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Tugal vs push-type planter: A comparative study in a tropical country

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Abstract

The application of appropriate planting technologies is crucial for improving smallholder agricultural productivity in tropical regions. The seed planting process affects crop yield, efficiency, and resource use. This study compares the performance of the traditional *tugal* planting method and the push-type planter to evaluate their suitability under tropical field conditions. This study conducted a comparative assessment focusing on four key parameters: labour efficiency, seed placement precision, soil adaptability, and economic feasibility. Data were collected through direct observation of plating rate, uniformity of seed spacing, adaptability across varying soil conditions, and the expense to smallholder farmers. The *tugal* method demonstrated advantages in terms of low cost, simplicity, and adaptability to diverse terrains. However, it was less efficient due to poor seed spacing uniformity and high labour requirements. Conversely, the push-type planter improves planting speed, seed distribution accuracy, and long-term labour savings. The weaknesses included the heavier weight, reduced effectiveness in uneven soils, and higher initial investment costs. The findings suggest that *tugal* is practical in resource-constrained environments, while push-type planters enhance efficiency and precision. The balance of technological benefits with socio-economic realities is crucial for guiding smallholder farmers in applying the appropriate planting technology in tropical agricultural systems.

Keywords: labour efficiency, mechanized seeding, precision agriculture, smallholder farming, seed planters

1. Introduction

Planting strategies, specifically in tropical countries, are crucial to establishing the overall efficiency and sustainability of agricultural practices. They have a direct impact on labor productivity, field capacity, precision seed planting, soil adaptation, energy usage, and environmental preservation [1]. Traditional tools, like the *tugal* planter, are primarily reliant on manual labor, making planting physically hard, time-consuming, and labor-intensive. This method is still widely used in small-scale farming, since it is inexpensive and simple [2], [3]. However, it reduces productivity and frequently leads to inconsistencies in seed distribution, which can lead to uneven development and low crop stands [4].

The push-type planter offers a more efficient alternative by optimizing the planting process and minimizing manpower demands [5], [6], [7]. It increases field capacity, allowing bigger areas to be planted in less time, which is especially useful for medium to large-scale agriculture [8]. The push-type planter enhances seed placement accuracy by maintaining regular depth and spacing, which promotes greater germination and reduces the weed onslaught [9]. Technological advancements in *tugal* planters, such as the incorporation of double-function spring systems, have led to enhanced efficiency and reduced physical strain. However, they continue to trail behind push-type planters in terms of overall performance.

The push-type planter integrates mechanical features and appears to use energy more efficiently. It often brings innovative designs that save energy while preserving planting accuracy, and it covers more ground with less human labor [10]. Even though the *tugal* planter is fuel-free, it is entirely dependent on manual power, which limits the scalability. Planting practices have a significant impact on environmental sustainability. Push-type planters are designed to reduce soil disturbance, preserve soil structure, retain moisture, and prevent soil compaction. All of which are necessary for long-term soil health and productivity [11].

Manual digging with the *tugal* planter, on the other hand, might result in localized soil compaction, which reduces water infiltration and root development [12]. Some modern push-type models even have precision agriculture capabilities that improve seed and fertilizer delivery, while reducing chemical release and increasing sustainability [13], [14]. *Tugal* planters remain appealing to smallholders due to their modest initial investment, despite having greater long-term labor expenses [2]. Although push-type planters are expensive, they provide long-term economic benefits by increasing efficiency and lowering labor costs [15]. The latest models have become more economical and efficient, making them available to a wider range of farmers.

Therefore, improving planting techniques to achieve high-value commodities like corn can be conducted by utilizing narrow spacing, specific planting patterns, and improved seed placement technology. This approach can increase yields and overall sustainability [16]. These developments contribute to increased resource efficiency, lower input costs, and reduced environmental impacts [17], [18], [19]. However, smallholder farmers frequently encounter problems such as limited access to modern equipment, low soil fertility, and insufficient knowledge about improved planting techniques [20], [21], [22], [23]. To address these concerns, targeted support and actions are required. Providing farmers with an inexpensive, effective planting technology, best practice training, and improved resource management tools is crucial to long-term agricultural productivity increase and sustainability [24].

Traditional planting methods, such as the *tugal* planter, need physical labor and result in inaccurate seed placement. It leads to uneven crop growth and inefficient land use [5]. Although push-type planters enhance efficiency, seed accuracy, and labor requirements, smallholder farmers frequently struggle with the high initial cost and adaptation to a variety of soil conditions [25], [26], [27]. Furthermore, while current push-type planters help to promote sustainability by reducing soil disruption and maximizing resource usage, the consideration of their accessibility and suitability for small farms persists [28]. Addressing these challenges is crucial to enhancing agricultural productivity while maintaining cost-effectiveness and environmental sustainability [29].

This study compares the labor efficiency, field capacity, and energy consumption of *tugal* and push-type planters. It also contrasts the amount of time and effort necessary to operate each kind to determine which planter produces more productivity and better energy utilization under varied field circumstances.

Another important goal is to understand how seed planting precision and soil adaptation influence crop emergence and total productivity. Proper depth and spacing during planting have a substantial impact on germination rates, crop uniformity, and final yields, making it an important aspect in evaluating planter effectiveness.

The study also aims to assess the environmental impact of various planting methods for tropical countries, namely in terms of soil disruption and resource optimization.

Understanding how each planter influences soil structure, moisture retention, and compaction can aid in determining sustainable agricultural practices.

Additionally, the study evaluates the economic viability of push-type planters for small and medium-sized farms. While the initial expenses may be higher, the long-term benefits of labor savings and increased efficiency may make them more cost-effective. At last, the study confirms the ergonomic benefits of push-type planters. This equipment contributes to less tiredness and improved overall working conditions for farmers who do everyday field tasks by reducing physical strain and enhancing operator posture.

2. Methods

The study compared the performance of *tugal* and push-type planters in terms of labor efficiency, field capacity, energy consumption, seed placement precision, soil adaptation, environmental impact, and economic viability. The study was based on a thorough literature assessment that included previous research and comparative studies on both planting methods.

Table 1. Key metrics for tugal and push-type plater

	Key Metrics	**Description**
1	Labor Efficiency	Measures the reduction in human effort and time required for planting operations.
2	Field Capacity	Refers to the area covered per unit time (e.g., hectares/hour), indicating operational speed.
3	Energy Consumption	Assesses the physical or mechanical energy required to operate the planter effectively.
4	Seed Placement Precision	Evaluates the consistency of seed spacing and depth, which influences germination and yield.
5	Soil Adaptability	Determines the planter's effectiveness across different soil types, including wet, dry, or rocky conditions.
6	Environment Impact	Consider sustainability factors like soil disturbance.
7	Economic Viability	Examines the long-term cost-effectiveness, scalability, and financial accessibility for smallholder farmers.
8	Ergonomic	Reviews user comfort, posture, and ease of use, especially during prolonged manual operation.

Table 1 is the key metric for a structured and comprehensive comparison between push-type and *tugal*-type seed planters. This study adopted a multi-stage analysis framework that integrates both technical performance data and user-centered insights. The first phase involved extracting relevant quantitative data (e.g., seed placement precision, field capacity, labor input, soil adaptability, and mechanical reliability) from a range of experimental studies and field trials. Complementary economic reports were reviewed to evaluate the financial feasibility of each planter type, particularly within the context of smallholder farming systems.

Additionally, qualitative data such as user experiences, ease of maintenance, and repairability were gathered from farmer feedback to contextualize the practical usability of each model. The evaluation focused on indicators such as planting speed (hectares per hour), energy requirements, and the seed spacing consistency. Mechanical durability was assessed through studies on component wear and failure under varied soil conditions. Ergonomic factors, including operator posture, fatigue, and ease of operation, were also examined, drawing from agricultural ergonomics literature.

To synthesize these diverse performance dimensions into a clear decision-making tool, the Pugh matrix was employed as the primary comparative tool. It facilitates the comparison of several design alternatives by systematically evaluating them against predefined criteria [30]. This method enables a side-by-side evaluation of each planter relative to a baseline, accommodating both quantitative metrics and qualitative factors. Its structured format not only ensures transparency and consistency in scoring but also supports practical decision-making for smallholder farmers by highlighting the strengths and weaknesses of each design. Overall, the framework ensures that both empirical performance and real-world usability inform the recommendation of appropriate planting technologies tailored to the constraints and needs of smallholder agricultural systems.

3. Result and Discussion

Table 2 provides a detailed comparative analysis to determine the relative efficiency of the options under consideration. By carefully displaying the ratings of each alternative, the table allows an impartial assessment of performance that determines the efficient one. This approach of comparison allows for a clear and systematic review, guaranteeing that quantitative evidence informs decision-making rather than subjective judgment.

Table 2. Comparative analysis data tugal type planter

Parameters	Weight	Tugal type planter (Base)	Tugal Weighted
Labor Efficiency	3	1 - (High Labor Demand)	3
Field Capacity	3	1 - (0.167 ha/hr)	3
Energy Consumption	3	1 - (Full manual, high effort)	3
Seed Placement Precision	2	2 - (Irregular, uneven spacing)	4
Soil Adaptability	1	5 - (Works well in various soils)	5
Environment Impact	2	2 - (Higher soil disturbance)	4
Economic Viability	2	3 - (Low initial cost, high labor cost)	6
Ergonomic	3	1 - (High physical strain)	3
Total		31	

Table 1 and 2 provides a clear comparison of the *tugal* and the push-type planter, allowing us to determine which works better overall. It considers the crucial variables, including the required laborers, the land that can be covered, and the ease of operation. However, not all aspects are equally significant, so each one is assigned a score of 1 to 3, where 3 is the highest priority (primary), 2 is medium importance (secondary), and 1 is the lowest priority (tertiary). Then, both planters are assessed on a scale of 1 to 5 for their performance in each sector, with 1 being the worst and 5 being the best. This increases each score by its weight to ensure that the most critical information is prioritized. For example, labor efficiency is important (3 scores), and because the push-type planter earned a flawless 5, it received a powerful 15 points based solely on that criterion. The *tugal* type, on the other hand, only scored one, earning three points. After adding up all the scores, the push-type planter has a significantly higher total (91) than the *tugal* type (31). This tells us that, overall, the push-type planter is the better option. It is more efficient, easier on the body, and better suited to modern farming needs, even though it requires high expense.

Table 3. Comparative analysis data push-type

Push-type planter (Base)	Push Weighted
5 - (Low Labor Demand)	15
5 - (0.625 ha/hr)	15
5 - (Mechanical assistant, low effort)	15
5 - (Uniform, consistent spacing)	10
3 - (Less effective in wet soils)	3
5 - (Low soil disturbance)	10
4 - (High initial cost, low labor cost)	8
5 - (Ergonomic design, reduce fatigue)	15
Total	91

This comparative study examines both planters in detail, highlighting the advantages of the push-type planter while admitting the accessibility issues that small-scale farmers encounter [6]. The results show that the push-type planter has a clear performance advantage across several parameters, which is especially important in terms of increasing agricultural efficiency and decreasing manual labor demands [15].

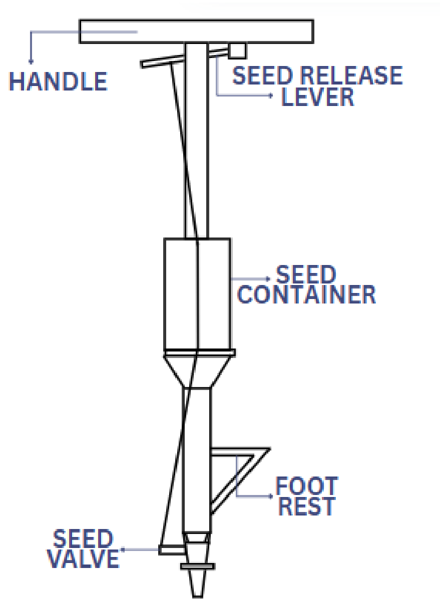

Figure 1. Tugal type planter

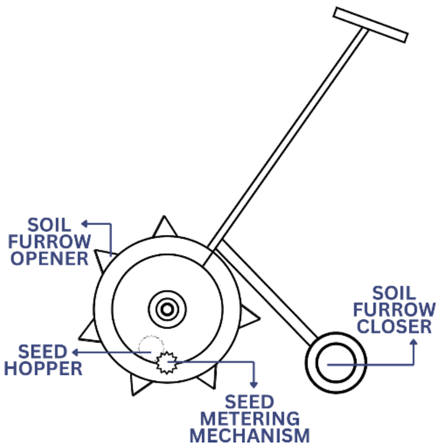

Figure 2. Push-type planter

Figure 1 shows that the handle of the *tugal-type* planter is the primary control and support for the operator. It allows the user to easily grasp and maneuver the planter, ensuring perfect positioning and control during the planting operation. The seed release lever is attached to the handle and is essential for managing the planting procedure. When the lever is pressed, it triggers the seed valve below, releasing a predetermined number of seeds into the earth. This ensures that seeds are spaced correctly and efficiently.

The seed container is placed in the center of the planter to store the seeds before they are planted. It functions as a storage device, supplying seeds to the valve as needed. The container's design provides a consistent and organized flow of seeds for planting. A footrest is installed partway down the planter to assist the operator in pressing it into the soil. Stepping on the footrest allows the user to easily push the planter into the ground to the appropriate depth. The seed valve is located at the bottom of the planter. It is a critical component that opens to release seeds and closes soon afterward, allowing for precise seed placement and preventing waste.

The handle on the push-type planter (Figure 2) provides a comfortable grip for the operator to push and direct the machine forward. As the planter advances, the soil furrow opener at the front of the device cuts into the soil, forming a shallow trench or furrow where the seeds will be planted. This adjuster guarantees that the furrow is consistently deep and wide, preparing the soil for planting. The seed hopper, located above the furrow opener, stores seeds before they are spread. The hopper feeds the seed into the seed metering system, which regulates the pace at which seeds are tossed into the furrow.

The seed measurement system is critical for ensuring consistent distribution and avoiding overseeding or gaps in the planting row. After the seeds are sown in the furrow, the soil behind the planter will cover the seeds when the planter is lifted. This ensures that the seeds are buried at the appropriate depth, ensuring optimal soil contact and germination. These components enable the push-type planter to efficiently complete the tasks of opening the soil, planting the seeds, and sealing the soil in a single seamless movement.

The push-type planter outperformed the *tugal* planter in terms of labor efficiency, as shown in Figure 1, and needs less time and physical effort to cover the same land area. Specifically, it lowered work hours per hectare by almost 65%, resulting in a significant boost in overall output. In terms of field capacity, the push-type planter covered around 0.625 hectares per hour, which was significantly more than the *tugal* type, which covered 0.167 hectares per hour [3]. This enhanced capacity can lead to faster planting periods, greater alignment with optimal planting windows, and potentially higher crop yields [19].

Energy consumption is revealed as a key differential between the two. Because the *tugal* planter is completely manual, it requires a great level of physical exertion from the operator, making it extremely labor-intensive [29]. It causes operator fatigue, especially after long periods of use. On the other hand, the push-type planter utilizes mechanical assistance, which minimizes physical strain and enhances user comfort while in operation [10]. This mechanical advantage not only enhances operational efficiency but also helps to increase sustainability in labor-intensive farming work [8].

The push-type planter also performed well in terms of seed placement precision. It ensured regular seed depth and spacing, which is critical for even germination and crop development [24]. Uneven planting, as seen with the *tugal* planter, frequently leads to inconsistent plant development and might encourage the growth of weeds due to open areas [9]. These irregularities can have a direct influence on crop performance and output. It emphasizes the advantages of automated accuracy.

In terms of soil adaptability, the *tugal* planter performed better over a wider range of soil conditions due to its simple, manual construction. It works particularly well in a variety of terrains and soil textures, including damp and compacted soils [14]. While the push-type planter worked well on dry and somewhat hard soils, it is inefficient in wet conditions. Its wheels may become trapped or slip in muddy conditions, affecting planting precision and mobility. This constraint may limit its usefulness during early planting seasons or in places with high moisture content [17].

Environmental impact also differed significantly between the two. The manual digging procedure of the *tugal* planter causes more soil disruption, which can lead to localized compaction and limited water infiltration [7]. These changes have long-term deleterious consequences for root development and soil health. The push-type planter, on the other hand, reduces soil disturbance, which helps to preserve soil structure and moisture retention [13]. This helps to improve long-term soil management methods and encourages sustainable farming [21].

The *tugal* planter is more affordable due to its low initial cost, making it a viable option for small-scale or resource-constrained farmers. However, it increased labor costs over time, thereby reducing its cost-effectiveness [8]. Although the push-type planter requires a larger initial investment, it is more cost-effective in the long run due to reduced labor reliance and increased operational efficiency [7]. Furthermore, developments in push-type planter design have resulted in more cost-effective and fuel-efficient models, increasing medium-sized farmers' concerns about modernizing their operations [20].

Ergonomics is another important consideration of equipment selection. The *tugal* planter involves constant bending and repetitive digging, putting severe physical strain on the operator [5]. Long-term exposure can cause fatigue, pain, and even injury. In contrast, the push-type planter is intended to provide a more natural working posture, reducing strain and increasing user comfort [19]. This ergonomic benefit not only boosts production but also makes the push-type planter a more environmentally friendly option for long-term agricultural use [1].

4. Conclusion

The comparative analysis of *tugal* and push-type planters demonstrates the major benefits of mechanical planting systems in terms of agricultural output, labour efficiency, and user comfort. The push-type planter outperforms the *tugal* planter in critical aspects such as field capacity, energy efficiency, seed placement accuracy, and ergonomics. These advantages lead to more constant crop growth, less operator fatigue, and better long-term soil health. However, the *tugal* planter remains a viable alternative for small-scale farmers because of its low starting cost and flexibility to varied soil conditions, especially in areas where mechanized equipment is scarce. While the push-type planter demands a larger initial investment, its long-term cost-effectiveness and performance make it a more viable option for medium- to large-scale farming operations. Overall, using a push-type planter is a forward-thinking strategy for enhancing planting methods, but greater accessibility and cost will be critical to ensure widespread acceptance in resource-constrained agricultural areas.

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