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RESEARCH ARTICLE — Open Access

Effectiveness of Corn (*Zea mays* ssp L. var. Saccharata) Seed Harvesting Speed Using a Mini Combine Harvester in Corn Seed Production

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Abstract

Malaysia's animal feed production exceeds demand, accounting for about 45-65% of the composition of most feed products. In Malaysia, grain corn imports increased from approximately 2.5 million tonnes in 2000 to 4.0 million tonnes in 2019 for use as animal feed. This experiment was conducted at MARDI Seberang Perai, Penang, from June 2018 to the end of February 2020, using a Worldstar 7.0 PLUS (WS7.0PLUS) mini combine harvester. The basic operation of this mini combine harvester is similar to the Kubota mini combine harvester, which is widely used for paddy and grain corn harvesting. During the harvesting process, three methods were employed to test the speed of the mini combine harvester. Although this harvester is capable of harvesting four rows at once, considerations about potential plant losses necessitated harvesting only three rows for the purposes of this study. The harvester's speed directly affected the loss rate and work efficiency, depending on the soil surface conditions in the test plot. Harvesting losses were categorized into two types: losses on the cutting table and losses during seed separation. Losses on the cutting table occurred in front of the harvester during the cutting process and were measured by collecting plants left in each row after the harvester passed. Losses during separation occurred when plant seeds fell behind the machine during the separation process, and these were measured by collecting samples using a 2 m x 2 m PVC quadrant placed behind the machine. The total losses due to the cutting table and separation system during harvesting using the mini combine harvester ranged from 2.45% to 6.43%. Each harvester speed produced varying results, significantly affecting the overall loss rate and efficiency of the operation.

Keywords: Effectiveness, Harvesting Machine, Harvesting Speed, Loss, Mini Combine Harvester

1. Introduction

Sweet corn (*Zea mays* ssp L. var. Saccharata) is widely regarded as more beneficial than regular corn due to its shorter growing season and higher harvest index, which reduces production costs and increases farmer income. Sweet corn is increasingly well-known to the public and is widely consumed because of its sweeter taste compared to regular corn. The sugar content of sweet corn is 5–6%, significantly higher than that of regular corn, which has a sugar content of only 2–3%. Its shorter production period makes sweet corn highly suitable for cultivation (Widihastuty, 2022).

Corn plants in Indonesia are among the most important food crops and play a strategic role in the national economy due to their multi-purpose functions as a source of food, feed, and industrial raw materials. Domestic demand for corn for animal feed reached 3.48 million tons in 2004, increased to 4.07 million tons in 2008, and was projected to rise to 6.6 million tons by 2010. If this increasing demand is not met by sufficient production growth, Indonesia will need to import corn in large quantities (Haitami, 2019)

The effectiveness of the speed of harvesting corn kernels using a mini combine harvester is very important to increase the productivity of corn farming. A fast and efficient harvesting process can reduce post-harvest losses and save time, which ultimately has a positive impact on corn production. The mini combine harvester, as a sophisticated harvesting tool, is designed to harvest simultaneously, including cutting, separating seeds from cobs, and cleaning seeds, thus speeding up the process that

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previously required more human labor. In addition, this tool also reduces the potential for seed damage that often occurs in manual harvesting, ensuring that the quality of corn seeds is maintained properly. The resulting speed and efficiency also allow farmers to harvest more corn in a shorter time, thus maximizing their agricultural yield potential. By saving time and energy, farmers can focus more on other agricultural activities, such as land preparation or planting the next crop.

Corn (*Zea mays* ssp L. var. Saccharata) is one of the world's most important food crops, alongside wheat and rice. As the main source of carbohydrates in Central and South America, corn is also an alternative food source in Europe. Residents of several regions in Indonesia, such as Madura and Nusa Tenggara, also use corn as a staple food. In addition to being a source of carbohydrates, corn is also planted as animal feed (greens and cobs), its oil is extracted (from the grains), made into flour (from the grains, known as corn flour or cornstarch), and used as industrial raw materials (from grain flour and cornstarch). Corn cobs are rich in pentoses, which are used as raw materials for making furfural. Genetically engineered corn is now also grown to produce pharmaceutical ingredients. Over time, the development of corn cultivation in Indonesia has progressed rapidly. One notable advancement is the use of composite corn seeds. Seeds are the main determining factor in corn production (Listyarini, 2024).

In the context of corn farming, time is a very important factor. Late corn harvesting can reduce the quality of the corn kernels and increase the risk of losses due to bad weather or pest attacks. Mini combine harvesters, with their ability to work faster than traditional methods, can minimize the time needed to harvest corn. This allows farmers to be timelier in harvesting, ensuring that the corn kernels produced are in the best condition. In addition, timely harvesting using mini combine harvesters can also reduce the risk of fallen or damaged kernels, which often occur in manual harvesting. The speed of this machine allows farmers to immediately process the harvest with the next step, such as drying, thereby reducing the possibility of quality degradation due to delays. Thus, the use of mini combine harvesters not only increases time efficiency but also maintains the quality and quantity of corn harvests optimally.

Corn plants are the type of plants most often used as host plants in mycorrhizal propagation. This is because corn plants are ideal for the development of hyphae and propagation of endomycorrhizae, have a large and fine root system, and microorganisms, including endomycorrhizae, easily grow in the roots (Fau, 2024).

In addition to increasing speed, the use of mini combine harvesters also provides benefits in terms of reducing labor. Manual corn harvesting usually requires many workers to cut, separate seeds, and clean the cobs. By using a mini combine harvester, this process can be done with only a few workers, reducing operational costs. This is especially beneficial for farmers, particularly in areas with limited labor or on large land. Reducing the number of workers also minimizes the potential for human error that can occur during the harvesting process, thereby increasing the consistency and quality of the harvest. Moreover, by reducing dependence on manual labor, farmers can allocate resources to other important agricultural activities, such as crop maintenance or post-harvest management. Thus, mini combine harvesters not only save labor but also increase overall efficiency in the corn farming system.

In Indonesia, corn is the second most important food crop after rice. Corn is not only used as food but also as animal feed. Corn plants are still utilized by the community in various ways.

Presentation forms, such as corn flour (maizena), corn oil, food ingredients, as well as animal feed, are commonly derived from corn. Especially sweet corn, which is very popular in the form of boiled or roasted corn (Novita, 2021).

The speed and efficiency of the mini combine harvester also has a positive impact on reducing crop losses. In manual harvesting, many corn kernels fall or are damaged during the process of separating the kernels from the cobs. However, with mini combine harvester technology, corn kernels can be separated more carefully and precisely, reducing the level of seed damage. This machine is designed to minimize losses by processing corn kernels automatically, so that more kernels are maintained in quality. Thus, more corn kernels are successfully saved and can be sold or stored for further consumption. In addition, less damage to corn kernels also contributes to increasing the selling value of corn, as better quality makes the kernels more desirable in the market. This reduction in losses provides greater financial benefits for farmers while increasing overall efficiency in the corn supply chain.

The use of mini combine harvesters also increases the consistency of the harvest. In manual harvesting, there is a possibility of irregularity in the way the kernels are separated from the cobs, which can affect the quality of the harvest. With machines, each corn kernel is processed in the same way, resulting in a more uniform product and improving the quality of the commodity being marketed. In addition, with more efficient processing, the time required for harvesting can be minimized, allowing farmers to immediately proceed to the next processes, such as drying and packaging the corn kernels.

In various regions in Indonesia, the increase in corn cultivation has shown a general decline in corn production. Meanwhile, the population continues to grow, resulting in an increase in demand for corn. As a result, the gap between total national corn production and the amount needed is widening from year to year. If this situation continues without intervention, corn imports will increase, leading to greater dependence on foreign countries to meet the nation's corn needs (Kerawing, 2024).

On the other hand, although mini combine harvesters offer many advantages, the use of this tool also requires asignificant investment. Farmers must consider the cost of purchasing and maintaining the machine, as well as the training required to operate the tool effectively. Without adequate understanding of how it works and how to maintain it, the potential benefits of this machine can be hampered. Therefore, the implementation of mini combine harvesters should be supported by training programs or government assistance to ensure that farmers can use it optimally. With this support, farmers can gain maximum benefits, increase production efficiency, and reduce losses due to late harvesting.

The development of the livestock sector in Indonesia has experienced a significant increase, along with the rising demand for animal products such as meat, milk, and eggs. However, this increase is not balanced by the availability of adequate animal feed. The limitations of traditional feed sources, such as green fodder and meal, are among the main challenges faced by livestock farmers. In this context, hybrid corn emerges as a potential solution to meet the increasing need for animal feed. Hybrid corn, with its advantages in terms of higher nutritional content and better productivity compared to local varieties, is considered an effective and efficient alternative for animal feed. (Nasution, 2024)

Overall, the mini combine harvester proved effective in increasing the speed and efficiency of corn seed harvesting, reducing operational costs, and minimizing crop losses. The use of this technology can be a good solution to increase corn farming productivity, especially in facing the challenges of limited labor and the need to boost agricultural output in a short time. In addition, mini combine harvesters can also reduce dependence on limited human labor, allowing farmers to work more efficiently. However, the application of this technology needs to be adapted to local conditions, such as the availability of funds and the skill level of farmers, to achieve optimal results. Support in terms of training and access to financing is also important to ensure that this technology can be accepted and effectively utilized by farmers.

2. Material and Methods

2.1. Place of Study

This study was conducted at MARDI Seberang Perai, Penang Island, Malaysia. {Latitude: 5.3625° N} The experimental layout was divided into three sub- plots, namely L, H, and W, whichrefer to the harvest pattern, and will be replicated into three additional sub-plots measuring 3m x 15m as shown in Figure 1. The procedure for data collection is in Figure 2.

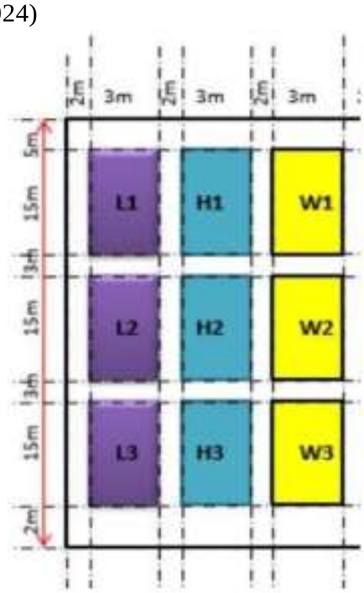

Figure 1. Study site (SubPlot)

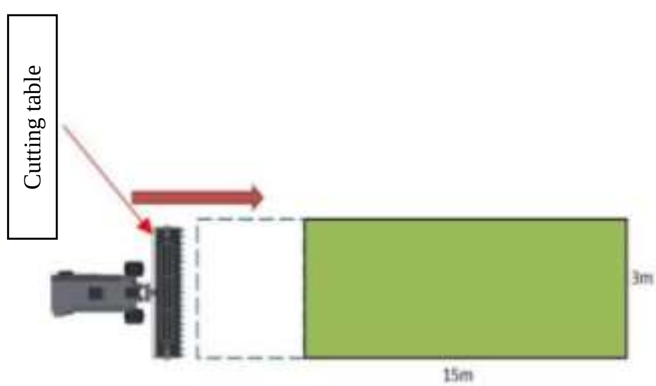

Figure 2. Data collection procedures Harvest speed

Mini harvesters, like the Worldstar 7.0 Plus, have an appropriate speed to harvest crops efficiently without damaging them. The speed is usually controlled by a gear transmission that allows the user to adjust the harvesting speed depending on terrain conditions, moisture, and crop thickness. For this test, three types of speeds were used: L representing low gear, H for harvesting, and W for fast gear. These speed gears were tested to determine whether the harvesting speed would have an impact on crop losses in the field.

2.2. Mini Corn Cutter

The use of the Worldstar 7.0 PLUS brand mini harvester (Model: WS7.0 PLUS) is shown in Figure 3. This model was selected because it is mainly used by government agencies and contractors in the state. Table 1 provides information about the study site and the harvester used. The specifications for the harvester are shown in

Table 2.

Figure 3. Worldstar 7.0 PLUS

Table 1. Machine Information for the Experiment

Plot	Mini Cutter Model	Areha (ha)
L	Wordlstar 7.0 PLUS	3m x 15 m (0.004 ha) 3 replicas
H		3m x 15 m (0.004 ha) 3 replicas
W		3m x 15 m (0.004 ha) 3 replicas

2.3. Harvest Considerations

In harvesting operations, basic considerations must be emphasized so that the corn is not damaged, free or minimal of plant residue, and the level of seed loss is minimal. The harvesting process carried out carefully will ensure that the corn seeds produced remain in the best condition and have high quality. Harvesting will generally be carried out after 10 a.m., depending on the weather, to ensure that the corn trees and stalks are dry with an ideal seed moisture percentage (less than 25%) and are not damp (Mohamad BAG, 2019). That way, the harvest will be easier to process and store properly. Harvesting is done by cutting closer to the base of the corn cob to reduce plant residue that can increase losses or damage seed quality. The four main components in this harvest—command and function, speed, accuracy, loss reduction, and plant residue reduction—are important factors that support the success of efficient and optimal corn harvesting.

2.4. Field Performance

They were tested in the MARDI Seberang Perai plot to assess the performance of the harvester. The performance assessment covered various factors such as land capacity, efficiency, harvest loss, machine speed, and other aspects relevant to the harvesting process with two corn rows per trip. The harvest time was recorded carefully, and then the machine speed was determined by dividing the length of the harvest line by the recorded harvest time. This measurement allows for a more accurate evaluation of the performance of the mini combine harvester in increasing efficiency and reducing losses during the harvest process (Sattar, 2020). The results of this assessment can provide an overview of the effectiveness of the machine in actual field conditions, as well as provide important information for farmers to maximize their corn yields.

2.5. Determination of Field Work Rate (FWR)

Field Work Rate (FWR) indicates the harvesting efficiency of a combine harvester. Theoretically, this work rate is proportional to the "width of the cutting blade and the speed of the machine." However, the work rate can vary depending on several factors, such as the shape and size of the field, soil conditions, and the condition of the plants at the time of harvest. These conditions affect the effective operation of the machine in harvesting corn. The operating speed of the test should be more than 0.4 m/s to ensure that the harvesting process is running efficiently. In addition, the harvesting work must be carried out smoothly without any technical disturbances, including effective separation of kernels from corn cobs and reduction of kernel damage. The National Test Code for Combine Harvesters sets these standards to ensure that the machine can operate at its optimum level in the field and deliver the expected results.

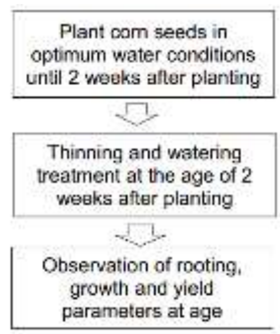

Figure 4. Research stage

2.6. Grain Losses

Losses during harvesting can be determined by two situations. First, losses at the cutter header during harvesting, and second, losses during corn kernel separation. Losses at the cutter header were measured by collecting plants in each row after the mini combine passed the harvesting line in. Losses during separation were measured by collecting samples of corn kernels that fell to the back when the mini combine harvested. Losses in the field were determined by a sampling technique, collecting all corn kernels that fell to the ground. The sample area was 2 m x 2 m with a randomized complete block design (RCBD) in Figure 5. To determine corn losses due to corn dregs, corn cobs that fell along the harvesting line during the operation were collected. All corn cobs that fell and were not harvested during the harvesting process were weighed and considered as grain losses in the field, assuming that 1 kg of corn cob can produce 0.75 kg of kernels. When the seed storage tank is full, a tractor with a trailer and a jumbo bag in it is ready to receive the harvested kernels. The kernels are lifted from the tank by the rim auger discharge and discharged through a side pipe (mini combine unloader) that flows into the jumbo bag on the trailer. This operation will continue until all plots have been harvested. The data collected is used to calculate effective and efficient field capacity and theory.

Figure 5. The remaining grain that falls to the ground is collected using a 2 m × 2 m box to obtain data values for grain losses.

3. Results and Discussion

Table 2 shows that WS7.0 PLUS with H speed produces alowloss percentage, which is below 2.5%. This indicates that speed H is the optimal and most suitable speed for corn harvesting. The use of this speed resulted in a lower level of speed loss compared to the other speed. In contrast, speed L and speed W resulted in a fairly high level of speed loss, at 5.6% and 6.43% respectively. Therefore, choosing the right speed is very important in increasing harvesting efficiency. Speed H proved to be more effective in minimizing seed loss, while speeds L and W increased the risk of speed damage, which could be detrimental to overall yields.

Table 2. WS7.0 PLUS Field Work and Losses of Split Beans

Harvester Gear	Size Testing Plot (ha)	Speed (km/h)	Field work (FWR) (hectare/hour)	Total lossin (Kg/ha)	Cuttingtable losses (HL)	Seed dissolution losses (TL) (%)	Total Loss (%)
L	0.004	2.3	1.1	154.8	(%)4.2	2.23	5.6
H	0.004	3.6	1.3	91.6	1.7	0.91	2.45
W	0.004	4.9	1.81	218	4.46	1.83	6.43

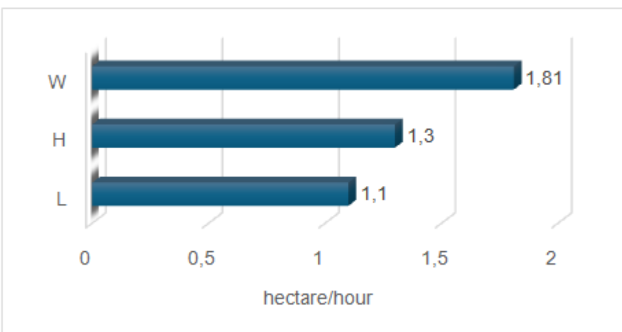

Figure 6. Field Work (FWR)

FWR is shown in Figure 6, highlighting the fieldwork rate of the mini combine harvester. The results indicate that only pattern C is slightly different from 0.26 in the work rate of the WS7.0 PLUS compared to patterns A and B. During this time, Block B for the WS7.0 PLUS was slightly grassy due to rain crops occurring every day. This may have made it difficult for the combine to harvest smoothly. This shows that there is no significant difference between pattern A and pattern B in terms of FWR, as the t-stat value is lower than the critical t-value at the tail (Hossain et al., 2020). A previous study by Yunus (2019) on the effectiveness of mini combine harvesters in corn seed production investigated how varying harvesting speeds impacted seed quality and harvesting efficiency. The research was conducted in a corn seed production field, utilizing a mini combine harvester to test different speeds ranging from 2 km/h to 5 km/h. The findings revealed that while faster speeds increased harvesting efficiency by reducing time, they also led to a decrease in seed quality, particularly in terms of seed damage and germination rates.

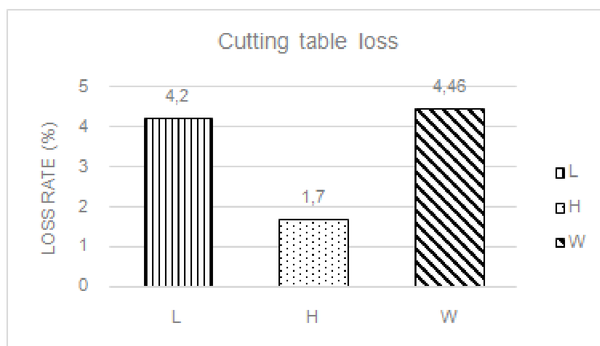

Figure 7. Largest Loss (HL)

From the results shown in Figure 7, the header loss for L speed on the WS7.0 PLUS was 4.2%, H speed was 1.7%, and W speed was 4.46%. W speed, which had a loss result of 4.46%, was higher for the WS7.0 PLUS compared to other speeds. Header loss occurs because the combine header often hits the crop, causing the crop to fall when making a straight turn.

The main factor affecting header loss is the operator's ability to adjust the forward and turning speeds of the combine harvester (Tanveer, D. et al., 2019). Improper speed settings can increase seed loss and damage crops, making good operator skills essential. However, in this study, the mini combine harvester may be able to harvest up to 4 rows at a time with skilled operators, which can significantly reduce header loss and improve harvesting efficiency.

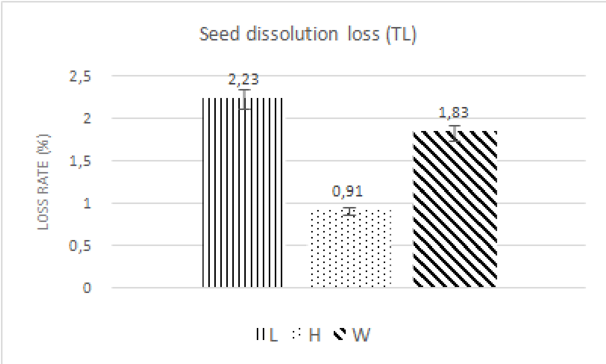

Figure 8. Seed breakage loss (TL)

This data was taken from a 2 m × 2 m area by collecting grains that fell to the ground. Figure 6 shows the results of each speed on the harvester. At speed L (low), the grain loss reached 2.23%, speed H (high) resulted in a loss of 0.91%, and speed W (medium) reached 1.83%. These results indicate that speed L has a higher loss compared to other speeds. For example, the distance between the beater teeth, profile, and a very accurate corn separation unit is needed to prevent grain damage. Factors such as operator skill, forward speed, feeding rate, and separator drum speed also significantly affect the loss rate (Tanveer, D. et al., 2019). Conversely, the loss rate is also influenced by the harvesting speed itself, where too high or low speeds can increase damage to corn grains.

Figure 9. Total Loss

4. Conclusion

The harvester's speed directly affected the loss rate and work efficiency, depending on the soil surface conditions in the test plot. Harvesting losses were categorized into two types: losses on the cutting table and losses during seed separation. Losses on the cutting table occurred in front of the harvester during the cutting process and were measured by collecting plants left in each row after the harvester passed. Losses during separation occurred when plant seeds fell behind the machine during the separation process, and these were measured by collecting samples using a 2 m x 2 m PVC quadrant placed behind the machine. The total losses due to the cutting table and separation system during harvesting using the mini combine harvester ranged from 2.45% to 6.43%. Each harvester speed produced varying results, significantly affecting the overall loss rate and efficiency of the operation.

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