Optimizing Small-Scale Farming: A Review of Manually Operated Vegetable Seed Sowing Machine Performance

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ABSTRACT:

Small-scale farming plays a crucial role in global vegetable production, particularly in regions where resources and mechanized equipment are limited. Traditional manual sowing methods are labor-intensive and often result in inconsistent seed placement, leading to suboptimal crop yields. This review paper examines the performance of manually operated vegetable seed sowing machines as a means to optimize small-scale farming practices. By analyzing recent advancements and evaluating key performance metrics—such as field capacity, seed placement accuracy, labor efficiency, and cost-effectiveness—this review highlights how these machines can enhance productivity and reduce labor costs. The paper also discusses the influence of various design features on machine performance, including seed metering mechanisms, furrow openers, and ergonomic considerations. Through a comprehensive analysis of existing literature and case studies, this review aims to provide insights into the effectiveness of these machines and offer recommendations for future improvements to better support small-scale farmers. The findings underscore the potential of manually operated seed sowing machines to contribute significantly to the optimization of vegetable production in resource-constrained settings.

Keywords: Small-Scale Farming, Manually Operated Machines, Seed Sowing Performance, Field Capacity, Labor Efficiency, Cost-Effectiveness, Machine Design, Ergonomics, Manual Sowing Techniques, Agricultural Innovation, Performance Metrics

1. INTRODUCTION

Vegetable production plays a crucial role in global agriculture, significantly contributing to food security and economic stability, particularly for small-scale farmers. However, these farmers often face challenges such as labor intensity, inconsistent seed placement, and inefficiencies with traditional sowing methods. These issues can reduce productivity and crop yields, ultimately impacting farmers' incomes and food availability. Traditional seed sowing methods are typically manual and labor-intensive, requiring considerable effort and time to ensure proper seed placement and spacing. Inconsistent seed distribution can lead to uneven crop growth, increased competition among plants, and reduced yields. Additionally, these methods often involve significant physical strain on farmers, affecting their health and overall productivity.

To address these challenges, manually operated vegetable seed sowing machines have been developed to improve efficiency and precision in small-scale farming. These machines streamline the sowing process by providing consistent seed placement, optimal depth, and uniform row spacing. This enhances crop uniformity, reduces labor requirements, and is particularly advantageous in resource-limited settings where access to powered machinery is limited.

Mechanization not only boosts production and productivity but also lowers labor costs and reduces drudgery. Tailored seed application specific to the site is crucial for maintaining crop growth and minimizing production costs (Guru PK et al. 2015). However, a significant constraint in boosting productivity is that planting operations are among the least mechanized in farming, with only 29% mechanization (Mehta CR et al. 2014).

Agdag et al. (2001) noted that row spacing affects grain yield and various agronomic traits of millet. In India, millets are typically sown using broadcasting methods or traditional implements, leading to uneven seed distribution, excessive plant populations, and irregular spacing, which ultimately reduces crop yield (Norris, 1988). Broadcasting and drilling methods also impede intercultural operations and effective weed control, making harvesting and threshing more efficient when sowing is done in lines (Khan and Sahrigi, 1990).

The inclined plate seed metering device features a metering plate with peripheral cells, each designed to carry a single seed from the hopper to the furrow at the appropriate time (Kepner et al., 1978). Uniform seed spacing is a crucial consideration in the design of these devices.

India ranks second globally in agricultural output (Kumar et al., 2016). However, around 65 percent of Indian farmers are small-scale or marginal landholders, making it difficult for them to afford costly agricultural machinery and equipment. Anusha et al. (2021) emphasizes the need for affordable and accessible farm machinery to reduce physical strain on farmers and minimize product damage. Nandede et al. (2018) highlight that a lack of available labor can cause delays in transplanting, directly affecting crop production and farmers' economic conditions. Vignesh et al. (2017) note that despite advancements in transplanting vegetable seedlings, many small-scale farmers cannot adopt advanced non-renewable power sources due to their socio-economic status.

The shortage of farm labor during critical times underscores the need for mechanization in onion cultivation to expand the net sown area (Rao JH et al. 2019). India ranks second in the world for fruits and vegetable production, with significant outputs during 2023-24, including 112.62 million metric tonnes of fruits and 204.96 million metric tonnes of vegetables.

This review paper aims to evaluate the performance of manually operated vegetable seed sowing machines with a focus on optimizing small-scale farming practices. By analyzing various performance metrics such as field capacity, seed placement accuracy, labor efficiency, and cost-effectiveness, the review seeks to provide a comprehensive understanding of how these machines can improve agricultural practices. It will also examine the influence of different design features and operational parameters on machine performance, offering insights into potential areas for improvement. The review covers a range of manually operated seed sowing machines, highlighting advancements in design and technology, and providing a comparative analysis of their effectiveness across various contexts. Challenges and limitations associated with these machines will also be addressed, with suggestions for future research and development.

2. PERFORMANCE EVALUATION OF MANUALLY OPERATED MACHINE.

Waikar A. V. designed a lightweight, cost-effective, and reliable manually operated seed sowing machine aimed at improving crop efficiency while reducing labor and expenses for small-scale farmers. The machine, specifically designed for sowing cotton seeds, addresses outdated agricultural methods by requiring less energy and increasing efficiency. It integrates autonomous systems to enhance accuracy and productivity, helping to reduce costs and boost profitability in the agricultural sector.

Nakate Shivaprasad Madan designed a manually operated single-row multi-crop planter. After successful laboratory calibration, it was field-tested over 0.075 hectares at 1.80 km/h. The planter achieved a field efficiency of 69.44%, a capacity of 0.075 ha/h, and an operational cost of Rs. 357 per hectare.

Ghosal and Sarkar developed a low-cost manual multi-crop seed drill. With cup dimensions of 6 mm × 2.89 mm at a peripheral speed of 18.84 m/min, it effectively sowed black gram. The seed drill achieved a field capacity of 0.063 ha/h and a field efficiency of 78.75%, saving Rs. 1780/ha compared to traditional methods. Priced at Rs. 1850, its operating cost was Rs. 13.85 per hour for row sowing.

Vijay developed a manually operated double-row vegetable planter and fertilizer applicator, weighing 38 kg and costing Rs. 22,890. It achieved recommended seeding rates for okra (13.97 kg/ha), pea (152.80 kg/ha), and corn (16.20 kg/ha), with actual field capacities of 0.068 ha/h, 0.066 ha/h, and 0.064 ha/h, respectively. Field efficiencies were around 75%, and the machine features a gear and chain drive, T-shaped furrow opener, plastic hoppers, and a flat conveyor belt for efficient operation.

Verma developed a 40 kg manually operated double-row vegetable seed planter for small farmers with less than 1 hectare of land, costing Rs. 17,150. It features a chain and sprocket drive, seed hopper, drive wheels, and plastic seed delivery tubes. Tested for okra, cowpea, dolichos bean, and pea, it achieved seeding rates of 14.97–152.80 kg/ha, field capacities of 0.049–0.052 ha/h, and efficiencies of 68%–72.2%. Sowing costs ranged from Rs. 1019.2 to Rs. 1081.6 per hectare.

Shubham Shravan et al. evaluated a manually operated single-row vegetable planter for okra, coriander, and cowpea, addressing traditional sowing inefficiencies in Chhattisgarh. The planter, costing Rs. 5930, features a power transmission system, seed box, and furrow opener. Tested with "Kashi Kanchan" cowpea, "Pant Haritama" coriander, and a local okra variety, it achieved effective field capacities of 0.104 ha/h for okra, 0.093 ha/h for cowpea, and 0.039 ha/h for coriander, with field efficiencies of 78% to 83.2%.

Shravan and Jogdand evaluated a manually operated single-row vegetable planter for okra, coriander, and cowpea to improve traditional sowing methods in Chhattisgarh. The planter, costing Rs. 5930, features a power transmission system, seed box, and furrow opener. It achieved effective field capacities of 0.104 ha/h for okra, 0.093 ha/h for cowpea, and 0.039 ha/h for coriander, with field efficiencies ranging from 78% to 83.2%.

Shravan developed a 19 kg manually operated single-row vegetable planter for okra, coriander, and cowpea, priced at Rs. 5930. Featuring a chain and sprocket system, it was tested for seed calibration, moisture content, and field capacity. The planter achieved seed rates of 15.39 kg/ha for cowpea, 16.2 kg/ha for okra, and 20.7 kg/ha for coriander, with field efficiencies of 78% to 83.2%. Sowing costs were Rs. 423/ha for okra, Rs. 473/ha for cowpea, and Rs. 1128/ha for coriander.

B.M. Nandede et al. developed a manually drawn three-row planter for kodo and little millet after testing optimal slot sizes (2×3 mm, 2.5×3 mm, 3×3 mm). Slot size MS3 was best for kodo millet, while MS1 was optimal for little millet. The planter achieved a field capacity of 0.09 ha/h, efficiency of 55%-59%, and saved 76%-93% of seeds compared to traditional methods. It cost Rs. 8650 with an operational cost of Rs. 565/ha, yielding 1650 kg/ha for kodo millet and 1545 kg/ha for little millet.

B.M. Nandede et al. developed a manually operated single-row planter-cum-fertilizer drill for kodo and little millet. The optimal slot size (3×3 mm) achieved seed spacings of 5.90 cm for kodo and 5.70 cm for little millet, with seed rates of 4.50 kg/ha and 2.24 kg/ha. The drill had field capacities of 0.048 ha/h and 0.05 ha/h, with 68%-69% efficiency, saving 76%-93% of seeds compared to traditional methods. Operational costs were ₹750/ha for kodo and ₹662/ha for little millet, yielding 1870 kg/ha and 1560 kg/ha.

Nandede and Solanki developed a low-cost manually operated nursery seeder for tomato, brinjal, and chili. It included a base plate, media firming-cum-watering plate, hole-forming plate, and seeding plates. Optimal for brinjal was a 2 mm thick plate with a 2.9 mm orifice, and for chili and tomato, a 2 mm thick plate with a 3.5 mm orifice, providing cost and time savings.

Meena et al. assessed a manually operated two-row planter for onion seeds. Designed to address high labor demands and low productivity in India's largely manual onion cultivation, the planter allows for direct seed sowing in prepared fields and can be operated by a single person walking behind it, aiming to improve efficiency and productivity.

Lokesh and Anusha introduced a pull-type three-row dibble wheel to enhance planting efficiency by creating evenly spaced holes for accurate seed placement, reducing manual labor. The tool's ergonomic design reduces operator fatigue. The performance metrics indicated notable enhancements in effective field capacity (EFC), field efficiency (FE), operational cost (COP), and cost savings (SC) when compared to traditional methods. Statistical analysis revealed notable differences in intradibble spacing, EFC, and FE, while hole diameter and depth remained consistent, making the dibble wheel beneficial for small-scale farmers.

Lohakare developed a manually operated nursery vegetable planter for chili, brinjal, and tomato, featuring a horizontal plate seed metering mechanism. Designed for raised bed nurseries with four rows, it includes an adjustable handle and is constructed from M.S. angle iron. Performance tests at speeds of 1.0–1.5 km/h achieved seed rates of 2.19 g/m² for chili, 2.28 g/m² for brinjal, and similar for tomato, with minimal seed damage. The planter had an effective field capacity of 0.036 to 0.053 ha/h, field efficiencies of 90-92%, and 67.2% cost savings compared to traditional methods. Its total cost was Rs 6650, with significantly lower operational costs.

Kumar et al. evaluated a manually operated ridge vegetable planter for okra, featuring an ABS polymer seed-metering roller, mainframe, and tyne. With a forward speed of 1.60 km/h and roller speed of 1.40 km/h, it achieved an effective field capacity of 0.046 ha/h and 86.79% field efficiency. The planter saved Rs. 813 per hectare, reduced labor by 51.1%, and had a payback period of 2.01 years compared to manual methods.

Kotwal et al. developed a Single-Row Manual Seedling Planter for small-scale farmers. It operates solely on human effort, using a gear and chain drive system. Designed for single-row planting with two operators, it reduces labor costs and prevents back pain. Its affordability, low maintenance, and ease of use make it ideal for small-scale farming.

Korla Harshavardhan et al. developed an affordable, manually operated single-row vegetable seedling planter for ridges and mulched beds. The transplanter, which weighs 2.4 kg and costs Rs 500, features a jaw assembly and delivery pipe. It plants 12 seedlings per minute, compared to 5 manually, with a field capacity of 0.0166 ha/h and field efficiency of 42-57%. Operational costs are reduced to Rs 1753/ha from Rs 9218/ha, significantly outperforming traditional methods.

Geetanjali Dhupal et al. developed a low-cost, manually operated two-row tomato transplanter for raised beds. It features a dropping structure, main frame, furrow opener, handle, and seeding plate. Tested at speeds of 0.083 m/s, 0.079 m/s, and 0.076 m/s, it achieved a field efficiency of 72.9%, a theoretical field capacity of 0.0343 ha/h, and an effective field capacity of 0.024 ha/h. The planter averaged a planting depth of 5.8 cm, with a missing percentage of 5.33% and 1.07 seedlings per hill.

Dixit et al. developed a manual single-row vegetable transplanter for brinjal, chili, and tomato seedlings. It features a hopper, delivery tube, jaw lever, and jaw mouth. The transplanter achieved an effective field capacity of 0.029 ha/h and a field efficiency of 91.34%. It reduced labor by 52.83%, lowered transplanting costs to Rs 1308.16/ha, and minimized discomfort compared to traditional methods.

Dhupal and Sahu developed a manual two-row tomato transplanter to improve efficiency and affordability. It features a dropping structure, furrow opener, and press wheels. Tested at speeds of 0.083, 0.079, and 0.076 m/s with 45-day-old seedlings, it achieved an average field efficiency of 72.9%, and theoretical and effective field capacities of 0.0343 ha/h and 0.024 ha/h, respectively. Higher speeds led to increased missing percentages and wider plant spacing but lower capacities and efficiency.

Balveer Singh Meena et al. developed a manually operated two-row onion planter to reduce labor and costs. It features a vertical rotor-type metering mechanism with a 2.5 mm × 3 mm slot, achieving a seed rate of 7-8 kg/ha at 2 km/h. The planter demonstrated a field capacity of 0.042 ha/h, 78% efficiency, and required 48 man-hours per hectare, compared to 800-960 hours manually. It achieved yields of 14.9 t/ha, similar to manual methods, and facilitated cost savings and uniform crop establishment.

Balveer, S. M. et al. developed a manually operated two-row planter to address the challenges in onion cultivation, where India, the second-largest producer globally, still relies heavily on manual labor. The unmechanized nature of onion farming leads to high labor demands and low productivity. The newly developed planter allows direct sowing in prepared fields and can be operated by a single person walking behind it. It was tested in both laboratory and field conditions, focusing on key performance metrics: missing index, multiple index, and quality of feed index, which were recorded as 11.5%, 25%, and 63%, respectively.

Arun Joseph Thomas et al. developed a manual vegetable seeding machine to address labor shortages and inefficiencies in nurseries. The machine, designed with CAD, includes soil removal blades, seed hoppers, a covering plate, a braking mechanism for seed feeding, and a water tank. It aims to reduce time and effort in nurseries and enhance practicality for farmers.

3. SUMMARY AND CONCLUSION

This section details the development and performance evaluations of various manually operated vegetable planters and transplanters, aimed at improving efficiency and reducing labor for small-scale and marginal farmers. Each device is tailored to specific crops and farming conditions, with a focus on cost-effectiveness, ease of use, and field efficiency.

This transplanter featured a frame, a seedling drop tube, furrow openers, press wheels, and a handle. Designed for small-scale farmers, it could be operated by a single person and was particularly effective in reducing labor costs and time compared to traditional methods.

Manually operated seed sowing machines offer a practical solution for small-scale farmers, particularly in regions with limited access to powered machinery. They help address common challenges associated with traditional sowing methods, such as labor intensity and inconsistent seed distribution. The review evaluates various performance metrics, including field capacity, seed placement accuracy, labor efficiency, and cost-effectiveness. Key design features, such as seed metering mechanisms, furrow openers, and ergonomic considerations, are discussed in relation to their impact on performance.

Case studies and research findings demonstrate that manually operated machines can significantly enhance farming efficiency. For example, improved seed placement accuracy and reduced labor requirements contribute to better crop yields and lower overall costs. However, challenges remain, including the need for regular maintenance and operator training.

The review concludes that manually operated vegetable seed sowing machines are a valuable asset for optimizing small-scale farming. These machines provide a cost-effective and efficient solution for improving seed sowing practices, which is crucial for smallholder farmers who may not have access to advanced mechanized equipment.

Future research should focus on addressing the challenges identified, such as improving machine durability and ease of maintenance. Additionally, there is a need for further innovation in design to cater to specific crops and diverse field conditions.

Overall, the adoption of manually operated seed sowing machines holds promise for enhancing small-scale vegetable farming, making it more efficient and sustainable. Continued development and optimization of these machines will support the goal of achieving greater productivity and sustainability in smallholder agriculture.

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