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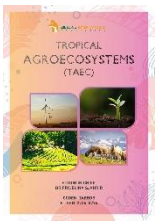

RESEARCH ARTICLE

ASSESSING *CUCURBITA MOSCHATA* PLANT GROWTH AND FRUIT QUALITY AT DIFFERENT PLANTING DISTANCES

Mohamad Daniell Mohd Dali, Mohamad Affandi Mohd Shukri, Kumara Thevan Krishnan*

Faculty of Agro-Based Industry, Universiti Malaysia Kelantan, 17600 Jeli, Kelantan, Malaysia.
Corresponding author email: thevan@umk.edu.my

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ABSTRACT

This study specifically examined *Cucurbita moschata* cultivation and the optimal planting distances for this crop in Malaysia's climate. An experiment was conducted to identify the optimal planting distances required in Malaysia for cultivating *C. moschata,* commonly known as butternut squash, on a commercial basis that would minimize land wastage and maximize land use efficiency. The objective of this study was to assess the impact of three distinct planting distances, specifically 20 cm, 40 cm, and 60 cm, on *C. moschata*. The variables recorded were leaf surface area and fruit quality. This study was carried out at Universiti Malaysia Kelantan, Jeli Campus (5° 44′ 51″ N, 101° 52′ 08″ E). A total of 75 *C. moschata* plants planted across 23 beds. Each bed consists of three different planting distances, 20 cm, 40 cm, and 60 cm where each planting distances for each bed were set randomly. The results indicated that there were no statistically significant variations in leaf surface area among the planting distances of 20 cm, 40 cm, and 60 cm (p=1.000). Similarly, there were no significant differences in fruit weight (p≥0.579), fruit length (p≥0.208), and fruit width (p≥0.583) among the different planting distances. Nevertheless, the fruit size of planting at 60 cm is larger compared to other planting distances. However, the fruit weight across the planting distances experimented with failed to achieve the desired fruit weight as specified in the Fresh Pumpkin (*Cucurbita moschata*) Specification - Malaysia Standard 2403:2011.

KEYWORDS

Cucurbita moschata, cultivation, fruit, pumpkin.

1. INTRODUCTION

Cucurbita moschata, also known as pumpkin, winter squash, or butternut squash, is a highly nutritious vegetable that belongs in the Cucurbitaceae family. It is widely consumed around the world, and the consumption rate has increased because of its health benefits in anti-inflammatory, antioxidant, anti-diabetic, and anti-cancer properties (Men et al., 2021). The fruit weighs between 1 kg and 3 kg with a cylindrical and bulbous blossom end, almost the same shape as a pear, with cream beige skin and orange's color flesh (Figure 1-A). *Cucurbita moschata* fruit contains high nutritional value and is low in calories. The fruits are used to make a variety of products for food production, cosmetic products, animal feed, cosmetics, and biofuel (Kamarubahrin et al., 2018; Men et al., 2021).

In commercial planting, one of the important factors that must be considered that affects the yield and quality of *C. moschata* is the planting distance and the planting densities. Studies show that a closer planting distance increases the number of fruits but reduces the fruit size (Reiners and Riggs, 1997). However, excessively wide spacing can reduce total yield, so it is important to find the right planting density (Gunes et al., 2007). The number of plants planted on the bed influenced fruit size, the number of fruits per hectare, and the number of fruits per plant. Recommendations from authors suggest that the squash be planted 20 cm, 30 cm, and 45 cm apart in rows, while other author suggest planting distances of 35 cm, 40 cm, and 45 cm apart (Wetzel and Stone, 2019; Balkaya et al., 2010). Others suggest a 50 cm planting distance or 91 cm–243 cm (36–96 inches) to produce a higher yield and higher fruit quality (Che Ya et al. 2023; Newenhouse, 2011).

Nevertheless, there was a lack of comprehensive data regarding the optimal planting distance and its specific influence on the overall crop output, particularly in the tropical climate of Malaysia. In addition, the *C. moschata* plants demonstrate considerable morphological variety because of their inherent capacity to adapt to various environments (Seka et al., 2023). Planting distance will contribute to the planting densities, which determine the number of plants being planted on the farm. A previous study on *C. maxima* found planting density impacted the fruit weight, number of fruits per hactare, and number of fruits per plant, although it did not impact yield statistically (Wetzel and Stone, 2019). Therefore, to optimize land use and maintain the fruit qualities necessary to commercialize *C. moschata*, planting density needs to be standardized, especially in tropical climates such as Malaysia. In this study, three different planting distances were applied to determine the suitable distance between plants in Malaysia's climate for cultivating *C. moschata* while comparing its fruit quality as per Malaysia Standard 2403:2011: Fresh Pumpkin (*Cucurbita moschata*) Specification.

2. METHODOLOGY

2.1 Study site

This study was located at Universiti Malaysia Kelantan Jeli's Campus, Kelantan (5° 44′ 51″ N, 101° 52′ 08″ E). The cultivation site for *C. moschata* is at Agro-Techno Park at Universiti Malaysia Kelantan Jeli's Campus, Kelantan.

2.2 Preparation of Bedding and seeds.

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A total of 23 planting beds with trellis (~ 1.8m height) were prepared, and each bed was constructed at 60 cm (wide) by 500 cm (length) (Figure 1-B). A total of 75 *C. moschata* plants were planted. The experiment was arranged in a Randomized Complete Block Design (RCBD). Each bed consists of different planting distances (in rows), 20 cm, 40 cm, and 60 cm where each planting distance was set randomly. *Cucurbita moschata* from 3 cultivar were tested (F1 760 - Soon Huat Seed; Crookneck- Mango Garden Seed; Waltham- De Seeds). *Cucurbita moschata* has diverse fruit shapes, such as globular, round, flattened, dumbbell, disc, oblong, cylindrical, oval, acorn, heart shaped, pyriform, crookneck, or elongated (Hazra et al., 2007; Ketsakul et al., 2020). The current research did not consider the differences between these 3 cultivars, as each cultivar differentiated based on the fruit shape, and past research found no significant differences in the yield of *C. moschata* observed between the other varieties (Abbey, 2016; Smith, 2007). The seeds were directly sown into the soil.

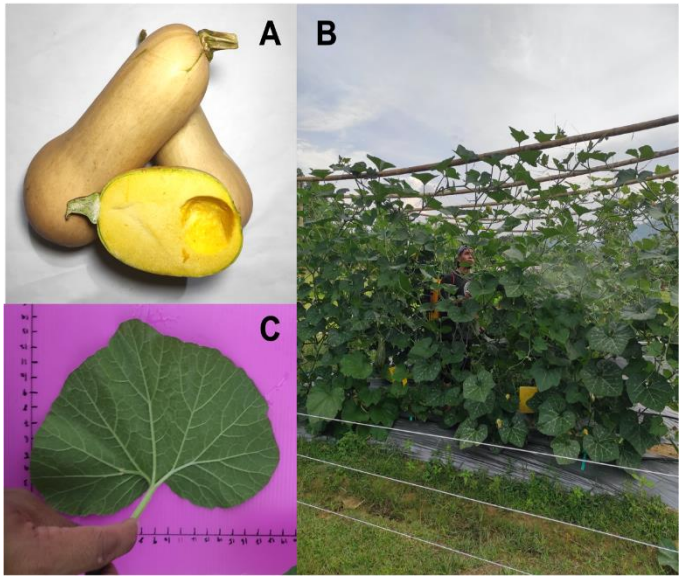

Figure 1: A- *C. moschata* fruits; **B**- Trellis setup at the research plot; **C**- scaling technique to measure the leaf surface area.

2.3 Environment Variables

Cucurbita moschata plants require sunny, warm, and well-draining soil for optimum growth. Data on the mean temperature and relative humidities of Jeli District, Kelantan, Malaysia, were requested from the Malaysia Meteorological Department throughout the study period (June 2023–September 2023).

2.4 Growth rate and Fruit Quality

The growth rate of *C. moschata* was determined by measuring the leaves of the plant and fruit quality after harvest. The method used in determining the samples was the direct measurement method. The leaf area was measured by taking a bird's-eye view of the leaf (Figure 1-C), and an application called the ImageJ program (https://imagej.net/) was used to measure the leaf surface area. The leaf area measurement was done from week 5 onwards, forthnightly. The fruit quality was determined by weight, length, and width upon harvesting. Harvesting of the fruits is done once they reach the maturation level of Index 6 as per Fresh Pumpkin (*Cucurbita moschata*) Specification (Malaysian Standard MS2403:2011, 2011).

2.5 Fertilization regiment

Two types of fertilizers were used during the cultivation of *C. moschata*: N.P.K. (15:15:15) (AgroHarta Sdn. Bhd.) and fish emulsion (Mxtra, Permentharvest, and Smart Growth) with a dosage of 30–50 ml per liter. N.P.K. green was applied to the plants two weeks after seedlings, while fish emulsion was applied to *C. moschata* one month after seedlings had been planted. The application of fish emulsions took place once every two weeks.

2.6 Statistical analysis

One-way ANOVA statistical test was applied using SPSS software (SPSS Statistic 27, IBM SPSS Inc., US) to analyze the differences in leaf surface area and fruit quality produced at 20 cm, 40 cm, and 60 cm planting distances.

3. Result and Discussion

3.1 Leaf surface area of *Cucurbita moschata*

The result shows that there were no significant differences (p = 1.000) in leaf surface area of *C. moschata*, regardless of the planting distances of 20 cm, 40 cm, and 60 cm. The first 6 weeks of *C. moschata* observed as vegetative states, during which the plants had less leaf surface area. In this stage, the plants focus on building the basic structure of roots, stems, and leaves, and their primary goal is to establish a strong root system for future plant support (Malinowski, 2013). From week 7 onwards, the plant began producing flowers, and the fruit started to develop. Thus, the plant is in its maturity stage, making the leaf surface area reach its peak. A group researchers observed similar results, with *C. moschata* exhibiting maximum plant height growth and leaf production around 7-8 weeks after sowing (Che Ya et al., 2023). Leaf surface area at this stage is often large, as they need to capture more sunlight to provide the energy for flowering and fruit ripening (Loy, 2004).

Meanwhile, from week 11 onwards, senescence of the leaf was observed, and there was a reduction in the leaf surface area. In this stage, the leaf begins to die or wilt, and the plant goes through a natural aging process that causes the leaf to fall off or wilt as a mechanism to relocate nutrients from the aging tissue to other parts of the plant, such as the fruit maturity process (Malinowski, 2013). Furthermore, developing fruit places heavy demands on the plant, reducing the growth of new leaves, roots, and any other fruit developing at the same time. (Loy, 2004; Maynard, 2007). The highest mean number of leaf surface areas was between weeks 7 and 9 (Figure 2). The current study found that *C. moschata* requires 79 days from seeding to fruit harvest and senescence. However, this differs from other researchers, who take about 130 to 160 days at an annual temperature of 24°C (Newenhouse, 2011; Rodríguez et al. 2023).

Cucurbita moschata is a tropical plant, and its growth and development are favored by mean temperatures ranging from 18 to 24 °C (Maynard, 2007). Researchers explored the relationship between the thermal requirements and productivity of *C. moschata* in a temperate climate, optimizing productivity by determining the sowing time and its thermal requirements. As in Malaysia, due to its tropical climate and photoperiod of 6-7 hours per day with a weekly mean temperature of 27.3±0.8 °C and weekly mean relative humidities of 81.5±3.5 (Figure 3 and Figure 4), this is probably the main factor for the faster growth in the current study. Researchers found that temperature plays an important role in the growth of *C. moschata*. Temperatures below 15 °C delay the germination rate, high temperatures promote male flowers and delay female flower development; and exposure to daytime temperatures of 32 °C and nighttime temperatures of 21 °C causes the death of female flower buds (Abbey, 2016; Souza et al. 2017; Nascimento, 2005; Maynard, 2007).

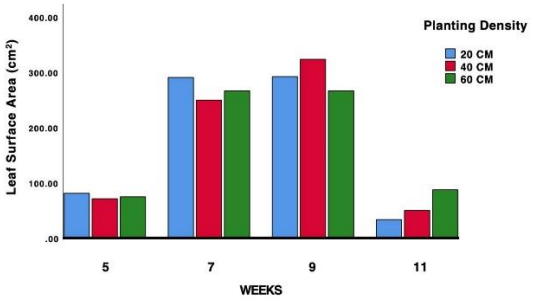

Figure 2: Mean leaf surface area of *C. moschata* from week 5 until week 11 at different planting distances.

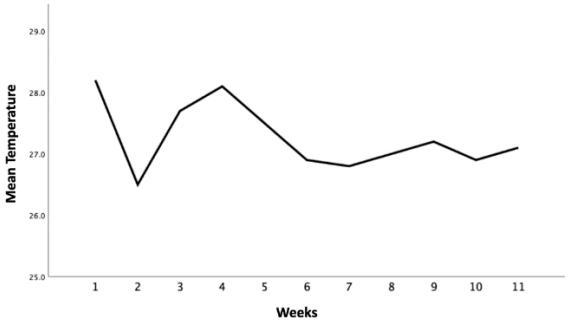

Figure 3: Weekly mean temperature of the planting site for the duration of the study. (Source: Malaysia Meteorological Department)

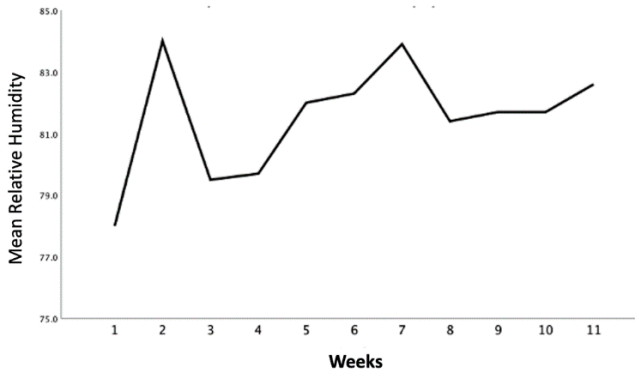

Figure 4: Weekly mean relative humidity of the planting site for the duration of the study. (Source: Malaysia Meteorological Department)

3.2. Fruit Quality of Cucurbita moschata

Statistical analysis showed that there are no significant differences in fruit weight ($p \geq 0.579$), fruit length ($p \geq 0.208$), and fruit width ($p \geq 0.583$) across the planting distances of 20 cm, 40 cm, and 60 cm (Table 1). At current planting distances, with a bedding of 5 meters (length) and 0.6 meters (wide), 20 cm planting distances will have 15 151 plants; 40 cm planting distances contain 9 803 plants, and 60 cm contain 6 849 plants within a hectare of land.

The current study found, the fruit quality of *C. moschata* in terms of its weight, length, and width was not affected by the planting distance. In Egypt, researchers suggested planting distances of 75 cm, as the fruit was larger in weight than those produced from plants grown 50 cm apart but smaller than others grown at 100 cm (Abdel-Rahman et al., 2012). By determining the planting distance, the planting densities can be decreased or increased. A study on pumpkins showed that by increasing plant density, pumpkin fruit size decreases, fruit number per area increases, and fruit weight per area increases (Heagy et al., 2023). Though the overall yield increases due to the increased number of fruits produced, the weight of each fruit decreases. Others reported, an increase in planting density did not increase yield significantly, but it did decrease fruit size (Wetzel and Stone, 2019). In the current study, the 60 cm planting distance produced slightly bigger fruits, though overall there was no significant difference across the 20 cm and 40 cm planting distances. For commercial planting, the quality of fruits depends on market demand and local regulations.

Currently in Malaysia, as per the Fresh Pumpkin (*Cucurbita moschata*) – Specification, based on the fruit weight specification, fruits weighing below 500, are considered extra small, whereas fruits weighing between 500-1000 g are small, 1000g-1500g are medium, 1500g - 2000g are large, and above 2000g are extra-large. Unfortunately, at the planting density of 20, 40, and 60 cm, all the fruits weigh between 467-573g (Table 1), which is the fruit grade of extra small and small. Therefore, for the determination of planting distances and planting density, it must be based on the fruit specifications. The current study, which is intended to minimize the chemical fertilizer and focus on organic *C. moshcata*, produces small fruit weights as per Fresh Pumpkin (*Cucurbita moschata*) Specification (Malaysian Standard MS2403:2011, 2011). Though various researchers suggest different planting distances, all agreed that smaller planting distances (in rows) decreased the fruit weight (Abdel-Rahman et al., 2012; Heagy et al., 2023; Wetzel and Stone, 2019). Therefore, any future research with regards to planting distances or density should support the fruit grading standard so that the fruit produced can be marketed at commercial establishments. For example, for the seed production of *C. moshcata*, large sized fruits should be selected at the field level to ensure the production of healthy, vigorous seedlings (Geetharani et al., 2007). However, based on market demand, farmers able to manipulate their squash plantations to meet the requirements needed by consumers, as some want the fruit to be smaller and some want it to be bigger.

Table 1: Effect of planting distances on fruit weight, fruit length and fruit width of C. moschata

Planting Distances	Weight (g)	Length (cm)	Width (cm)
20 cm	496.5 ± 29.0	17.4 ± 0.5	26.6 ± 0.5
40 cm	498.4 ± 23.2	16.8 ± 0.4	26.5 ± 0.5
60 cm	538.2 ± 35.2	18.0 ± 0.6	27.4 ± 0.7

4. Conclusion

The current study found there are no significant differences in the growth and fruit quality of *C. moschata* between 20 cm, 40 cm, and 60 cm planting distances. The life cycle from sowing to harvest is much faster in the Malaysian climate, which suggests potential for commercialization compared with other countries. Though the 60-cm planting distance showed a higher mean weight of fruits, it did not meet the requirement of Fresh Pumpkin (*Cucurbita moschata*) Specification, Malaysia Standard 2403:2011. For future recommendations, it is suggested to extend the planting distances beyond 60 cm and optimize fertilizer to meet the commercial fruit weight of more than 1 kg per fruit.

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