ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Comparison of Grain Corn Production Performance Between Zero-Tillage and Conventional Tillage at MARDI Seberang Perai

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Abstract: Grain corn is one of the ingredients for formulating animal feed, especially for poultry. Recently, Malaysia has given a higher priority for grain corn to be produced locally due to high import costs. Malaysia imported 3.7 million metric tonnes of corn worth approximately RM 3 billion in 2020-2021. However, locally produced grain corn faces high production costs. The main contributors to the high costs are mechanisation services and agricultural input. Agricultural input costs, such as seeds, fertilisers, herbicides, and pesticides, are very dependent on market prices that can go up or down and are difficult to control. Tillage, or land preparation, is the most expensive mechanisation service for grain corn production. Conventional tillage involves three operations; ploughing, harrowing, and rotary tillage. These operations cost at least RM900 per hectare. A zero-tillage planting system does not require any tillage. Therefore, a study was conducted to see the performance of zero-tillage as compared to conventional tillage in terms of final yield produced at MARDI Seberang Perai, Pulau Pinang. A randomised plot design experiment with 3 replications on plot sizes of 20 × 15 m each was used. All agronomic practices such as fertiliser requirement, pest and weed control, and irrigation were the same for both. The difference was only in the tillage practice where conventional tillage involved 3 tillage operations, ploughing, harrowing, and rotary tilling while there was no tillage operation needed for a zero-tillage planting system. The final yields were analysed using T-test statistical analysis. The yields recorded at 14 % moisture for zero-tillage and conventional tillage were 6.32 ± 0.9 and 6.62 ± 0.6 metric tonnes, respectively. No significant differences were found by t-test analysis with a p-value of more than 0.05. This shows that zero-tillage has the potential to be implemented in Malaysia to reduce the cost of grain corn production by eliminating tillage operations which can save up to RM900 per hectare. Further study for various types of soil shall be conducted to categorise suitable soil for the planting system.

Keywords: Grain corn; high-cost; mechanisation; tillage; zero-tillage

Received: 12th April 2023

Received in revised form: 20th November 2023

Available Online: 15th January 2024

Published: 28th June 2024

Citation: Abdul Rani, R., Ahmad Sayuti, A. F., Khadzir, M. K., *et al.* Comparison of grain corn production performance between zero-tillage and conventional tillage at MARDI Seberang Perai. *Adv Agri Food Res J* 2024; 5(1): a0000416. https://doi.org/10.36877/aafrj.a0000416

1. Introduction

Grain corn is one of the ingredients for formulating animal feed, especially for poultry. Recently, Malaysia has given a higher priority for grain corn Malaysia to be produced locally due to high import costs. Grain corn is also considered a new source of wealth for farmers as well as a new source of income for Malaysia (Rosali *et al.*, 2019). In the year 2020 to 2021, Malaysia imported 3.7 million metric tonnes of corn worth approximately RM 3 billion, where the main grain corn exporters to Malaysia were Argentina and Brazil (Anon, 2023).

In general, corn is cultivated in all areas in Malaysia. However, according to Wong (1992), grain corn was cultivated by smallholder farmers in river valleys in Kelantan, Terengganu, and Pahang. Over time, the production of grain corn is gradually decreasing and replaced by sweet corn. Until today, there is no commercial grain corn production for feeds in Malaysia. Locally produced grain corn faces high production costs which can achieve up to RM 0.78 per kg (Mohammad Nor *et al.*, 2022). The main factors contributing to the high costs are mechanisation services and agricultural input, which account for 46.5 % and 30 %, respectively, of the total production cost of RM 5024.60 (AB Ghaffar & Sheng, 2019). Agricultural input costs, such as for seeds, fertilisers, herbicides, and pesticides, are highly dependent on market prices that can go up or down and are difficult to control. Based on a published study of grain corn production economics from MARDI, tillage or land preparation is the costliest mechanisation service for grain corn production (AB Ghaffar & Sheng, 2019). Primary tillage and secondary tillage are the two tillage procedures typically used for land preparation. The primary goals of tillage operations are to create an ideal seed bed, eliminate weed competition, and enhance the soil's physical condition (Robert, 2020). Conventional tillage involves three operations; ploughing, harrowing, and rotary tilling. These operations cost at least RM975 per hectare (AB Ghaffar & Sheng, 2019).

A zero-tillage planting system is not a new method of planting and has been widely practised by many countries and believed to have started in the 1940s but it was not until the development of powerful herbicides such as paraquat (Savage, 2017). The system does not require any tillage operation on-site (Roy *et al.*, 2009). Planting directly after harvesting saves time and production costs. Besides potentially reducing the cost of production, the zero-tillage planting system also has other benefits such as maintaining soil structure by preventing soil compaction, loss of topsoil, and wind erosion (Victor & Carmen, 2008). In terms of yield comparison between zero-tillage and conventional tillage, several studies showed various results that make many of the possibilities such as those reported by Buhler (1992) that corn yields were not affected by tillage. On the other hand, Mulugeta and Stoltenberg (1997) reported opposite results, which stated that both corn and soybean yields were greater in mould board ploughing than in zero-tillage. Meanwhile, Buah (2017) reported mean grain yield of zero-tillage corn was 68% higher than that of conventional tillage. With reference to the variety of possibilities that can occur, zero-tillage planting has some potential to be tried in Malaysia.

In Malaysia, zero-tillage planting in corn production and other crop cultivation is a relatively a new method. Many uncertainties have to be cleared before being practised in Malaysia. Therefore, this study was conducted with the objective of comparing the performance of zero tillage planting systems for grain corn production with the conventional method in terms of final yield produced and mechanisation performance. This is important in a way to find the best solution to reduce the cost of local grain corn production and to have a sustainable industry.

2. Materials and Methods

The comparative study between zero-tillage and conventional tillage planting systems was conducted at MARDI Seberang Perai Station, Pulau Pinang. The exact location of the area was at longitudes 100°28'22.72"E and latitudes 5°32'33.56"N with an average of 10 m from sea level which is located in Argo-climatic zone 1 that has 3 to 4 months of clear and regular dry season. Agro-climatic zone 1 has been gazetted as the most suitable zone for planting grain corn (Anon, 2022). The dry season is needed and important in grain corn production especially at early planting and harvesting operations to ensure a good growth and quality of the plants. Planting in the wet season can reduce the efficiency of the planting machine meanwhile harvesting in the wet season causes a lot of damage to the corn kernels and accelerates the growth of fungi that can reduce the quality of the yield.

The soil of the experimental plot area is coarse sandy clay loam soil in the Holyrood soil series. The main soil characteristic of the Holyrood series is well-drained and brown which is derived from sub-recent riverine alluvium. The entire area is fenced with chain link fence to ensure no disturbance from pests such as wild boars or domestic animals such as cows and goats.

A randomised plot design experiment with 3 replications on plot sizes of 20 × 15 m each was used as shown in Figure 1. The plots were separated by 0.5 m spaces from each other and 5 m spaces at the starting and ending points of the plot for tractor turning. With a row spacing of 75 cm apart, this plot size allowed for 20 rows of plants. The experimental plot was developed complete with irrigation and a proper drainage system to handle unforeseen droughts and heavy rain because grain corn is quite sensitive to adverse weather conditions.

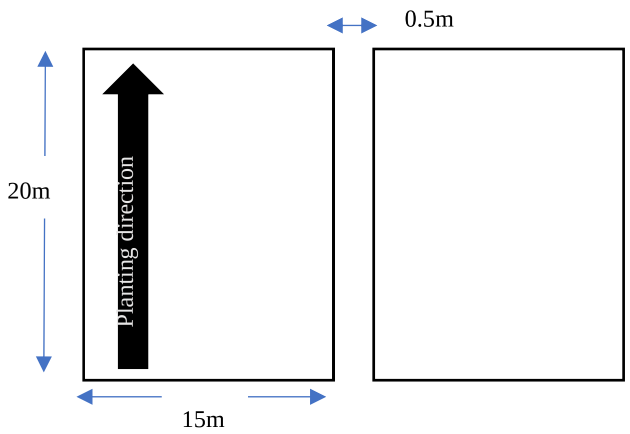

Figure 1. Experimental plot size and direction of planting

Land preparation for the conventional tillage plot involved 3 tillage operations, ploughing, harrowing, and rotary tilling meanwhile no tillage operation was involved for the zero-tillage plot. The ploughing operation was done using a disc plough implement (Figure 2. a) with three 660 cm diameter discs for one round operation at depths of 25 to 30 cm. Meanwhile, the harrowing operation used a single action harrow disc implement (Figure 2. b) with seven 600 cm diameter discs at a depth of 25 cm, and a 200 cm width rotavator (Figure 2. c) was utilised for the rotary tilling operation at a depth of 15 cm. Both implements were also executed for one round of operation each. All the implements were mounted on the 4-wheel drive, 95-hp wheeled tractor. Each operation's time consumption to finish one pass of 20 m travelling was recorded to determine the tractor's travelling speed to analyse the performance in terms of field capacity. The field capacity was calculated based on Equation 1:

$$Theoretical\ field\ capacity = \frac{S \times W}{10} \quad (1)$$

Herbicide spraying was used to eradicate weeds from both plots before land preparation. The herbicide used was glyphosate, a nonselective systemic herbicide, particularly effective against perennial weeds that can kill both broadleaf plants and grasses. The plot was left over for about 2 weeks to ensure all weeds were killed and to prevent any adverse effects of the herbicide on corn crops.

a b c

Figure 2. Tillage operation, (a). Disc plough; (b.) Disc harrow; (c.) Rotavator

All the plots were planted on the same day by using one machine, a 4-row pneumatic seeding machine specially designed for the zero-tillage planting system as shown in Figure 3.0. The machine has a special mechanism or component to penetrate no-tilled and tilled soil to sow corn seed. The machine is equipped with a fertiliser applicator that enables the fertilising concurrently during the planting operation. The fertiliser applicator is equipped with two hoppers that can hold up to 200 kg of granular-type fertiliser each. It also has four fertiliser metering devices for regulating the fertiliser rate needed by the plants based on agronomist recommendations. The machine was operated with the same tractor used for operating the tillage implement. The travelling speed of the planting operation was set between 4 and 5 km/h. Before planting, the equipment was calibrated to ensure that the seeds and fertilisers were sown throughout the operation. This is important to reduce the risk of yield shortages due to unplanted seeds.

Figure 3. Planting machine used in the study

Agronomy practices for both planting systems or treatment were the same. The planting density or distance used was 75 cm between rows and 20 cm between the plants in a row which gives about 66666 plants per hectare. Variety Pioneer 4546 was used in the study. The variety is an imported seed from Thailand. The seed was tested several times prior to the study and performed well in many locations, particularly in MARDI Seberang Perai, with an average yield of 5 to 7 Mt per hectare at 14% moisture (AB Ghaffar, 2019). Before planting, the corn seeds batch underwent a germination test in a petri dish to examine their viability before being utilised. If the batch achieves a germination percentage of less than 90%, the batch will not be accepted for planting and replaced by a new seed batch.

Just after planting, each plot was sprayed with pre-emergence herbicide for weed control using a high-clearance self-propelled sprayer. Pre-emergence herbicide must be applied within 24 hours after planting to prevent any risk of misapplication of the chemical to the crop planted (Anon, 2020). The herbicide used was atrazine, a selective active ingredient type herbicide that has no harm to corn plants with a rate of 2 L per hectare. The herbicide was sprayed as a blanket spraying. This herbicide can give up to 4 weeks of protection from the infestation of weeds. To maintain the effectiveness of the pre-emergence spray, no one was allowed to enter the plot just after the herbicide was sprayed.

Each plot was irrigated three times a day for 15 min when there was no rain with a sprinkler-type irrigation system. The irrigation rate was increased to four times a day for 30 minutes at crop ages 45 to 65 days, and for ages 66 to 90 days, the irrigation period was increased to 50 min with the same irrigation frequency. To be fair to all plots, irrigation was carried out simultaneously.

The crops for both treatments were fertilised with 400 kg/ha NPK green (15:15:15) applied during planting, and the second was 130 kg/ha urea 28 to 30 days after planting. Pest and disease control for both experimental plots were the same using chemical spraying.

2.1. Data Collection and Analysis

Two days before harvesting, a crop-cutting test (CCT) was implemented. Crop cutting is a statistical survey method used to estimate crop yield in a population by cutting the crops in small sections per plot in size of 5 m × 3 m (15 m^2) each. The corn cobs in the sampling section were harvested manually. Grain yield was calculated using grain weight, which is the dry cob weight adjusted for a 14% moisture content and an 80 % kernel-to-cob weight ratio. (Ahmad *et al.*, 2020). Moisture content is measured using the Agratronix MT-16 grain moisture tester. The data were analysed using T-test statistical analysis.

3. Results and Discussions

Table 1 shows the average yields obtained from each treatment; conventional and zero-tillage which are 6.62 ± 0.6 and 6.32 ± 0.9 Mt/ha respectively. The yields were obtained at 14% moisture, which is the standard moisture required for storage to reduce the risk of fungi development. Statistically, there was no significant difference between the yield obtained for both planting treatments with a p-value of more than 0.05. This shows that the zero-tillage planting system has the potential to be implemented in Malaysia, especially for the Holyrood series of soil and equivalent. The soil's main characteristic is well drained and a bit loose because of sand content but needs proper irrigation, especially during drought season. Well-drained soil is good because corn will be stunted or delayed growth in water-logging areas (Ren *et al.*, 2014). Compacted areas such as soil with a high clay content may make it difficult to implement a zero-tillage planting system and need to be tilled once to loosen the soil structure. This kind of method will not be categorised as a zero-tillage planting system but as a minimum-tillage planting system.

Table 1. The yield, working rate, and cost of operation of each treatment

Treatment	Average yield at 14% moisture (Mt/ha)	Field capacity (ha/hour)	Total time required to complete per ha (hour)	Mechanization service cost per ha (RM/ha)
Conventional tillage	6.62 ± 0.6	Ploughing: 0.45 Harrowing: 0.525 Rotary tilling: 0.5 Planting: 1.2	7	Ploughing: 375 Harrowing: 300 Rotary tilling: 300 Planting: 300 **Total: RM 1275**
Zero tillage	6.32 ± 0.9	Planting: 1.2	0.8	Planting: 300 **Total: RM 300**

Conventional tillage planting involves four operations; ploughing, harrowing, rotary tilling and planting with a field capacity of 0.45, 0.525, 0.5, and 1.2 ha/hr, respectively. The combined field capacity of conventional tillage planting operation was 0.14 ha/hr meanwhile, zero tillage planting was 1.2 ha/hr, which means that zero tillage needed only 0.8 hours for a complete one-hectare planting compared to conventional tillage which required 7 hours if only one tractor is available. With a zero-tillage planting system, more hectares can be completed in one day of planting by one tractor. In addition, less equipment needed to be used means less maintenance and saving the cost of operations.

Besides that, the use of a zero-tillage planting system can minimise the risk of unpredictable weather disrupting planting activities. In the normal practice of conventional tillage, ploughing is implemented at least two weeks before planting, followed by harrowing seven days later and rotary tilling on the day of planting. The difference in the day's work is likely to be affected by weather, especially rainy days, which can disrupt the cultivation operation. After the rain, it needs about two or three days of dry weather to ensure that the soil is suitable to be operated by machinery. This sometimes makes the planting activity to be out of schedule and risk facing unfavourable weather during harvesting time which can affect the quality of the yield.

Zero tillage has the potential to reduce the cost of grain corn production by RM975 per hectare by eliminating land preparation operations. These costs were obtained through a survey of the company in the farm mechanisation service provider business. This cost reduction increases the farmer's income by increasing the profit margin per hectare.

4. Conclusions

Zero-tillage planting system is comparable to conventional tillage planting in a certain area and showed good potential to be implemented in Malaysia to reduce the cost of grain corn production by eliminating tillage operation. This is considered as the best solution that will give a new era to the grain corn industry in Malaysia because the cost of production is the main factor in the failure of this industry to grow so far. The industry has to sustain to secure source feeds for Malaysia. These will also help farmers to increase their profit margin. Furthermore, farmers can reduce the risk of unpredictable weather disrupting planting activities by using zero tillage. For planting and harvesting to take place during the dry season, grain corn planting needs to be planned in accordance with rainfall. However, because of the increasingly noticeable variations in the weather, this is challenging to achieve. Farmers always facing significant challenges as a result of climate change. Farmers frequently have to alter their planting plans, and they run the risk of having to harvest during the wet season, which can lower the produce's quality. However, by utilising a zero-tillage planting system, this risk can be decreased. In order to obtain the true potential of the planting system, further study for various types of soil shall be conducted to categorise suitable soil for the planting system. This can accelerate the development of the Malaysian grain corn industry and secure the feed and our food.

Acknowledgements: Author wants to thanks to all MARDI supporting staff from Engineering Research Centre and Horticulture Research Centre that were involved in this study.

Conflicts of Interest: Declare conflicts of interest or state "The authors declare no conflict of interest."

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