0.558	0.322	0.050	14.82	17.01
CV (%)	0.058	0.052	0.131	0.044	0.070	0.09	0.021

seed and the 4 mm hole plate is selected for maize.

In this experiment, the performance of the maize planter was evaluated for different plant spacings. The maize planter achieved consistent and accurate seed picking for 20 cm (SD = 1.69, CV = 1.10% to 2.19%) and 25 cm (SD = 6.22, CV = 3.65% to 7.63%) plant spacings, indicating minimal variation. With mean values of 214.42 seeds (20 cm) and 166.33 seeds (25 cm) in 20 revolutions of the ground wheel, the planter demonstrated uniform and precise planting.

Moreover, the "Standard Deviation (S.D.)" row illustrates the dispersion or spread of data points around the mean for each parameter, with smaller values indicating less variability within the dataset. The "Coefficient of Variation (CV %)" row expresses the variation as a percentage, allowing comparison of relative variability among replications. Smaller CV% values indicate less relative variation.

The tests are conducted with maize seeds at different gear combinations to obtain the recommended seed rate with spacing of 20 and 25 cm. The seed rates obtained for different combinations and for different gears of the primary driving shaft are recorded. Based on the results obtained in the laboratory, the performance of the pneumatic planter is evaluated in the field. Data on performance parameters of the planter, such as plant-to-plant spacing, miss index, multiple index, quality feed index, actual field capacity, and field efficiency, is collected and analyzed. The average values of the field trials conducted are calculated and shown in Table 4. At 20 cm plant spacing, the seed rate is 18.5 kg/ha, while at 25 cm plant-to-plant spacing, it is 22 kg/ha. These results demonstrate the performance of the pneumatic planter for maize crop planting and can be used to assess its efficiency and suitability for practical agricultural applications.

The performance of the tractor-operated pneumatic planter was assessed under various speed and plant spacing conditions. The theoretical field capacity was higher at 4 km/h (1.2 ha/h) compared to 2 km/h (0.6 ha/h) for both 20 cm and 25 cm plant spacings. Similarly, the effective field capacity was slightly higher at 4 km/h (0.91 ha/h for 20 cm, 0.95 ha/h for 25 cm) than at 2 km/h (0.51 ha/h for 20 cm, 0.53 ha/h for 25 cm).

In terms of field efficiency, the planter showed higher efficiency at 4 km/h for both plant spacings, particularly achieving 79.17% efficiency at 25 cm spacing. The mean seed spacing for the 20 cm spacing was consistently smaller at both speeds (19.1 mm at 4 km/h and 19.3 mm at 2 km/h) compared to the 25 cm spacing (25.8 mm at 4 km/h and 24.8 mm at 2 km/h). Ahmad *et al.* (2021) and Kumar *et al.* (2015) reported comparable findings. The seed placement depth for the seed is maintained at 5 cm, ensuring that the seeds are sown at the optimal depth in the soil. Additionally, the row-to-row spacing between each planted row is set at 60 cm, providing adequate space for the maize plants to grow and develop without crowding.

The miss index and multiple index were generally low for all cases, indicating accurate and precise seed placement. The 25 cm plant spacing exhibited slightly better performance in this regard. The quality feed index remained consistently high for all combinations, indicating the planter's reliable seed placement capabilities. In conclusion, the tractor-operated pneumatic planter demonstrated accurate and precise seed placement with high-quality feed

Table 3: Calibration of Maize Planter in the Laboratory for Number of seeds in 20 Revolutions of the Ground Wheel

Rep	20 cm Plant Spacing				Mean	SD	CV (%)	25 cm Plant Spacing				mean	SD	CV (%)
	R1	R2	R3	R4				R1	R2	R3	R4			
Rep 1	210	217	219	210	214.00	4.69	2.19	165	170	172	161	167.00	4.97	2.97
Rep 2	215	216	215	220	216.50	2.38	1.10	163	168	157	175	165.75	7.63	4.60
Rep 3	218	209	212	212	212.75	3.77	1.77	175	161	165	164	166.25	6.08	3.65
Avg.	214	214	215	214	214.42	3.62	1.69	167	166	164	166	166.33	6.22	3.74

Table 4: Result of field performance evaluation

Parameter	S_1 (2 km h^{-1})		S_2 (4 km h^{-1})	
	20 cm	25 cm	20 cm	25 cm
Theoretical field capacity, ha/h	0.6	0.6	1.2	1.2
Effective field capacity, ha/h	0.51	0.53	0.91	0.95
Field efficiency, %	85.00	88.33	75.83	79.17
Mean seed Spacing, mm	19.3	24.8	19.1	25.8
Miss index, %	1.9	1.3	2.7	1.9
Multiple index, %	2.1	2.3	2.6	3.1
Quality feed index, %	96	96.4	94.7	95

indices for all speed and plant spacing conditions. The choice of planting speed and spacing should be based on the specific needs of the farming operation, considering factors like field efficiency and seed placement accuracy to optimize maize crop planting and enhance overall agricultural productivity.

CONCLUSION

The research paper evaluated the performance of a tractor-operated pneumatic planter for maize crop planting. Maize, being a crucial staple crop globally, necessitates efficient and precise planting methods to meet increasing demands and ensure food security. The study focused on assessing the technical specifications especially seed metering mechanism of the pneumatic planter, which employs air suction for accurate seed distribution and field performance of the planter.

The research explored the physical properties of maize seeds, providing insights into seed characteristics crucial for planter setting. The data on seed size, shape, and bulk density offered valuable information for selecting appropriate hole sizes in the metering device, ensuring optimal seed pick-up and metering.

Furthermore, the pneumatic planter exhibited commendable field performance, with notable results across varying speed and plant spacing conditions: at 4 km/h, it achieved an effective field capacity of 0.91 ha/h for 20 cm spacing and 0.95 ha/h for 25 cm spacing, accompanied by high field efficiency (79.17% for 25 cm spacing). seed placement accuracy was affirmed by low miss and multiple indices, while the quality feed index remained consistently high across conditions. These findings substantiate the reliability of the pneumatic planter's capabilities.

Overall, the study highlights the importance of tractor-operated pneumatic planters in modern agricultural practices, offering advantages like adjustable row-to-row spacing, uniform seed placement, and high efficiency. Understanding the planter's capabilities and limitations will empower farmers and agricultural practitioners to optimize their planting practices, leading to improved crop establishment and enhanced productivity.

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Received: August 10, 2023
Accepted: August 21, 2023