Original Research Article

Field Testing and Evaluation of a Seven-Row Inclined Plate Planter for Mustard Cultivation

Abstract:

Mustard seed (Brassica nigra) is a crucial oilseed crop extensively cultivated in several countries, especially in South Asia. Enhancing seed planting techniques is essential to optimize crop output and overcome the challenges faced by farmers. Traditional manual planting methods are inefficient and time-consuming, creating obstacles to overall agricultural productivity. To address this issue, a field test and evaluation of a seven-row inclined plate planter for mustard cultivation were conducted. Precision planting, which involves accurate seed placement at desired intervals, is vital for maximizing crop productivity. The study encompassed a comprehensive analysis of soil parameters, including soil type, moisture content, bulk density, and cone index. Various operational parameters such as seed spacing, row spacing, and ground wheel slip were evaluated. The economic aspects, including cost analysis, breakeven point, payback period, and benefit-cost ratio, were considered to assess the financial feasibility of the tractor-operated planter.

Calibration results revealed variations in seed rates among different rows and hopper capacities, impacting seed placement uniformity. Additionally, the study examined seed breakage under different operational parameters, emphasizing its influence on germination rates. Field performance data included soil moisture (12.61%), bulk density (1.45 g/cc), and field efficiency (82.30%), offering insights into real-world planter operation. The cost analysis determined a favorable economic outlook, with a benefit-cost ratio of 1.2, signifying the economic viability of machine harvesting compared to manual methods.

Keywords: Mustard seed, inclined plate planter, precision planting, soil parameters, operational parameters, economic analysis.

Introduction

Mustard seed (Brassica nigra) is a plant of the family Cruciferae or Brassicaceae that is part of the genum Brassica. Mustard seeds are used as a spice in South Asia. Mustard seeds which is also known as Rai or Black Sarson, Sarisa, Kadugo and Kaduku. Agriculture is vital to the Indian economy, employing a large number of people and adding to the gross national product. India has a massive agricultural area of 142.6 million hectares, with rainfed agriculture accounting for 61.38% of the total. This rainfed area produces 42% of all food grains, with pulses and oilseeds (Mdluli, 2018; Kalra, 2018).

The agriculture industry is a critical component of the global economy, assuring food security and providing a living for millions of people worldwide. To meet rising food demand, agricultural techniques and technology must be constantly improved (Loos et al., 2014).Seed planting is one of the most important phases in crop growth since it has a direct impact on crop output and quality. Traditional manual planting methods, however, are inefficient, labor expensive, and time-consuming, creating difficulties to overall agricultural output (Dogan and Zeybe, 2009). As a result, it is critical to enhance seed-planting techniques in order to maximize agricultural output and overcome the constraints that farmers confront.

There is a need for an effective and dependable planting method in the context of mustard seed production (Layek et al., 2021), which is an essential oilseed crop extensively farmed in diverse countries (Afzal et al., 2019). Mustard seeds are tiny and sensitive, necessitating careful positioning and excellent soil-to-seed contact in order to germinate and establish. Existing market planters frequently lack the elements required to suit the special needs of mustard seed planting, resulting in unsatisfactory outcomes and diminished crop production (Pooniya et al.,2015).

In light of the advancements in precision planting technology and the growing demand for tractor-mounted sowing implements, this research aims to focus on the field testing and evaluation of a seven-row inclined plate planter for mustard cultivation. The precision planting concept, which involves the accurate placement of a single seed at the desired plant spacing, has proven to be essential for maximizing crop productivity (Šarauskis et al., 2022).In order to overcome these challenges, inclined and vertical plate planters evolved as more efficient options (Murray et al., 2006).

Materials and method

In this research paper, the materials and methods employed for the evaluation of a tractor-operated seven-row inclined plate planter for mustard seed cultivation are comprehensively outlined. The field tests were conducted at the Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS), situated in Prayagraj, Uttar Pradesh, India, within a designated testing area on the institution's premises. The study initiated with a thorough analysis of essential soil parameters, including soil type, determined through particle size analysis utilizing the International pipette method, which provided insights into the percentage composition of sand, silt, and clay. These preliminary investigations laid the foundation for the subsequent performance evaluation of the tractor-operated planter, encompassing various agricultural and economic aspects. Additional parameters were investigated and the procedures for these parameters are detailed below:

Soil Moisture Content Soil moisture content was assessed by collecting soil samples from six randomly selected locations within the field. These samples were then subjected to an eight-hour oven-drying process at 105 degrees Celsius. The moisture content on a dry weight basis was calculated using the formula:

$$MC\ (\%) = \frac{\mathrm{W1} - \mathrm{W2}}{\mathrm{W1}} \times 100$$

Where,

W1 = Initial weight of the soil sample (in grams) W2 = Dry weight of the soil sample (in grams)

Bulk Density The bulk density of the soil, representing its compactness, was determined using the core cutter method. The bulk density of the soil sample was calculated using the formula:

Bulk density (ρ) = $\frac{\mathrm{M}}{\mathrm{V}}$

Where,

ρ = Bulk density (in grams per cubic centimeter, g cm^3); M = Mass of the soil (in grams); V = Volume of the soil (in cubic centimeters, cm^3)

To measure bulk density, a cylindrical core cutter with known dimensions was utilized. The weight of the empty core cutter was recorded, and it was pressed into the soil, followed by the removal and weighing of the soil-filled core cutter.

Cone Index The cone index, indicating soil resistance, was measured using a soil cone penetrometer. The soil cone penetrometer was driven into the soil at a constant rate, and the force required for the cone to penetrate the soil to different depths (5, 10, 15, and 20 cm) was recorded at various locations within the study area.

The field evaluation of the tractor-operated seven-row inclined plate planter for mustard seed was carried out at a dedicated testing plot within the institution. The evaluation encompassed the assessment of various crucial parameters to gauge the planter's real-world performance under field conditions. These observed parameters included:

Seed Spacing Seed-to-seed spacing (in centimeters, cm) for one meter length was measured at five different locations in the field using a steel scale.

Row Spacing The spacing between two adjacent rows (in centimeters, cm) was measured at five different locations in the field using a steel tape.

Width of Operation The width of operation (in centimeters, cm) of the entire machine was measured at five different locations in the field using a steel scale.

Ground Wheel Slip The number of ground wheel revolutions for a distance of 20 meters covered by the unit was recorded to calculate the wheel slip using the provided formula.

Draft The draft of the unit was measured using a load cell dynamometer attached to the test tractor, as per the RNAM (Regional Network for Agricultural Machinery) test code. The draft requirement was recorded both with and without the implement, and the difference in readings indicated the draft needed to pull the implement at the optimized speed.

Fuel Consumption Fuel consumption was measured by attaching a fuel consumption meter to a tractor. The volume of fuel consumed was determined based on the difference in the volume of fuel in the measuring jar before and after the operation.

Speed of Operation The operating speed of the planter was recorded as the time taken to travel 20 meters in the field, using a measured tape and digital stopwatch.

Field Capacity The field capacity and field efficiency were calculated based on the total time taken to cover a specified area, accounting for time lost during turning and other operational time losses.

Depth of Seed Placement The depth of seed placement was measured by excavating the soil and recording the depth at which the seed was placed.

Germination Count (100 Seed) A germination test was conducted to determine the actual germination rate of the mustard seeds used in the study. One hundred seeds were planted in an experimental plot, and the total number of seeds that germinated was recorded.

Plant Population The plant population was assessed by counting the number of plants in a known area at randomly selected locations in the field.

Theoretical Field Capacity: The theoretical field capacity is calculated based on the width of the working and the speed of operation using the following formula:

Theoretical field capacity (ha/h) = $(W \times S) / 10$

Where, S = Speed of operation, km/h ;W = Theoretical width covered, m

Effective Field Capacity: The effective field capacity is calculated by recording the time required for complete sowing and using the following formula:

Effective field capacity (ha/h) = A / T

Where, A = Actual area covered, in hectares (ha) T = Total time required to cover the area, in hours (h)

Field Efficiency: Field efficiency is calculated by comparing the actual field capacity to the theoretical field capacity and expressing it as a percentage:

Field efficiency = (Actual field capacity / Theoretical field capacity) × 100

Missing Index: The missing index measures how frequently seeds deviate from the desired spacing, specifically when the spacing is more than 1.5 times the theoretical spacing. It is expressed as a percentage and calculated using the following formula:

Missing Index (M) = n1 / N

Where, n1 = Number of occurrences where the spacing is greater than 1.5 times the theoretical spacing N = Total number of observations

Multiple Index: The multiple index, denoted as M_2, indicates instances where more than one seed is dropped within a desired spacing. It quantifies the percentage of spacings that are less than or equal to half of the theoretical spacing. The formula for calculating the multiple index is as follows:

Multiple Index (M_2) = n2 / N

Where, n2 = Number of occurrences where the spacing is less than or equal to half of the theoretical spacing N = Total number of observations

Additionally, the economic evaluation considered fixed costs such as depreciation, interest on investment, shelter/housing cost, insurance, and taxes, as well as variable costs like lubricants, repair and maintenance, and operator and labor wage. The study calculated important financial metrics, including the breakeven point, payback period, and the Benefit-Cost (B:C) ratio to assess the financial feasibility of the tractor-operated planter.

Results and Discussion

In the present study, a comprehensive evaluation of a seven-row inclined plate planter for mustard seed was conducted under both laboratory and field conditions. The following key findings and their implications are presented below.

Calibration of Planter Metering Mechanism

The calibration of the planter's metering mechanism was carried out within a controlled laboratory environment, involving various hopper capacities. The seed rate variations across seven rows for mustard seeds are summarized in Table 1. These evaluations were performed at a speed of 2 km/h, and the average seed rates were computed for different hopper capacities.

Table 1: Seed Rate from Inclined Plate Planter for Mustard at Different Hopper Capacities under Laboratory Conditions at 2 km/h

Hopper Capacity	**Row 1**	**Row 2**	**Row 3**	**Row 4**	**Row 5**	**Row 6**	**Row 7**	**Average**
1/4th	317	321	321	319	318	316	318	318.572
Deviation from average, %	0.015	-0.024	-0.024	-0.004	0.005	0.025	0.005	
1/2th	332	335	333	330	334	329	334	332.429
Deviation Fromaverage, %	0.004	-0.025	-0. 005	0.024	-0.015	0.034	-0.015	
3/4th	345	346	348	348	345	346	343	345.858
Deviationfromaverage, %	0.008	-0.001	-0.021	-0.021	0.008	0.001	0.028	
Full	355	352	356	349	351	354	352	352.715
Deviation Fromaverage, %	-0.022	0.007	-0.032	0.037	0.017	-0.012	0.007	

The results from this calibration indicate variations in seed rates among different rows and hopper capacities. Such variations may have significant implications for the uniformity of seed placement and, subsequently, crop establishment.

Effect of Operational Parameters on Seed Breakage

The study also explored the impact of various operational parameters on seed breakage. The results are presented in Table 2 and were obtained at a constant speed of 2.0 km/h for different hopper capacities.

Table 2: Seed Damage (%) for 2.0 km/h Speed

Sl. no.	Speed (km/h)	Capacity of hopper	Seed Damage (%)
1.	2.0	At full capacity	0.29
2.	2.0	At 3/4th capacity	0.31
3.	2.0	At 1/2 capacity	0.30
4.	2.0	At 1/4th capacity	0.39

The results illustrate the varying degrees of seed damage under different operational parameters. This is a critical factor as it can significantly influence germination rates and overall crop yield.

Field Performance Evaluation of the Inclined Plate Planter

The field performance evaluation was conducted in sandy loam soil at a dedicated testing plot within the institution. The data collected on various soil and machine parameters is summarized in Table 3.

Table 3: Field Performance of Tractor-Operated Seven-Row Inclined Plate Planter for Mustard

Sl. no.	Particulars	Details
1	Place of Test	VIAET, SHUATS Allahabad
2	Size of Plot, m^2	1500 m^2
3	Soil Type	Sandy loam
4	Soil Moisture, %	12.61
5	Bulk Density, g/cc	1.45
6	Crop Type	Mustard (RLC-1)
7	Soil Resistance, MPa	1.50

8	Source of Power	Tractor, 50 HP
9	Travelling Speed, km/h	2.00
10	Draft, N	2900
11	Fuel Consumption, m^3/h	3.21×10^{3}
12	Ground Wheel Slip, %	4.8
13	Average Depth of Sowing, mm	35.00
14	Effective Working Width, mm	210
15	Theoretical Field Capacity, ha/h	0.51
16	Effective Field Capacity, ha/h	0.42
17	Field Efficiency, %	82.30
18	Germination After 15 Days, %	96.8
19	Plant Count, Plants per sq. m	16
20	Average Plant to Plant Distance, mm	15.65
21	Row to Row Distance, cm	35.00
25	Miss Index, %	2.6
26	Multiple Index, %	3.8

This field evaluation provides critical insights into various parameters such as ground wheel slip, draft, fuel consumption, operational speed, field capacity, depth of seed placement, germination rates, and plant population. These parameters play a significant role in determining the effectiveness of the planter under real-world field conditions.

Cost Economics

The economic aspects of operating the tractor-drawn seven-row inclined plate planter were analyzed by considering labor, depreciation, fuel, maintenance, and other related costs. The key findings include:

- The total operating cost per hour, encompassing fixed and variable costs, was calculated to be Rs. 755.93.
- The Break-Even Point (BEP) was determined to be approximately 69.19 hours per year, indicating the minimum annual utilization required to cover acquisition and operating costs.
- The Payback Period (PBP) was estimated at 1.5 years, representing the time needed to recover the initial machine cost through net annual profits.
- The Benefit-Cost Ratio (B:C ratio) demonstrated a favorable economic outlook, with a ratio of 1.2, suggesting that machine harvesting is economically advantageous compared to manual harvesting.

Conclusion

The comprehensive evaluation of the seven-row inclined plate planter for mustard seed, conducted under both laboratory and field conditions, has provided valuable insights into its performance and economic feasibility. Calibration results indicated that seed rates varied among different rows and hopper capacities. At a speed of 2 km/h, the average seed rates were computed for different hopper capacities, with deviations from the average ranging from 0.01% to 0.03%.

Furthermore, the study explored the impact of various operational parameters on seed damage at a constant speed of 2.0 km/h and different hopper capacities. These results are critical, as seed breakage can significantly influence germination rates and overall crop yield.

The field performance evaluation conducted in sandy loam soil revealed key data, including soil moisture (12.61%), bulk density (1.45 g/cc), and effective field capacity (0.42 ha/h). Parameters such as ground wheel slip (4.8%), average depth of sowing (35.00 mm), and field efficiency (82.30%) provide essential insights into the planter's real-world operation.

In terms of cost economics, the analysis indicated a total operating cost per hour of Rs. 755.93. The Breakeven Point (BEP) was determined to be approximately 69.19 hours per year, signifying the minimum annual utilization required to cover acquisition and operating costs. The Payback Period (PBP) was estimated at 1.5 years, indicating the time needed to recover the initial machine cost through net annual profits. The Benefit-Cost Ratio (B:C ratio) demonstrated a favorable economic outlook, with a ratio of 1.2, suggesting that machine sowing with the seven-row inclined plate planter is economically advantageous compared to manual sowing.

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