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Economic evaluation of partial mechanisation in watermelon production

(Penilaian ekonomi mekanisasi separa dalam pengeluaran tembikai)

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Abstract

Watermelon (*Citrullus lanatus*) accounts for about 8.8% of total tropical fresh fruit production in Malaysia. Most of these plants are grown in Kelantan, Pahang, Johor and Terengganu yielding 92,762 mt in 2021 (DOA 2021). Currently, watermelon cultivation activities involving planting, fertilising, fixing mulch plastic and harvesting carried out in Malaysia are conventional, except for land preparation. Therefore, the mechanisation package of watermelon cultivation was introduced to provide more efficient farming techniques and time and labour needs in planting activities. Until now, there has been no study evaluating the economic impact of the use of mechanisation in watermelon cultivation. The study of the economic impact of the use of mechanisation is important to determine the feasibility of the use of mechanisation and conventional techniques on yield and production costs. Partial budgeting analysis is used in analysing the ability to implement a business by expected returns as a result of changes in terms of technology adaptation or direct management. Watermelon production using conventional and mechanised packages was found to be viable. Crop yield can be increased (low damage rate) and reduced operating costs (labour costs) if the mechanisation package is used. Overall, a partial budget analysis shows that the benefit exceeds the implication value by RM2,700 if watermelon cultivation is mechanised. Considering the high price of mechanisation packages, the existence of service providers can help farmers through the rental of related machines. Intervention from the development agency is important to ensure that information related to this mechanisation package reaches users.

Introduction

Watermelon (*Citrullus lanatus*) is a flowering plant of the Cucurbitaceae family. It is native to Africa. There are more than 150 varieties of watermelon worldwide and among the famous varieties are Bradford Family, Sugar Baby, Jubilee Bush, Georgia Rattlesnake, Odell's White, Charleston Grey, Mountain Sweet Yellow, Moon and Stars, Ravenscroft and Ledmon where each variety has different characteristics. In Malaysia, watermelon is also known as *semangka* or *timun cina*. Some varieties are used by Malaysian farmers including Princess, Sin Fon, Prime and Boci. Each of these varieties has different characteristics of seeds, sweetness and fruit structure.

In 2021, the total world production of watermelon was 101.635 million mt (FAOSTAT 2022). China is the main producer of watermelon (60.86 million mt) with a market size of 60%, followed by

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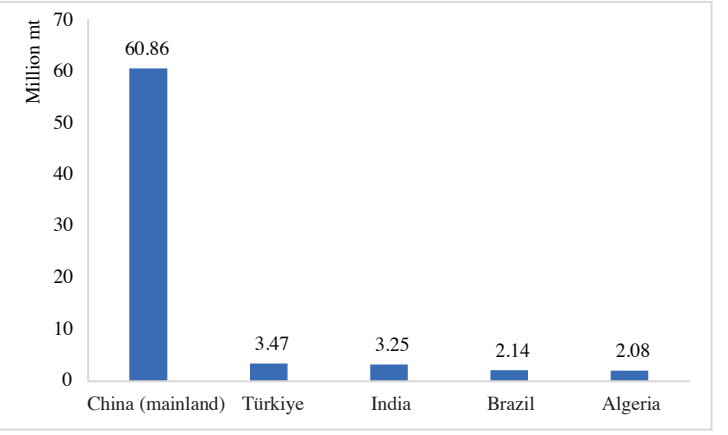
Turkey (3.47 million mt) and India (3.25 million mt) (*Figure 1*). Malaysia is the 57th largest producer in the global ranking with a market share of 0.08% in the same year. The main producer of watermelon in Malaysia is Bachok, Kelantan which contributes to 19.914 mt of watermelon, followed by Rompin, Pahang (13.386 mt) and Kota Tinggi, Johor (7.684 mt). Malaysia showed a decreased trend in watermelon production from 192 thousand mt in 2016 to 127 thousand mt in 2021 (*Table 1*).

In 2021, the world watermelon export value reached USD1.9 billion, a decrease of 1.23% from 2020. Spain remains dominant (29.0%) in the world watermelon market with the highest export value (USD555 million) followed by Morocco (USD209 million) and the United States (USD154 million). Malaysia is ranked 21st and contributed 0.6% of the world export market (UN Comtrade 2021).

The quantity of watermelon exports from Malaysia showed a decrease of 25% from 60,610 mt in 2019 to 45,324 mt in 2020. Singapore is the main importer with a 93% export share, followed by China (4.5%) and UAE (1.9%). Total imports showed a 27% increase from 5,827 mt in 2019 to 7,394 mt in 2020. (SUA, 2016 – 2020).

Planting technology of watermelon

Agricultural mechanisation is the application of engineering principles and technology in the production, control and processing of agricultural products. It involves the use of machines in whole or in part to replace human and animal labour. Mechanisation is not limited to the use of tractors or motorised equipment but the used of multiple implements to ease the whole processes of cultivating, harvesting and dan post harvest handling of crops (Jabatan Pertanian Malaysia 2023).



Source : FAOSTAT (2022)

Figure 1. Five main producers of watermelon in 2021

Table 1. Planted area, production and trade of watermelon in Malaysia, 2016 – 2021

Year	2016	2017	2018	2019	2020	2021
Planted area (ha)	11,986.8	10,405.8	10,456.8	8,921.5	9,247.4	7,568.3
Production (mt)	192,909.8	172,275.4	150,260.6	144,146.9	134,225.4	127,894.7
Export (mt)	72,023.1	63,046	64,225.9	60,610.7	45,324.3	43,067.9
Import (mt)	4,876.3	4,773.1	3,432.7	5,827.8	7,394.1	6,868.6

Source*: Perangkaan agromakanan* (2022); SUA (2022)

Developing countries tend to formulate food security development strategies considering the challenges they face in increasing economic growth (Emami et al. 2018). Despite its great importance, technological development in the agricultural industry has lagged far behind other industries. Until today, almost all agricultural industries in developing countries, as well as third world countries, rely on old and conventional ways of agricultural activities. This not only results in low yields but also creates a huge gap between the supply and demand of agricultural products (Mentsiev et al. 2020). Previous studies have explored ways to increase income in agricultural activities where mechanisation is one of the input that needs to be emphasised in increasing agricultural income (He et al. 2016; Yao et al. 2021).

Agricultural machinery can perform the functions of land levelling, soil preparation, deep turning and deep scarification (Asla et al. 2007), which can improve land quality better than the traditional manual and livestock operation methods, especially in the transformation of medium- and low-yield fields (Zhou et al. 2019; Peng and Zhang 2020). It can increase the degree of multiple cropping of cultivated land to provide the potential for multiple crop cycles/year, thus improving production capacity and land output rates (Peng et al. 2020; Ji et al. 2021). The use of standardised agricultural machinery can reduce agricultural losses and improve product quality (Qu et al. 2021). Tang et al. (2018) found that the use of agricultural machinery can reduce agricultural production losses, thereby reducing agricultural production costs/ unit outputs and promoting high-quality agricultural development.

Mechanisation is not only acquired by ownership but also by renting. Renting this mechanisation has been found to give a higher return on investment compared to purchasing. It can allow smallholder farmers to farm with modern methods. The high cost of mechanisation is a constraint for smallholder farmers to increase return on investment. Some studies show that most smallholder farmers in developing countries hiring the services of tractors or machineries from the service provider, which is more viable (Diao et al. 2014; Benin 2015; Takeshima et al. 2015a). Labour shortages in agricultural areas have opened up space for the use of mechanisation which is often facilitated by the service provider this provision that contributes to the continued viability of smallholder agriculture (Takeshima 2017).

The aim of this study is to make a comparison in monetary return based on the conventional methods and the mechanised applications of the watermelon production using the package of technology generated by MARDI. There are seven types of machines developed and assambled by MARDI. In order to determine the pricing system, this study made an assumption of the rental cost of each items of machineries and time used of certain types of activities between conventional method and mechanised mode. The mechanisation rental is expected to increase crop production and reduce dependence on labour and allow efficient application of agricultural inputs.

Comparison of mechanised and conventional watermelon cultivation

Watermelon takes 65 – 75 days after planting to harvest. Depending on crop management and the variety, watermelon has the potential to produce up to 35 t/ha but most farmers can produce between 25 – 28 t/ha.

Watermelon cultivation requires intensive labour for the main operations such as land preparation, planting, crop management and harvesting as conventional watermelon production faces the risk of increased labour costs. Therefore, MARDI has come up with a solution by developing a mechanised watermelon production package to help speed up farm operations and reduce dependency on labour. This mechanisation

package has been evaluated at a large scale level which is 10 ha with farmers in Kelantan. Through the evaluation, the use of the mechanisation package can reduce up to 263 man-hours/ha compared to conventional operations. *Table 2* shows the list of machines in the mechanisation package that has been developed.

Comparatively, the use of mechanisation systems in watermelon production can reduce the number of man-hours for the operations involved. The reduction reaches up to 263 man-hr/ha which will benefit the farmers. Through the savings, it will give farmers the opportunity to increase the area of cultivation to get the maximum return. However, pollination operate manually or with the help of insects to get a good fruit set and optimal results. *Table 3* shows the comparison of activities between conventional and mechanised method.

Table 2. List of machines in the mechanisation package

No.	Type of machine	Use
1	Automatic seeding	Filling a peat moss into nursery tray and sow a watermelon seeds
2	Disc plough	Making a plant-bed
3	Manure spreader	Spreading an organic fertiliser on a plant-bed with specific rate
4	Plastic mulch and drip tape layer	Install plastic mulch and drip tape on the plant-bed prior planting
5	Planter	Planting watermelon seedlings
6	Mechanical weeding and fertiliser applicator	Control weeds and spreading NPK fertiliser
7	Drone/powered sprayer	Spraying pesticide for pest and disease control
8	Harvester and collector	Harvesting watermelons and transport the harvest from the farm to collecting centre

Table 3. Comparison of activities between conventional and mechanised method

No.	Activity	Sub activity	Man-hour/ha	
			Conventional	Mechanised
1	Seedling preparation	Peat moss filling into a seedling tray	4	2 (combined operations)
		Sowing watermelon seed	20	
2	Land preparation	Ploughing	2 (Mechanised)	2
		Plant-bed making	3.5 (Mechanised)	3.5
		Manure spreading	36	12
		Installation of drip tape and plastic mulch	16	8
3	Planting	-	30	14
4	Crop management	Pest and disease control (Spraying)	40	10
		Fertilising	80	6 (combined operation)
		Weed control	40	
		Pollination	168	168 (manual)
5	Harvesting	-	77	28
Total		-	516.5	253.5

Methodology

Data collection

The assessment of financial viability and feasibility was carried out using projected cashflow analysis and partial budgeting involving several cost estimates such as service capacity, capita cost, operating cost and service cost. Primary data obtained through face-to-face meetings with three farmers were used for this financial analysis. The farmers are currently cultivating watermelon conventionally with an average planting area of 0.5 ha. However, MARDI has given trials of mechanised watermelon cultivation for three seasons to obtain input and cost information.

Cash flow projection analysis

This method is used for the determination of key indicators in the decision to invest. Investors found that the predictability of future cash flows can be increased by emphasising the analysis of operating cash flows instead of income when making investment decisions (Lee et al. 2019). Investors will estimate the worth of firms, investment opportunities, capital projects, new enterprises and cost-cutting strategies through cash flow analysis (Ouyang 2023). Through this method, the Net Present Value (NPV), Internal Rate of Return (IRR), Benefit Cost Ratio (BCR) and Pay Back Period (PBP) can be calculated to predict the viability and feasibility of a business. NPV is widely used for investment decisions (Magni and Carlo Alberto 2005). The value of the project will be measured by comparing the value of NPV with other similar tools including IRR and PBP. It can illustrate the advantages and disadvantages of the project. The IRR is the maximum opportunity cost of the capital that can be accepted by the investor. If the discount rate is higher than the IRR, the NPV would be negative, which means the project is not worth investing in (Haotian 2022).

The four systematic approaches for investment analysis indicators are as follow:

I. Net Present Value (NPV)

$NPV = C_0 + PV$

where:

NPV = Net Present Value

PV = Present Value

$PV = \sum C_t / (1+Kt)t$

where:

C_t = Future Cash Flow for Year t

K_t = Discounted Rate In Year t

II. Internal Rate Return (IRR)

$$IRR = r_a + \left(\frac{NPV_a}{NPV_a - NPV_b}\right)(r_b - r_a)$$

Where:

r_a = Lower discount rate chosen

r_b = Higher discount rate chosen

NPV_a = Net Present Value at r_a

NPV_b = Net Present Value at r_b

III. Benefit Cost Ratio (BCR)

BCR = Total discounted income/total discounted expenses

IV. Pay Back Period (PBP)

$DF = 1 / (1+i)t$

where:

DF = Discount factor

i = Current interest rate

t = Year

Projected income statement

An income statement (profit and loss) shows the income and expenses for a certain period. It shows net income (after expenses are taken into account) and whether there is profit or loss. The purpose of the income statement is to show how an investment generates profit or incurs a loss over a specific period. The income statement provides the company with the situation of earnings which can help the company understand the profitability and the return

to equity holders, including gross profit, operation profit and profit before taxation (Subramanyam 2009).

Two investment indicators can be obtained from this income statement, which are return on investment (ROI) and break even point (BEP)

I. Return on investment (ROI)
ROI = (Profit - Investment capital)/ Investment capital

II. Break even point (BEP)
BEP is the situation where business is at the stage of not making a profit but not losing. The term usually used is ROI.

BEP = Fixed cost/(Sales price/unit - Variable cost/unit)
Variable cost: Cost that will increase with the increment of production (Raw materials, shipping costs and others).

Fixed costs: Costs that are fixed and not affected by production (Depreciation cost of store rent, employee salary, employee training and so on).

These economic indicators are important and interrelated. Each of these indicators will give a clear picture of the viability and feasibility of the business in terms of the financial investment involved.

Partial budgeting analysis

In analysing the ability to implement a business, partial budgeting is usually used to determine expected returns as a result of changes in terms of technology adaptation or direct management. Partial budgeting is a tool used to assess the costs and benefits associated with a specific change in a farm (Soha 2014). Partial budgeting is very useful in making such changes in a farm (Alimi and Alofe 1992).

This partial budget analysis was developed involving four sections which are added income, reduced cost, added cost and reduced income. The basic principles of partial budgeting include focusing only on the changes in income flows or expenses such as added income, reduced costs, reduced income, and increased costs (Kay et al. 2011). This situation is caused by several factors such as adaptation of new technology, changes in project management, increase in workforce, changes in project operation period etc. The results of this analysis are very important as the main indicator that can be used as a guide to the viability of the project when the situation as stated occurs or needs to be adapted to one project.

Results

Watermelon cultivation in Malaysia takes 65 – 75 days to harvest, depending on how the crop management practices and weather factors. With a planting distance of 3.5 m x 0.5 m, the plant density is estimated at 3,600 plants/ha and only 3,420 plants fruited . The harvesting is on the 65 – 85th day. *Table 4* shows information on the production of watermelon cultivation conventionally and using mechanisation. The mechanisation method involves leasing the machine package to farmers based on a charge/ha for a season. The leasing includes wages, fuel and maintenance costs. The total yield (grade A, grade B and grade C) conventionally was 28,730 kg/ha for the season, but by using the mechanisation method the rate of losses can be reduced from 4.1% – 1.7% and make the total yield 29,222 kg/ha. Generally, 70% of the yield is categorised under grade A where the average weight is 5kg, 28% is under the grade B category with an average weight of 3kg while the rest (2%) is grade C or damaged with an average weight of 2kg. The selling price at the field level for each grade is RM1.30 (Grade A), RM1.00 (Grade B) and Grade C is discarded due to too small size.

Table 4. Differences in watermelon production conventionally and using mechanisation (1 ha)

Item	Conventional	Mechanisation
Planting distance	3.5 m x 0.5 m	3.5 m x 0.5 m
Plant density/ha (plant)	3,600	3,600
Plant harvested/ha (plant)	3,420	3,420
Estimated weight/whole (kg)		
Grade A	5	5
Grade B	3	3
Grade C	2	2
Total production/ha/season (kg)	28,730	29,450
Grade A	22,958 (70%)	23,533 (70%)
Grade B	5,510 (28%)	5,648 (28%)
Grade C	262 (2%)	268 (2%)
Price/kg (RM)		
Grade A	1.30	1.30
Grade B	1.00	1.00
Estimated damage (%)	4.1	1.7

The capital cost of watermelon cultivation using conventional and mechanised methods is RM12,273/ha/season. There is a similarity in capital cost where these two methods still use the same machinery for land preparation. However, there is a difference in the operating cost where the total operating cost using the mechanised method is lower at RM18,713/ha/season. This 9% reduction in operating cost is due to a 54% reduction in labour cost (from RM6,320 – RM2,880). Although there was an increase in machine rental cost from RM1,050 – RM2,675, the increase was small compared to the reduction in labour cost. The conversion to this mechanisation method has reduced the production cost for each kg by RM0.78/kg compared to RM0.85/kg. *Table 5* shows the difference in financial indicators for watermelon cultivation using conventional and mechanised methods by using projected cash flow analysis for 10 years. The net present value (NPV) for production using the conventional method is RM46,136 with an internal return rate (IRR) of 37% and a benefit cost ratio (BCR) of 1.3. The ROI is estimated at 61% starting in the second year. While the NPV value for cultivation using mechanisation is higher at RM62,479. The IRR shows 46% with a BCR of 1.5. There is no significant difference for ROI where the value using this method is 67% starting the second year.

Meanwhile, the mechanisation package will be offered to small-scale farmers with less than one ha through service providers as shown in *Table 6*. The capital cost of the mechanisation package is RM380,500 including the transplanter, rotavator, manure spreader and harvester, with the operating cost being RM2,100 including labour wages, diesel, machinery or equipment maintenance, depreciation and other related/ha. The suggested gross rent that will be charged for the mechanisation package is RM3,500 taking into account the costs involved and also referring charges by other service providers. This approach through the service provider will give a net return of RM1,400/ha for a season which is around 40% of the rental rate charged (net profit below 40% if area is below one ha). Based on the financial analysis, the optimum size that allows this project to be viable and feasible is 77 ha for a season. If as many

as 77 ha are involved in the rental of this mechanisation package, the gross return obtained is as much as RM269,500 or a net profit of RM107,800 (40% of the rental charge).

A partial budget analysis shows that the benefit or excessive value exceeds the implication value of RM2,700 if watermelon cultivation is mechanised. The increase in machine rental costs can still be accommodated by the increase in yield of RM885 and the reduction of labour costs by RM3,440 with the recorded change value being positive. This shows that the technology can be accepted if the benefit value exceeds the implication value (*Table 7*).

Table 5. Information on watermelon production financial (one ha)

Item	Conventional (RM ha/season)	Mechanisation (RM ha/season)	Note
Income	35,356	36,241	
Development cost	12,273	12,273	
Operation cost	20,619	18,713	
Net margin	2,463	5,254	
Production cost/unit	0.85	0.78	
NPV (RM)	46,136	62,479	The value over 10% indicates that the project can give a return on investment taking into account the current value of money. The project is viable.
Internal rate of return (IRR)	37%	46%	A positive value (more than 0) indicates that the project has a very good cash flow throughout the project
Benefit cost ratio (BCR)	1.3	1.5	A shorter payback period is better
Return on investment (ROI)	61% (first year)	67% (second year)	It is based on an investment of RM 1. If the value is more than 1 then this project has a return on investment. The greater the value the better the project.
Payback period (year)	3.23	2.77	The closer it gets to 100%, the better the project's return on investment is.

Table 6. Service provider financial analysis

Item	Mechanisation package (RM/ha/season)
Machine rental price	3,500
Machine development cost	380,500
Machine operating costs	2,100
Net margin	1,400
Net margin from the rental rate	40%

Table 7. Impact of conventional and mechanised watermelon production

Benefit		Cost	
A) Added income	RM/ha/season	A) Added cost	RM/ha/season
Income	885	Increased machinery rental costs	1,625
Sub total	885	Sub total	1,625
B) Reduced cost	RM/ha/season	B) Reduced income	RM/ha/season
Reduction of labour costs	3,440	None	
Sub total	3,440		
Total benefit	4,325	Total cost	1,625
Net benefit	2,700	per ha/season	

Conclusion and recommendation

A financial analysis has been carried out on watermelon production either through conventional activities or using a mechanisation package in the form of machine rental. Service provider services are suggested (machine rental to farmers) because of the high capital cost of the machine (the total price of the machine is RM380,500) and this cost burdens the farmer to invest it due to the lack of the scale of production. With the service provider, farmers only need to rent the necessary machines at a reasonable price. The rental rate can be reduced if there is an increase in use with an increase in the number of ha (high number of ha). Watermelon production using conventional and mechanisation packages was found to be viable. However, crop yield can be increased (low damage rate) and reduced operating costs (labour costs) if the mechanisation package is used. The comparison of income between cultivation using conventional methods and the mechanisation package was also evaluated. It was found that there is a net benefit difference between the two of RM2,700/ha/season where conventional production costs are higher than mechanisation production. This difference is due to reduced labour costs through the mechanisation approach. Although there is an increase in machine rental costs, however this increase is less than the labour costs.

Based on the partial budgeting that has been developed, about RM2,700 of benefit was obtained for each ha of watermelon cultivation, showing that this approach is very viable and practical to implement. In general, the use of mechanisation packages can save farmers time in the field. However, the high cost of development and acquisition of mechanisation packages has become a constraint for small farmers to use. Therefore, the service provider's approach is a reasonable suggestion for overcoming the problem by providing rental services involving machinery packages to needed farmers. In realising this desire, intervention from the government through the agencies involved whether from the researcher, development or marketing sectors is necessary. At the same time, the government's support in providing financial resources such as loans, grants and incentives to service providers is needed as a catalyst in providing a complete mechanisation package to benefit the target farmers, including through the rental method. In addition, qualified and capable farmers can also become service providers for the mechanisation package involved for the benefit of farmers who are less able to purchase the mechanisation package. Indirectly, the income of service providers can be increased and further contribute to increasing the stability of the local economy.

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Abstrak

Tembikai (*Citrullus lanatus*) menyumbang kira-kira 8.8% pengeluaran buah-buahan segar tropika di Malaysia. Kebanyakan tumbuhan ini ditanam di Kelantan, Pahang, Johor dan Terengganu dengan hasil sebanyak 92,762 mt pada tahun 2021 (DOA 2021). Pada masa ini, aktiviti penanaman tembikai di Malaysia seperti menanam, membaja, memasang plastik sungkupan dan menuai dijalankan secara konvensional, kecuali proses penyediaan tanah. Oleh itu, pakej mekanisasi penanaman tembikai diperkenalkan kepada petani bagi membantu memudahkan dan mengurangkan jurang masa aktiviti penanaman. Sehingga kini, belum ada kajian mendalam berkenaan penilaian impak ekonomi selepas penggunaan mekanisasi dalam penanaman tembikai. Kajian mengenai impak ekonomi penggunaan mekanisasi adalah penting dalam menilai kebolehlaksanaan penggunaan mekanisasi dalam perbezaan hasil penanaman dan kos pengeluaran. Analisis belanjawan separa digunakan dalam menganalisis keupayaan untuk melaksanakan perniagaan dengan pulangan yang dijangkakan hasil daripada penyesuaian teknologi atau pengurusan langsung. Pengeluaran tembikai secara konvensional dan pakej mekanisasi didapati berdaya maju. Hasil tanaman boleh ditingkatkan (kadar kerosakan yang rendah) dan mengurangkan kos operasi (kos buruh) jika pakej mekanisasi digunakan. Secara keseluruhan, analisis separa belanjawan menunjukkan manfaat atau nilai faedah melebihi nilai implikasi sebanyak RM2,700 jika penanaman tembikai diaplikasikan secara mekanisasi. Memandangkan harga pakej mekanisasi yang tinggi, kewujudan penyedia perkhidmatan dapat membantu petani melalui penyewaan mesin berkaitan. Intervensi daripada agensi pembangunan adalah penting bagi memastikan maklumat berkaitan pakej mekanisasi ini sampai kepada pengguna.