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Enhancing sesame yield and profitability through refurbished tractor-drawn seed drills in coastal Andhra Pradesh

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Abstract
Sesame, a valuable oilseed crop in north coastal Andhra Pradesh, is primarily sown by broadcasting - a cost-effective method that, however, results in high weeding expenses and increased production costs. This study explores refurbishing a 4-row bullock-drawn seed drill to be tractor-compatible, addressing labour shortages and enhancing sesame cultivation efficiency. Field trials with the YLM-66 sesame variety at the Agricultural Research Station in Yelamanchili demonstrated that line sowing with the modified seed drill improved plant growth, yielding a 28% increase over broadcasting and achieving gross returns of ₹61,110 per hectare. Using a Random Forest (RF) model with 10-fold cross-validation, the study identified key predictors of sesame yield, achieving high accuracy (R^2 = 0.943, RMSE = 27.83) and validating the influence of the line sowing method on growth and yield parameters. This innovation offers small-scale farmers a cost-effective solution, promoting mechanization and reducing reliance on manual labour.

Keywords: Sesame, seed drill, sowing method, mechanization, labour shortage, Random Forest (RF) model

1. Introduction

Sesame (*Sesamum indicum* L.), a revered oil crop of the Pedaliaceae family, boasts a rich history as one of the oldest oil-rich plants, with its origins tracing back to Africa (Katanga and Buba, 2014) [10]. Acknowledged as one of the earliest domesticated edible oilseeds, sesame, commonly known as Til, flourishes in tropical and subtropical climates, thriving particularly well in temperate regions. With seeds containing approximately 50-60% oil content, alongside significant levels of protein and carbohydrates, sesame maintains stability thanks to antioxidants such as sesamol, sesaminol, and tocopherols (Islam *et al*. 2008) [8].

Global sesame cultivation in 2018-19, covers 128.21 million hectares of area with a production of 65.49 million tonnes and productivity of 510.8 kg/ha, underscores its vital role in nutrition and livelihoods. Sudan leads with 42.43 million hectares, followed by Myanmar (15.05 million hectares) and India (14.19 million hectares). While India is among the top producers, its productivity is lower than Nigeria, Ethiopia, Tanzania, and Burkina Faso, with an average yield of 485.4 kg per hectare compared to Nigeria's 818.4 kg per hectare. India's total sesame production in 2019 is estimated at 399.16 million metric tonnes (Tripathi *et al* 2023) [17]. With the largest area (1947 mha) and the third-highest production of sesame (866 mt), India's productivity is abysmally low in comparison to the global average (535 kg/ha) i.e., 413 kg/ha.

In Andhra Pradesh alone, sesame cultivation covers over 39,000 hectares for both food and oil production, yielding 14,000 tonnes during the 2021-22 season at a productivity rate of 343 kg/ha (Thentu *et al*., 2022) [16]. Sesame's nutritional richness, encompassing protein, calcium, iron, and essential vitamins, renders it invaluable for dietary supplementation, particularly for pregnant and lactating women. Despite its economic significance and contributions to the global sesame trade, research and extension gaps persist, particularly in the North coastal districts of Andhra Pradesh, where production potential remains largely untapped.

Sesame cultivation offers high economic returns, especially considering the rising market prices in recent years (FAO, 2023) [5], making it an attractive option for farmers. However, persistent research and extension gaps impede farmers from realizing its full potential.

Major costs involved in sesame cultivation include seed and weeding expenses, which account for over 50% of the total cost. Labor migration to urban areas has resulted in a shortage of labour, with dynamic wages during peak agricultural periods often exceeding the budget of small and marginal farmers. Consequently, crucial operations such as weeding and irrigation are frequently delayed or halted, leading to significant yield losses, sometimes exceeding 50%. Weed infestation at the initial growth stages of sesame suppresses the crop's growth, as sesame is a slow grower until flowering.

Although coastal districts of Andhra Pradesh occupy substantial area for sesame cultivation, they lag in production and productivity compared to other districts and national and global averages. Despite the national consumption and export value of sesame, North coastal districts do not treat it as a cash crop but rather as an incidental crop after rabi rice cultivation. Key constraints contributing to low yields include soil roughness, sowing methods, and high seed rates.

To address these challenges and shift farmers' perception of sesame from a chance crop to a cash crop, an initiative was undertaken at ARS Yelamanchili to refurbish 4 rowed bullock drawn seed drills into tractor-drawn ones. This initiative aimed to compare the productivity and profitability of line-sown sesame crops with traditional broadcasting methods.

2. Materials and Methods

2.1 Experimental Site, Setup and Sowing

An observational trail was conducted at Agricultural Research Station - Yelamanchili, Anakapalli dt., Andhra Pradesh during Rabi Summer season of 2021 and 2022. The study area lies in 17.57° N latitude and 82.85° E longitude with altitude 27 m above the mean sea level at North coastal area of Andhra Pradesh. The MAP (mean annual temperature) and MAP (Mean Annual Precipitation) was 31.4 °C and 1101 mm respectively for over period of 1990 to 2010. The soil of the experimental site is sandy soil with low organic content (0.1%), low available Nitrogen (165 kg N/ha), high available Phosphorus (50 kg P_2O_5/ha) and medium Potassium (189 kg K_2O/ha). The soils were neutral with pH 7.2. The experimental field of 1 ac was divided into two blocks eh comprising 0.4 acre with 4 meters kept as buffer between the two plots (Fig. 1). Each block is assigned with Line sowing method (S1) and Broadcasting method of sowing (S2) respectively. The experiment was laid out in randomized complete block design (RCBD) with unreplicated plots. To prepare fine seed bed, soil was ploughed with rotovator in secondary tillage. Sesame seed variety YLM 66 (Sarada) was sown with a seed rate of 5 kg is the broadcasting method (farmers practice) and in the line sowing 2 kg seed was mixed with 10 kgs broken rice to reduce the number of seeds per pocket with refurbished seed drill. In Broadcasting method of sowing the handful of seeds were distributed homogeneously manually moving front and back in the plot then the levelling plank was run over the field to cover the seeds.

Fig 1: experimental site with parcel S1: representing the treatment (line sowing) plot and parcel S2: control (broadcasted) plot

2.2 Cultural Practices

In line sowing method the seeds were placed in the seed box of refurbished seed drill and sown with tractor as shown in the Fig 2. Spacing maintained was 45 cm between the rows and 10 cm between the plants. After completion of the sowing the seed were covered with soil with the help of levelling plank same as broadcasting method of sowing. fertilizers were applied in the form of urea, Diammonium phosphate (DAP), Murate of potash (MOP) for the source of nitrogen, phosphorus, and potassium respectively at the of 40:20:0 Kg NPK/ha. N fertilizer was applied in two splits 2/3rd dose applied as basal and remaining 1/3rd is applied at 30 DAS (Days After Sowing) P and K were applied as basal. Thinning operation was done in both the treatments at 21 DAS. In broadcasting method weed was scheduled twice at 20 and 30 DAS. In line sowing method, weeding was done at 30 DAS with power weeder in the interow.

Fig 2: Sowing operation with refurbished seed drill

2.3 Refurbishing of seed drill

The 4 rowed bullock drawn seed drill, which was developed by ARS Anantapur during 2010 -12 (Reddy *et al* 2015) [12] Fig 3 was refurbished into tractor drawn seed drill (Fig 4). The bullock drawn seed drill´s hitching unit consist of 2 MS pipes of 375 mm diameter and 3200 mm length; these hitch unit were removed. A frame and hitch developed to suit tractor (Fig 3). The seed consists of a seed hoper, a trough feed type seed metering mechanism, a 300 mm diameter ground wheel, and chains and sprockets for power transmission. 1.2 meters is the breadth of the planter. The spacing between plants and rows is 100 mm between plants and 300 mm between rows. The machine weighs a total of 55 kilograms and has a field capacity of 2.0 to 2.4 hectares per day. The expense for developing an original equipment was Rs. 8000, while the hourly cost of operation is Rs. 150 in the year 2015. Refer to Reddy *et al* 2015 [12] for other details of the seed drill. For refurbishment the additional amount of Rs. 5000 was spent.

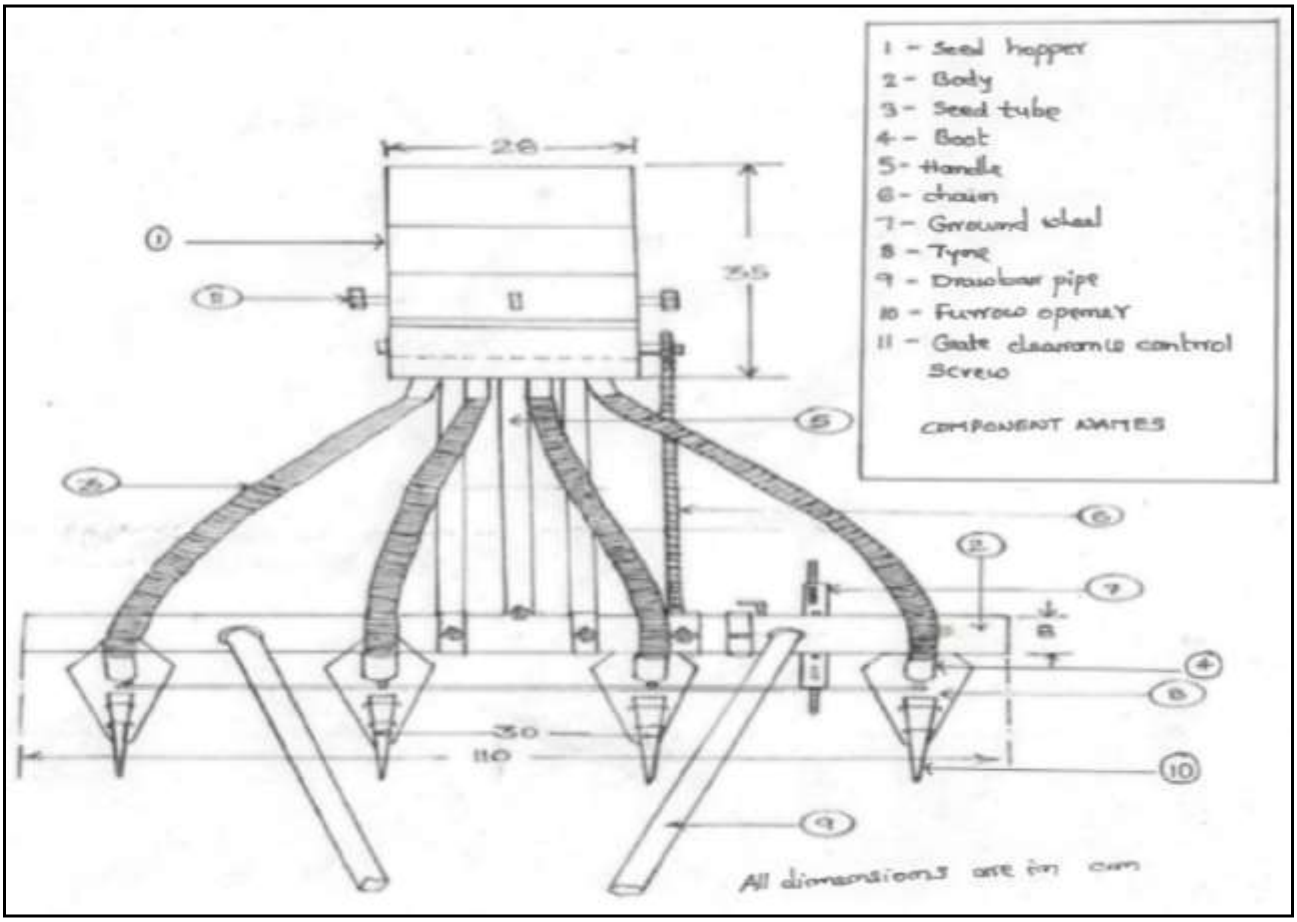

Fig 3: Seed drill developed by Reddy *et al*. 2015 [12]

Fig 4: Refurbished seed drill at ARS- Yelamanchili used in the experiment

2.4 Data collection and statistical analysis

Data on growth and yield parameters were collected from randomly selected plants within each block to ensure representativeness. A t-test was applied to evaluate statistically significant differences between treatments. Statistical analysis and data visualization were performed using R.

Due to the experimental limitations in randomization associated with the use of a seed drill, a Random Forest (RF) model was employed to enhance data robustness and validate the relationships between growth variables and seed yield. The RF model, consisting of 500 trees, was optimized using a 10-fold cross-validation approach to assess predictive accuracy. Key performance metrics, including Root Mean Square Error (RMSE), R-squared (R^2), and Mean Absolute Error (MAE), were used to evaluate model accuracy and determine the most influential factors affecting yield.

3 Results and Discussion
3.1 Growth parameters
Line sowing method yielded positive results in case of the growth parameters and the comparative results are presented in Table 1. Line sowing with seed drill led to significantly taller plants both at 45 DAS and at harvest compared to broadcasting. This is evident from the mean plant heights of 88.3 cm and 105.8 cm at 45 DAS and at harvest, respectively, for line sowing, whereas broadcasting resulted in shorter plants with mean heights of 80.8 cm and 98.1 cm at the same stages. This difference was statistically significant with a p-value of 0.01. The taller plant height observed in line-sown plants can be attributed to better seed placement and spacing, allowing individual plants to access more resources such as sunlight and nutrients. Adnan *et al*. (2015) [1] and Islam *et al*. (2008) [8] encountered the similar results and concluded that plant density and sowing method has significant effect on plant height. In line sowing, seeds are typically placed at regular intervals along rows, ensuring less competition among plants for resources compared to broadcasting, where seeds are scattered randomly. As a result, line-sown plants exhibit better vertical growth, which is crucial for maximizing photosynthesis and overall biomass production.

Similarly, resulted were encountered with greater number of branches per plant both at 45 DAS and at harvest compared to broadcasting. At 45 DAS, line sowing produced, on average, 4.0 branches per plant, whereas broadcasting resulted in only 2.8 branches. At harvest, the number of branches increased to 6.5 for line sowing and 4.5 for broadcasting. This difference was statistically significant with p-values of 3.65 and 8.97, respectively. Hamid *et al*. (2002) [6] also observed that line sowing resulted in highest number of branches/plant. The increased number of branches in line-sown plants indicates better branching architecture, which can contribute to higher overall productivity. More branches mean more sites for flower and fruit development, ultimately leading to increased yield potential. The uniformity achieved through line sowing likely promotes consistent branch formation and distribution, enhancing the plant's ability to capture sunlight and produce assimilates.

Additionally, the dry matter weight per plant was substantially higher for line sowing compared to broadcasting at both 45 DAS and at harvest. At 45 DAS, line sowing resulted in a mean dry matter weight of 8.5 g per plant, whereas broadcasting yielded only 6.1 g per plant. At harvest, these values increased to 27.9 g and 21.5 g, respectively. The differences observed were statistically significant with p-values ranging from 3.30 to 8.40. Hamid *et al*. (2002) [6] and Imoloame *et al*. (2007) [7] also achieved comparable results showing that shoot dry matter weight was consistently greater in line sowing compared to broadcasting across the entire growth period. The increased dry matter accumulation in line-sown plants reflects enhanced biomass production and better utilization of available resources. Line sowing facilitates optimal spacing between plants, reducing intraspecific competition and allowing each plant to access adequate sunlight, water, and nutrients. Consequently, line-sown plants allocate more resources towards above-ground biomass accumulation, resulting in higher dry matter weights compared to broadcasted plants. This increased biomass can translate to higher yields and improved crop quality.

Table 1: Effect of sowing methods on growth parameters of sesame

Treatment	Plant ht. at 45 DAS	Plant ht. at harvest	No. of branches at 45 DAS	No. of branches at harvest	Drymatter weight per plant (g) at 45 DAS	Drymatter weight per plant (g) at harvest
Line Sowing	88.3	105.8	4.0	6.5	8.5	27.9
Broadcasting	80.8	98.1	2.8	4.5	6.1	21.5
SD	11.6	7.0	0.8	1.3	1.4	3.8
S.Em (±)	1.5	0.9	0.6	0.2	0.2	0.5
t Stat	2.6	5.1	9.1	10.6	12.4	11.9
p-value	0.01	3.7	8.9	3.3	8.4	3.6
CV	13.8	12.9	22.4	23.3	19.7	15.5

3.2 Yield attributing characters
The comparison of yield attributing characters of sesame plants under different sowing methods, namely line sowing and broadcasting are shown in Table 2 and Fig. 5. The results indicate significant differences in various parameters, shedding light on the influence of sowing technique on yield-related traits. Firstly, the days to first flowering were significantly longer in line-sown plants (43.3 days) compared to those broadcasted (40.6 days), with a p-value of 0.0003, indicating statistical significance. This delay in flowering could be attributed to the denser arrangement of plants in line sowing, leading to increased competition for resources and subsequently delaying flowering initiation. Furthermore, the number of capsules per plant was significantly higher in line-sown plants (42.4) compared to broadcasted ones (32.6), with a t-statistic of 16.4 and a p-value of 4.7, highlighting the substantial impact of sowing method on reproductive output. This difference underscores the importance of proper seed placement and spacing in maximizing capsule formation, a crucial determinant of overall yield.

Additionally, the number of seeds per capsule was significantly greater in line-sown plants (56.3) compared to broadcasted plants (48.5), with a t-statistic of 11.01 and a p-value of 1.85. This suggests that line sowing promotes better seed set per capsule, possibly due to reduced intra-plant competition and more efficient resource allocation. Moreover, both seed weight per plant and 1000-seed weight were significantly higher in line-sown plants compared to broadcasted ones, with t-statistics of 25.02 and 6.86, and p-values of 1.16 and 6.48 respectively. This indicates that line sowing not only enhances seed production but also leads to the development of larger and heavier seeds, which are vital for improving overall yield and seed quality (Hamid *et al*. 2002, Caliskan *et al*. 2004 and Adnan *et al*. 2013) [6, 3, 1].

Table 2: Effect of sowing methods on yield attributing characters of sesame

Treatment	Days to 1st flowering	Number of capsules / plants	Number of seeds / capsules	Seed weight / plant (g)	1000 seed weight (g)
Line Sowing	43.3	42.4	56.3	5.3	2.6
Broadcasting	40.6	32.6	48.5	3.9	2.3
SD	3.02	5.5	4.8	0.7	0.24
S.Em (±)	0.39	0.7	0.6	0.09	0.03
t Stat	3.8	16.4	11.0	25.0	6.9
p-value	0.0003	4.7	1.9	1.2	6.5
CV	7.2	14.5	9.2	15.8	9.9

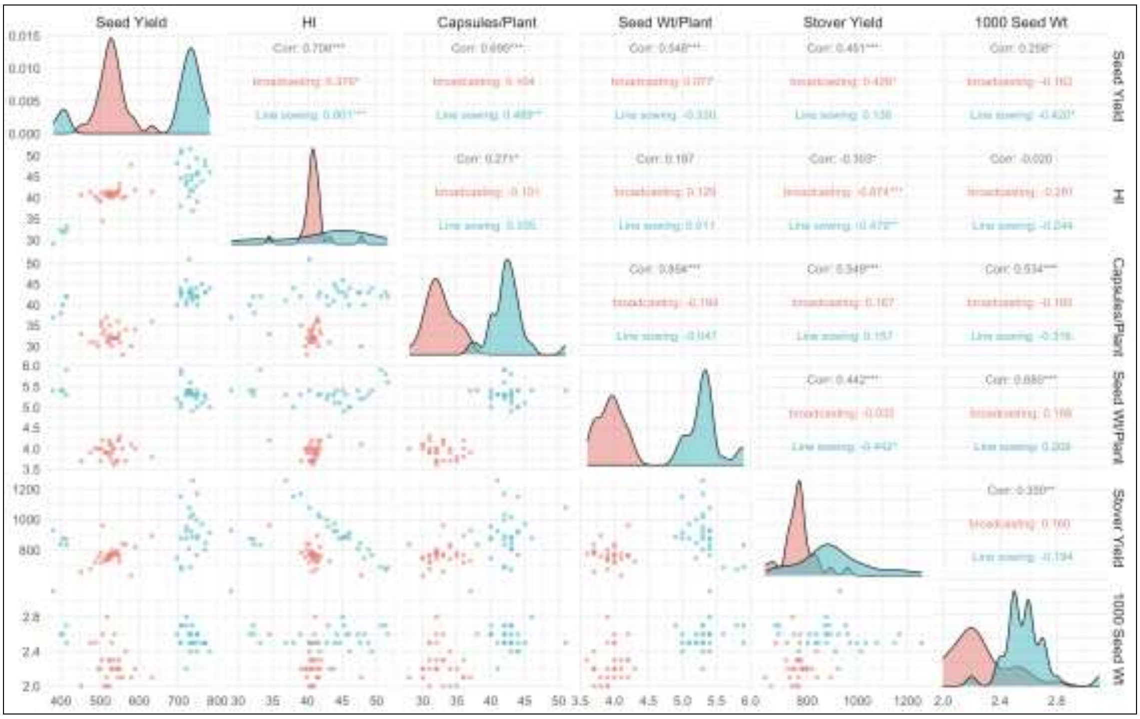

Fig 5: Yield parameter interactions for line sowing and broadcasting treatments

3.3 Yield and Economic

The results highlight significant differences between the two methods in terms of yield and economic indicators, shedding light on their effectiveness in sesame cultivation (Table 3). Line sowing resulted in a higher seed yield of 679 kg/ha compared to 530 kg/ha achieved through broadcasting. This difference in seed yield was statistically significant (t-statistic = 6.17, p-value = 5.66), indicating the superiority of line sowing in maximizing seed production. Similar results were encountered with Katanga *et al*. (2017) [10] stated that seed is significantly influenced by line sowing method. The increased seed yield under line sowing can be attributed to better seed placement and spacing, resulting in reduced intra-plant competition and more efficient resource utilization.

Similarly, line sowing also outperformed broadcasting in stover yield, with 905 kg/ha compared to 767 kg/ha, respectively. This difference was statistically significant (t-statistic = 4.95, p-value = 1.33), indicating the effectiveness of line sowing in maximizing overall biomass production. Wakweya and Meleta (2016) [18] supported the current findings. The higher stover yield under line sowing suggests better crop establishment and canopy development, leading to increased biomass accumulation. The harvest index, which represents the proportion of total biomass allocated to seeds, was slightly lower in line-sown plants (40.90%) compared to broadcasting (42.70%). However, this difference was not statistically significant (p-value = 0.14), suggesting that both sowing methods are comparable in terms of resource allocation efficiency.

In terms of economic indicators, line sowing resulted in higher gross returns (Rs/ha) compared to broadcasting, with Rs 61,110/ha and Rs 47,700/ha, respectively. Additionally, the B:C ratio was substantially higher for line sowing (2.72) compared to broadcasting (1.41), indicating better economic viability and profitability of line sowing.

Table 3: Effect of sowing methods on yield and economics

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Gross returns (rs/ha)	B:C Ratio
Line Sowing	679	905	40.9	61110	2.72
Broadcasting	530	767	42.7	47700	1.41
SD	119	127	4.7		
S.Em (±)	15.4	16.5	0.6		
t Stat	6.2	4.9	1.5		
p-value	5.7	1.3	0.1		
CV	19.7	15.3	11.1		

3.4 Random Forest Model Outcomes

The Random Forest model confirmed the importance of several key predictors for seed yield. Variables such as Harvest Index (HI), Number of Capsules per Plant, and Seed Weight per Plant had the highest importance scores, underscoring their strong influence on yield (Table. 4). The treatment factor (line sowing vs. broadcasting) also emerged as an influential predictor in the model, indicating that the choice of sowing method itself has a substantial effect on yield. However, it is important to note that treatment likely reflects a combination of effects across other growth parameters (e.g., plant height, branch count), as line sowing improved these factors relative to broadcasting.

Table 4: Key Predictors of Seed Yield

Predictor	Importance Score (IncMSE)
Harvest Index (HI)	17.26
Number of Capsules per Plant	15
Seed Weight per Plant	9.46
Stover Yield	9.19

The model achieved high predictive accuracy, with a 10-fold cross-validated R-squared of 0.943, a Root Mean Square Error (RMSE) of 27.83, and a Mean Absolute Error (MAE) of 21.93 as shown in table 5. These results reinforce the reliability of line sowing in enhancing sesame yield and validate the observed trends across growth parameters.

Table 5: Summary of Random Forest Model Performance and Variable Importance

S. No.	Metric	Value
1	Number of Trees	500
2	Optimal mtry	16
3	Cross-Validated R-squared	0.943
4	Root Mean Square Error (RMSE)	27.83
5	Mean Absolute Error (MAE)	21.93

4. Conclusion

Refurbishing traditional bullock-drawn seed drills into tractor-compatible models significantly enhances sesame productivity and profitability, presenting a practical solution to the labour-intensive broadcasting method. Line sowing using the modified seed drill achieved a 28% increase in productivity and higher gross returns, demonstrating its economic viability for small and marginal farmers in coastal Andhra Pradesh. The Random Forest model confirmed the reliability of line sowing, with high predictive accuracy (R^2 = 0.943, RMSE = 27.83), identifying Harvest Index and capsule count as key predictors of yield. These findings underscore the advantages of optimized sowing techniques, addressing labour shortages and promoting farm mechanization to make sesame cultivation more sustainable. Future initiatives should focus on promoting this innovation among farmers and further refining the equipment for broader adoption, ultimately enhancing the resilience and profitability of sesame farming in the region.

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