Research article

Effect of Pollination by the *Apis mellifera* on Yield and Fruit Productivity Quality of Greenhouse Produced Sweet Net Melon in Cambodia

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Abstract Sweet net melon (*Cucumis melo* L.) is an annual climbing plant famous for its delicious fleshy fruit. It is one of the most widely cultivated and consumed around the world. This study aimed to investigate the efficacy of pollination employing *Apis mellifera* L. (Hymenoptera: Apidae) on yield and growth in greenhouse conditions, compared to the traditional method of hand cross-pollination and self-pollination. The experiment was laid out using a completely randomized design (CRD) with three treatments and one hundred replications: T1 represented self-pollination, T2 – hand cross-pollination, and T3 – *Apis mellifera* pollination. Plant growth, fruit yield, and sugar content were analyzed by using a portable refractometer. Results revealed that the *Apis mellifera* pollination had resulted in a significantly greater fruit set of sweet net melon than hand cross-pollination and self-pollination (100%, 74%, and 62%, respectively). Furthermore, *Apis mellifera* had significantly enhanced fruit yield compared to both self-pollination and hand cross-pollination. In addition, self-pollination, hand cross-pollination, and *Apis mellifera* pollination were not significantly different in terms of sweetness, fruit thickness, fruit weight, number of seeds per fruit, and fruit size. Therefore, pollination by *Apis mellifera* can be used to increase fruit yield and ensure food security, in line with Cambodia's National Strategy for Food Security and Nutrition from 2019 to 2023. In addition, pollination by *Apis mellifera* may be one of the most powerful tools for agricultural adaptation to climate change.

Keywords *Apis mellifera*, pollination, thickness, flower

INTRODUCTION

Sweet net melon (*Cucumis melo* L.) is an annual climbing plant. It is widely cultivated and consumed for its flesh fruit (Kesh and Kaushik, 2021; Revanasidda and Belavadi, 2019; Silva et al., 2020). Reports indicate that global melon production increased by 9% between 2012 and 2016, with the cultivated area increased by 9000 ha, and the fruit yield increased from 24.6 tons/ha-1 to 25 tons/ha-1 (FAOSTAT, 2017). Nut et al. (2019) have reported that, in Cambodia, tens of thousands of melons are produced every year by local farmers. Melon plants have a shorter life, about 3 to 4 months, where anthesis and pollination occur 30 to 35 days after sowing. Following pollination, fruit development and growth are harvested 70 days after sowing (Azmi et al., 2019). Flowers of melon plants tend to be monoecious (Grumet et al. 2007) – in fact, they are either male or female, and both occur on the same plant. Generally, plants with monoecious flowers need pollinators, especially insects, to ensure enough pollination (Azmi et al., 2019; Dasgan et al., 1999).

Melon is typically grown in greenhouses; however, inadequate pollination prevents the highest levels of output and quality because suitable insects cannot enter the enclosed greenhouses, preventing pollinators from entering (Kwon and Saeed, 2003; Dasgan et al., 1999). To solve these pollination problems, staff are employed to hand-pollinate melon flowers, but this method is less efficient and more costly than using insects as natural pollinators to increase crop yield and quality (Azmi et al., 2019). For melon fresh fruit, quality is what mostly influences consumers' conduct and formulates recurring buying habits and brand loyalty within a reasonable price (Kyriacou et al., 2018).

Many greenhouses' crops rely on bee species for pollination (Sadeh et al., 2007). European honeybees (*Apis mellifera* L.) are the most frequent floral visitor of crops worldwide (Hung et al., 2018). The foraging behavior of honeybees, which collect nectar and pollen to maintain their colonies, provides multiple benefits to plant pollination (Young et al., 2007). Thus, honeybees are the main pollinators for increasing crop yields, where they provide commercial pollination services to plants grown in greenhouses (Lee et al., 2018).

OBJECTIVE

The aim of the study is to investigate the effect of pollination by *Apis mellifera* L. (Hymenoptera: Apidae) on the yield and quality of net sweet melon in the greenhouse, compared with hand cross-pollination and self-pollination.

METHODOLOGY

Experimental Conditions

Sweet net melon plants (*C. melo* var. mellon sweet net 77) were cultivated from seed on the seed trays in a 24 × 32 m greenhouse at the Faculty of Agriculture and Food Processing, National Meanchey University (NMU), Cambodia, which is located at latitude of 13°34'52.2"N and longitude of 102°55'50.3"E from February 1st to April 23rd, 2022. Seeds were purchased from Known-You Seed co, ltd, a company product in Taiwan. The seed was soaked in 40-degree water within one and a half hours to two hours and planted in moist peat moss in the seed tray and covered with Green Garden Shade Net. After 10 days, germinated seedlings were transplanted into white grow bags consisting of (40 × 40 × 50 cm) that contained 5 kg of coco peat and placed in the greenhouses. Each grow bag was fertilized with 5 g of amino acid 5% + 12.3.3 + OM 35% and irrigated by a dripping fertigation system (A and B Solid Fertilizer recommendation). Branches were removed to allow growth of the main stem, and supporting red plastic ropes were provided at each grow bag to facilitate plant climbing to supporter wires. The colonies of *Apis mellifera* were provided by the Khmer Beekeeping Farm, with more than 30,000 adults per hive. Two hives of *Apis mellifera* were used in the greenhouse while experimenting.

Treatments and Experimental Design

The experiments were laid out using completely randomized design (CRD) with a hundred replications. There were 300 plots, and each plot size was 0.8 × 1 m. There were two rows in each plot with a plant spacing of 0.4 × 0.4 m, and the plant population per plot was 4 plants. The experimental plots were divided into three treatments as the following:

Table 1 Treatment and adaptation of the pollination control

Treatment	Pollination method	Control
Treatment 1	Self-pollination	Uncontrolled
Treatment 2	Hand cross-pollination	Human pollinator
Treatment 3	*Apis mellifera*	Bee pollinator

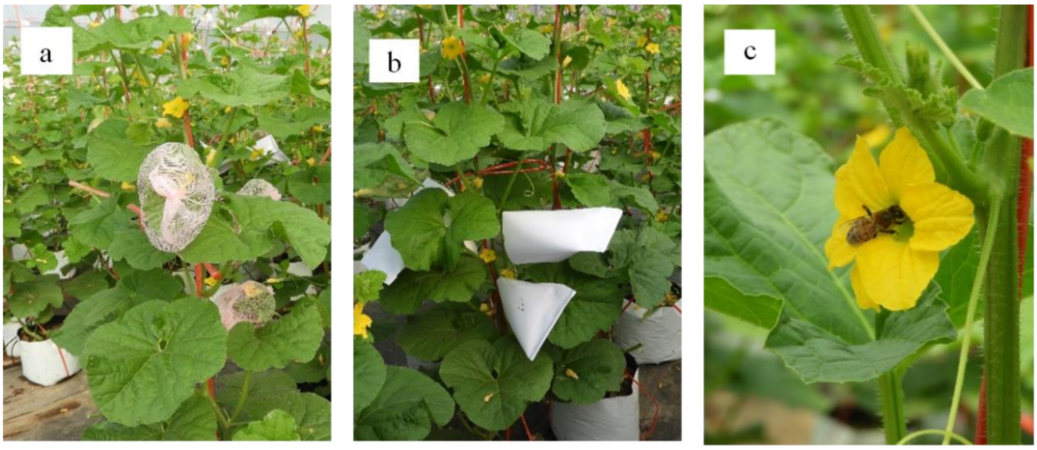

Fig. 1 T1 Self-pollination: use net size 3 × 3 mm to cover female flowers to protect against contamination by bees (a), T2 Hand cross-pollination: use white paper to cover female flowers to protect against contamination by bees and self-pollination (b), T3 *Apis mellifera*: use bees to pollinate (c)

Data Collection

Ten days after pollination, the fruit set on 100 plants from different treatments was recorded. The sweet net melons were harvested at 70 to 75 days using sharp knives or scissors. Generally, the ripe sweet net melons have senesced tendrils (Relf and Mcdaniel, 2020), and the minimum recommended sugar level for this fruit is 8 Brix. Below that level, the melons are not usually suitable for the market (Villanueva et al., 2004). Average fruit yield from 100 plants per treatment was also recorded, and 100 fruits from each of the 100 replication plants were chosen for weight, size, average number of seeds per fruit, and total soluble solids (TSS) content as a measure of sweetness. We measured the average number of seeds per fruit because a higher number of seeds leads to larger and heavier fruits (Cruz et al., 2005). First, the fruits were weighed (kg) using an electronic balance, and size (cm) was measured using a measuring tape. Then, the seeds were cut open to remove seeds. The thickness of the fruit flesh was cut into two wedges and measured the thickness. TSS content (Brix) of the fruit was tested from extracted juice, where a drop of juice from each cube was pipetted onto a screen panel of a portable refractometer.

Data Analysis

Data were collected from all samples of the three treatments and entered into Microsoft Excel. The data were statistically analyzed using R software (version 4.1.3).

RESULTS AND DISCUSSION

Sweet Net Melon Production

Table 2 shows that the average fruit set (%) of sweet net melon in treatment T3 = 100% was significantly different compared to other treatments. Thus, honey bees are the main pollinators for increasing crop yields. This probably provided commercial pollination services to plants grown in greenhouses (Lee et al., 2018). Meanwhile, T1 = 62% and T2 = 74% were not significantly different. This phenomenon may result from greenhouse cultivation, where high yields of sweet net melons are hindered by insufficient pollination due to the restricted access of pollinating insects within the enclosed structure. Pollinators are unable to enter greenhouses (Kwon and Saeed, 2003; Dasgan et al., 1999), necessitating manual pollination by staff. However, this approach is less efficient and more expensive than utilizing natural pollinators to enhance crop yield and quality (Azmi et al., 2019). Besides, the average yield of sweet net melon in treatment T1 = 0.66 kg and T2 = 0.78 kg per fruit were not significantly different from each other, but if compared with treatment T3 = 1.05 kg, it was significantly different. It indicates that the yield of sweet net melon is related to the fruit set.

Table 2 Effect of pollination method on fruit set and yield of sweet net melon fruit

Treatment	Fruit set (%)	Average yield (kg per plant)
T1 = Self-pollination	62 ± 0.49^{a}	0.66 ± 0.53^{a}
T2 = Hand cross-pollination	74 ± 0.44^{a}	0.78 ± 0.49^{a}
T3 = *Apis mellifera*	100 ± 0.00^{b}	1.05 ± 0.18^{b}

Note: Data are meant ± SD. Different letters within a column indicate treatment differences at P < 0.05 (n = 100)

Sweet Net Melon Quality

Table 3 shows that the average total soluble solids were not significantly different, respectively. TSS is a genuine indicator of melon-consuming quality, with a minimum standard of ten percent recommended. The effect of the irrigation schedule was also considered with respect to increasing melon quality. To date, the recommended practice has been to cause an irrigation deficit close to fruit harvest, with the intent of drying out or stressing the plant to bring on maturity and increase sugar accumulation. Irrigation showed that keeping plants stress-free close to harvest and during harvest facilitated the production of sweet fruit (Long, 2005) from the same variety applied in the experiment (Albuquerque et al., 2006).

Table 3 Effect of pollination method on TSS content, flesh, weight, seed production, and size of sweet net melon fruit

Treatment	TSS (Brix)	Flesh (cm)	Weight (kg)	Number of seeds per fruit	Size (cm)
T1	13.49 ± 1.59^{ns}	3.9 ± 0.54^{ns}	1.03 ± 0.19^{ns}	393 ± 77.24^{ns}	38.24 ± 2.16^{ns}
T2	13.20 ± 1.92^{ns}	3.78 ± 0.41^{ns}	1.02 ± 0.16^{ns}	388 ± 64.04^{ns}	38.39 ± 2.01^{ns}
T3	13.24 ± 1.89^{ns}	3.8 ± 0.44^{ns}	1.06 ± 0.20^{ns}	400 ± 68.16^{ns}	38.82 ± 2.70^{ns}

Noted: Data are means ± SD. Different letters within a column indicate treatment differences at P < 0.05 (n = 100).

The average fruit thickness in treatment T1 = 3.9 cm, T2 = 3.78 cm, and T3 = 3.8 cm were not significant amounts in treatment. This phenomenon may arise from using the same variety (Albuquerque et al., 2006) and the fertilizer, irrigation, and cultivation conditions applied in the experiment (Simsek and Comlekcioglu, 2011).

All the treatments have the average weight, T1 = 1.03 kg, T2 = 1.02 kg, and T3 = 1.06 kg, number of seeds per fruit, T1 = 393, T2 = 388, and T3 = 400, and size, T1 = 38.24 cm, T2 = 38.39 cm, and T3 = 38.82 cm, were not significantly different. Cultivars of melons with an average weight of 0.6 - 2.5 kg planted in greenhouses have been in high demand overseas (Lyan et al., 2021).

CONCLUSION

In conclusion, this study showed that *Apis mellifera* pollination produced a greater fruit set of sweet net melon than hand cross-pollination and self-pollination. Pollination by *Apis mellifera* produced a higher yield than self-pollination and hand cross-pollination. Self-pollination, hand cross-pollination, and *Apis mellifera* pollination did not affect the sweetness, thickness of the fruit flesh, weight, number of seeds per fruit, and size of sweet net melon fruits.

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