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Effect of an Eco–friendly Bloom Thinning Formulation on Fruit Growth and Profitability of Mango Trees in Vietnam

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Mango, *Mangifera indica* L. (Anacardiaceae), is a popular tropical fruit with a unique flavor and high nutritional value. The thinning of blooms and fruits, an important technique in mango growth, is used to limit the fruit number per tree while increasing the size and quality of fruits produced for commercial purposes. We tested the efficacy of an eco–friendly bloom thinning formulation (BTF) on three different mango varieties (Taiwan Yellow Gold, Cat Chu, and Hoa Loc) across three seasons in a trial conducted in three provinces (Can Tho, Dong Thap, and Tien Giang) of Vietnam. BTF treatment thinned the mango fruit crop causing a reduction in crop load, fruit set, and number of fruits per tree. Moreover, in the harvest season, the three BTF–treated mango tree varieties produced a greater proportion of high–quality mangoes than those produced by the control trees. Furthermore, compared with the control, BTF treatment increased the large fruit ratio of Taiwan Yellow Gold, Hoa Loc, and Cat Chu varieties by 16.0%, 11.0%, and 15.7%–8.9%, respectively. The income value of BTF–treated trees was also at least 20% higher than that of the control trees. However, no significant differences were observed in the percentage of soluble solid, acidity, vitamin C, or beta-carotene contents between BTF-treated and untreated fruits, without any physiological disorder. These findings indicate that BTF spray treatment enhanced the fruit weight, average production, and market price of all the tested mango cultivars from Vietnam.

Key words: environmentally friendly, fruit trees, mango, orchard management, thinning agent

INTRODUCTION

Mango (*Mangifera indica* L.), which originated in South East Asia and is now grown worldwide, is one of the most important fruit crops in tropical and subtropical countries (Liguori *et al.*, 2020; Vasugi *et al.*, 2012; Wei *et al.*, 2021). Because of its desirable taste and rich vitamin C and mineral contents, it is sometimes referred to as the “King of Fruits” (Tharanathan *et al.*, 2006). According to the productivity and planted area of mango, it has presently overtaken banana as the second most important tropical crop (Tewodros *et al.*, 2019). In mango farming, several varieties produce a significant number of fruits, of which more than half fall to the ground before harvest. Therefore, it is essential for farmers to perform thinning to achieve an adequate yield of large fruit and optimize their return on investment. Thinning methods, which are generally performed during the growing season, are important to maximize fruit size and quality (Kurlus *et al.*, 2020; Sutton *et al.*, 2020; Zaaroor–Presman *et al.*, 2020); in fact, thinning of fruits is generally a common procedure in fruit cultivation (Looney, 1993; Tromp, 1996). Specifically, the process involves removing particular blooms or fruitlets from a plant, which not only increases fruit yield and quality but also allows the plant to bloom again the following year (Ouma, 2012; Sutton *et al.*, 2020).

Thinning or crop load management can be accomplished in three methods, viz., by hand, mechanically, and chemically (Bound, 2021). Hand thinning is an expensive approach on a commercial scale because it is time– and labor–intensive (Meiand, 1998; Webster, 2002). Mechanical thinning, which is commonly used on fruits such as apples, pears, and peaches (Hehnen *et al.*, 2012; Lordan *et al.*, 2018), can be performed by shaking a tree, sweeping it with sharp bristled brushes, thrashing it with ropes or switches, or removing blossoms or fruitlets using water or air at high pressure (Bound, 2021). Nevertheless, these methods can cause substantial damage to the tree as well as remove larger fruit, leaving smaller, less desirable fruit behind (Lopes *et al.*, 2019; Rosa *et al.*, 2008; Webster, 2002). Chemical thinning is recognized as the most effective thinning method (Gonzalez *et al.*, 2020). A range of chemical thinning agents, e.g., ethephon, abscisic acid, ammonium thiosulfate, benzyladenine, endothall, carbaryl, lime sulfur, met-

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amitron, pelargonic acid, sulfcarbamide, thiram, naphthalene acetic acid, and gibberellins, are used worldwide to thin pome fruit (Bound, 2021; Greene *et al.*, 2011; McArtney *et al.*, 2012; Webster, 2002; Wertheim, 2000). The effectiveness of chemical thinning depends on environmental and cultivar circumstances, which can yield inconsistent results (Greene and Costa, 2013; Lordan *et al.*, 2018; Robinson and Lakso, 2004). Therefore, numerous studies have been conducted to address the problem of thinner reaction unpredictability (Greene and Lakso, 2013; Lakso *et al.*, 2001; Lakso and Robinson, 2015). Along with such inconsistencies, some chemical agents are hazardous to plants, pollinators, and mammals (Bertelsen, 2002; Bound and Jones, 2004; Tomlin, 1994).

Because of the increased focus on environmental protection, the availability of chemical thinning agents has been reduced, and environmentally friendly thinning agents are being considered as alternatives (An *et al.*, 2016; Bertschinger *et al.*, 1998). Studies have reported the thinning effects of agents such as vegetable oil, potassium bicarbonate, or molasses when they are sprayed at bloom time (Ju *et al.*, 2001; Lordan *et al.*, 2018; Stopar, 2004; Weibel *et al.*, 2012). Koduri plus, an eco–friendly bloom thinning formulation (BTF) derived from several organic compounds and minerals, is a product of Apple Bio Co., Ltd., Korea (https://apple1397.en.ec21.com/), aimed at reducing the cost and labor intensiveness of fruit thinning while enhancing fruit growth. Son *et al.* (2020a) recently observed that using Koduri plus for apple thinning improved the fruit quality of both Fuji and Arisu apple cultivars. They also found that Koduri plus treatment considerably decreased the total cost of production and the required labor force in the apple orchard (Son *et al.*, 2020a). Other studies have found that using Koduri plus for mango thinning does not harm the insect pollinator *Apis mellifera* L. (Hymenoptera: Apidae) (Jahan *et al.*, 2014; Son *et al.*, 2020b, 2021).

As the world's 13th largest mango grower, Vietnam grows mangoes in 59 of the country's 63 provinces (Diop and Ndiaye, 2019). Thinning is performed to avoid mango varieties producing undersized, low–quality export fruit and also to improve the properties of the fruit to sufficient levels (Yeshitela *et al.*, 2004). For instance, studies have found that thinning improves fruit weight, quality, and commodity prices (Bussi *et al.*, 2005; Serra *et al.*, 2016). The present study was conducted to evaluate the effectiveness of a BTF used on three different mango cultivars, Taiwan Yellow Gold (TYG), Cat Chu, and Hoa Loc, in three different provinces of Vietnam. Our findings indicated that BTF treatment improved fruit weight, average yield, market price, and fruit quality.

MATERIALS AND METHODS

Study site and experimental design

During the seasons of 2019, 2020, and 2021, experimental trials were conducted in mango orchards in three different regions of the Mekong River Delta in Vietnam (Figure 1).

Mango trees began blossoming, after which BTF [dilution ratio = 1:1000 (product:water)] was sprayed twice using a hand sprayer, i.e., once at the completion of the blossoming season, during which flowers were approximately 70% developed, and then at full flowering, when the flowers were almost completely developed. Table 1 shows the BTF treatment schedules for the three different mango cultivars. Trees in the control group were not sprayed. Field trials consisted of three replications in a randomized complete block design with

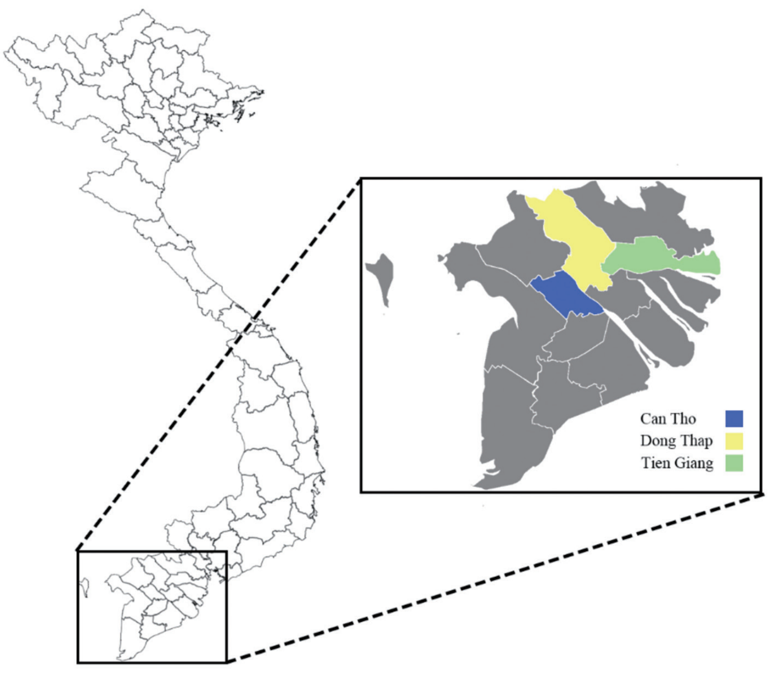

Fig. 1. Map of Vietnam showing the study sites.

Table 1. Experimental study of BTF treatment on the three tested mango cultivars

Variety	Year	First bloom	First spray**	Second spray***	Area
TYG*	2019–2020	2019.12.10	2019.12.25	2020.01.01	36 trees = 1080 m^2
Hoa Loc	2020–2021	2000.11.24	2000.12.10	2000.12.17	24 trees = 1600 m^2
Cat Chu	2020	2000.05.10	2000.06.05	2000.06.11	24 trees = 1200 m^2
Cat Chu	2021	2021.05.13	2021.06.07	2021.06.13	24 trees = 1200 m^2

*TYG: Taiwan Yellow Gold; **70% flower blossoming; ***100% flower blossoming

Table 2. Major components of BTF

Components	Proportions (%)	Main active ingredients
1. Extract of seaweed	<18	Alginate
2. Water–soluble amino acid fertilizer	<15	Amino acid
3. Extract of low–quality fresh *Panax ginseng*	<2	Ginsenoside
4. Extract of *Chenopodium ambrosioides*	>1	Limonene
5. Extract of *Houttuynia cordata*	<2	Essential oil
6. Extract of *Bupleurum falcatum*	<1	Saponin
7. Zinc propionate	<3	Zinc (for registration)
8. Boric acid	<1	Boron (for registration)
9. Wood vinegar	>1	Organic acid
10. Inert ingredient	56	Water

Diluted 1000 times when spraying

24–36 mango trees per block. Mango trees aged 5–15 years were investigated in this study (Table 1). Other cultivation practices, such as pesticide treatments, followed the general practices of mango growers.

Major components of BTF

BTF was supplied by Apple Bio Co., Ltd., Korea, and was formulated by combining numerous organic substances and minerals (Table 2).

Fruit yield parameters

Each elementary plot was evaluated to determine how BTF treatment affected fruit set and yield parameters. Before and after the treatment, we counted the total number of flower clusters per tree, the number of fruits per cluster, and the total number of fruits per tree. During the commercial harvest season, each orchard was harvested for each individual tree selected for the study. The total fruit yield (kg/tree) and weight (g) were measured using a commercial machine.

Determination of fruit quality

To investigate the quality of mango fruit treated with BTF, we evaluated only the mango pulp (mesocarp), the fruit's most important and directly consumable component. In 2020, 10 fruits were randomly selected for each treatment and juiced before the following data were collected: soluble sugar content, titratable acidity, vitamin A, and beta-carotene content. A digital refractometer (BS EN 12143:1997) was used to measure the soluble sugar content of mango fruits, which was expressed as a percentage of Brix (°BX). The titratable acidity was measured using NaOH titration (Vietnam standard TCVN 5483:2007). The vitamin C content was determined using the AOAC 2001 13 methods, respectively (http://www.boa.gov.vn/sites/default/files/234h0319l.pdf).

Statistical analyses

An independent samples t–test was conducted to determine the significant differences in fruit weight and fruit quality for each mango cultivar between BTF treatment and control, with significance set at $p < 0.05$. All statistical analyses were conducted using the PROC T–TEST procedure in SAS version 9.4 (SAS Institute, Cary, NC, USA) (SAS, 2013). The data shown in the tables indicate the mean ± standard deviation of five replications for all experiments.

RESULTS

Effects of BTF treatment on fruit set and fruit yield

Each of the orchards used in the field trials had a uniform bloom throughout the experimental period. All the three mango cultivars showed no significant differences in the initial number of flower clusters per tree. The number of fruits per cluster after BTF treatment was 1.3 ± 0.33 in the TYG variety, 2.3 ± 0.42 in the Hoa Loc variety, and 2.5 ± 0.46 (2020) and 6.1 ± 0.83 (2021) in the Cat Chu variety, whereas the respective numbers in the untreated groups were 1.7 ± 0.29, 2.8 ± 0.44, and 3.5 ± 0.56 (2020) and 8.9 ± 0.72 (2021) (Table 3). This result indicates a decrease in the number of fruits per cluster and the amount of fruits per tree before bagging

Table 3. Effects of BTF on fruit set and fruit yield of mango varieties

Varieties	Years	Treatments	No. of flower clusters per tree	No. of fruits per cluster	No. of fruits per tree before bagging	No. of fruits per tree at harvest	Yield per tree (kg)
TYG	2019–2020	BTF	60.3 ± 7.3a	1.3 ± 0.33a	77.7 ± 6.23a	52.7 ± 5.9a	38.4 ± 3.5a
		Control	58.7 ± 6.9a	1.7 ± 0.29a	98.0 ± 10.5b	62.3 ± 5.5a	33.1 ± 3.9a
Hoa Loc	2020–2021	BTF	62.3 ± 6.8a	2.3 ± 0.42a	142.7 ± 9.2a	109.3 ± 9.5a	58.5 ± 5.2a
		Control	68.7 ± 7.2a	2.8 ± 0.44a	189.0 ± 12.5b	136.3 ± 12.9b	52.7 ± 5.4a
Cat Chu	2020	BTF	79.7 ± 7.1a	2.5 ± 0.46a	198.7 ± 14.8a	139.3 ± 11.6a	66.9 ± 4.9a
		Control	85.0 ± 7.2a	3.5 ± 0.56a	296.3 ± 13.1b	175.3 ± 14.5b	57.8 ± 5.4a
Cat Chu	2021	BTF	220.0 ± 9.7a	6.1 ± 0.83a	521.3 ± 37.9a	388.0 ± 17.7a	156.6 ± 10.8a
		Control	212.7 ± 12.5a	8.9 ± 0.72a	730.1 ± 23.6b	472.3 ± 24b	143.7 ± 10.6a

*Values represent mean ± standard deviation of five replications.
Different lowercase letters in a column indicate a significant difference ($p < 0.05$) in mean values between the treated and untreated groups for each mango variety according to an independent samples *t*–test.

Table 4. Effect of BTF spray on large and small fruit production and their economic values of different mango varieties

Variety	Conditions	Large fruit*		Small fruit*		Total income (1000 VND/ tree)	Profit improvement (%)
		Weight (kg)	Price (1000 VND/kg)	Weight (Kg)	Price (1000 VND/kg)		
TYG	Treated	28.1	15	10.3	8	505 (422 + 83)**	27.3
	Untreated	14.6	15	18.5	8	367 (219 + 148)	
Hoa Loc	Treated	38.7	85	19.8	50	4280 (3290 + 990)	21.4
	Untreated	20.8	85	31.9	50	3363 (1768 + 1595)	
Cat Chu (2000)	Treated	57.6	25	9.3	15	1,580 (1440 + 140)	20.1
	Untreated	39.5	25	18.3	15	1263 (988 + 275)	
Cat Chu (2021)	Treated	120.5	23	36.1	12	3205 (2772 + 433)	22.0
	Untreated	96.6	21	47.1	10	2500 (2029 + 471)	

* the large fruit weights of TYG, Hoa Loc, and Cat Chu varieties were higher than 700, 450, and 330 g, respectively, and the small fruit weights of TYG, Cat Hoa Loc, and Cat Chu varieties were less than 700, 450, and 330 g, respectively.
** the combined price of large fruits and small fruits

for all the three varieties after BTF treatment. The number of fruits per tree at harvest after BTF treatment was 52.7 ± 5.9 in the TYG variety, 109.3 ± 9.5 in the Hoa Loc variety, and 139.3 ± 11.6 (2020) and 388.0 ± 17.7 (2021) in the Cat Chu variety, whereas the respective numbers in the untreated groups were 62.3 ± 5.5, 136.3 ± 12.9, and 175.3 ± 14.5 (2020) and 472.3 ± 24.0 (2021) (Table 3). Thus, the change in the number of fruits per tree at harvest showed a similar trend to the number of fruits per cluster and the number of fruits per tree before bagging, indicating that the early fruit set persisted into the harvest season. With BTF treatment, the number of fruits per cluster decreased for all the three mango varieties, and this phenomenon was similar for all the three varieties.

The average yield (kg) per tree for each mango cultivar was significantly different across treatments (Table 3). The average yield of each mango cultivar increased after BTF treatment compared with that of the control. Moreover, BTF treatment increased the yield of TYG, Hoa Loc, and Cat Chu varieties compared with that of the control (38.4 vs. 33.1 kg, 58.5 vs. 52.7 kg, and 66.9 vs. 57.8 kg or 156.6 vs. 143.7 kg, respectively) (Table 3).

Profit improvement of each mango variety as a function of large and small fruit ratio

The economic benefits of each variety as a function of large and small fruit ratio are shown in Table 4. For the Cat Chu variety, the 2020–year fruit production of large and small fruits was 57.6 and 9.3 kg in the treated

Table 5. Comparison of quality characteristics of the three mango varieties after BTF spraying treatment

Variety	Conditions	Fruit weight (g/fruit)		Soluble Sugar content (°BX)	Titrat-able acidity (%)	Vitamin C (mg/kg)	Beta-carotene (mg/kg)	Coloration	Physiological disorder
		Large	Small						
TYG	Treated	910a	401a	15.5a	0.23a	81.2a	1.12a	Green	none
	Untreated	902a	452a	14.9a	0.21a	81.5a	1.21a	Green	
Hoa Loc	Treated	547a	401a	20.5a	0.34a	80.2a	1.22a	Light green	none
	Untreated	468b	344a	20.2a	0.38a	79.4a	1.27a	Light green	
Cat Chu (2000)	Treated	394a	272a	9.0a	1.09a	85.5a	1.34a	Dark yellow	none
	Untreated	346b	242a	8.5a	1.15a	83.1a	1.44a	Light yellow	
Cat Chu (2021)	Treated	398a	270a	9.1a	1.06a	84.1a	1.3a	Dark yellow	none
	Untreated	351b	252a	8.8a	1.12a	78.3a	1.36a	Light yellow	

Different lowercase letters in a column indicate a significant difference ($p < 0.05$) in mean values between the treated and untreated groups for each mango variety according to an independent samples t–test.

plots compared to 39.5 and 18.3 kg in the untreated plots, respectively, resulting in 18.1 kg more fruit production in the treated plots. In the 2021–year experiment, the production of large and small fruits was 120.5 and 36.1 kg in the treated plots but 96.6 and 47.1 kg in the untreated plots, respectively, indicating a similar trend to the 2020–year experimental result, with the large fruit production being 23.9 kg higher in the treated plots. Moreover, for the TYG variety, the yield of large and small fruits was 28.1 and 10.3 kg in the BTF–treated plots but 14.6 and 18.5 kg in the untreated plots, respectively, indicating a 13.5 kg higher yield with BTF treatment (Table 4). The increase in the large fruit yield was 31.4% (2020) and 19.8% (2021) in the Cat Chu variety, 48.0% in the TYG variety, and 46.3% in the Hoa Loc variety, revealing an increase in the percentage of fruit in all varieties, indicating that BTF treatment contributed to fruit production.

The total income (1000 VND/tree) was 505 (1000 VND) in the group of BTF–treated TYG variety and 367 (1000 VND) in the untreated group, indicating a 27.3% higher yield in the treated group. The Cat Chu (20.1%–22.0%) and Hoa Loc (21.4%) varieties showed similar results to those of the TYG variety, with no significant differences between varieties, growing regions, and growing seasons (Table 4).

Quality characteristics of each mango variety after BTF treatment

Table 5 depicts the quality characteristics of each mango variety after BTF treatment. The weight per piece varied by varieties, and the classification of large and small fruits was based on the weight of 700 g for TYG, 330 g for Cat Chu, and 450 g for Hoa Loc varieties. The weight per fruit in the treated group was 910 g for TYG, 394.4–398.3 g for Cat Chu, and 547 g for Hoa Loc, whereas the respective values in the untreated group were 902, 346.1–351.3, and 468 g (Table 5). No statistically significant difference was observed in the fruit weight between the treated and untreated groups for the Hoa Loc variety [$t_{(8)} = 0.166$, $p = 0.872$]. According to Table 5, there are significant differences in fruit weight between the treated and untreated groups for Hoa Loc, Cat Chu (2000), and Cat Chu (2021) varieties [Hoa Loc: $t_{(8)} = 2.515$, $p = 0.036$; Cat Chu (2000): $t_{(8)} = 2.647$, $p = 0.031$; Cat Chu (2021): $t_{(8)} = 2.497$, $p = 0.037$]. Therefore, the profit improvement of TYG, Hoa Loc, Cat Chu (2020), and Cat Chu (2021) varieties was 27.3%, 21.4%, 20.1%, and 22.0%, respectively.

The BTF treatment used in this experiment caused no physiological impairment of mango trees in all the three regions, and there were no significant differences in coloration and the contents of beta–carotene, vitamin C, and soluble sugar compared with those in the untreated group (Table 5). Moreover, the BTF treatment caused no significant changes in the mango tree and fruit quality characteristics, except for the increase in fruit yield, confirming the possibility of using this formulation as an eco-friendly product.

DISCUSSION

Fruit trees are often overset, even in the absence of adequate pollination. An abundant crop can exert negative effects on fruit size, color, sugar contents, and other fruit quality components because of the unsuitable fruit ratio (Bangerth, 2000). Therefore, in modern fruit production, blossom or fruit thinning has become an important technique. Fruit thinning can be used to modify the fruit load of each individual plant according to its vegetative vigor and thereby improve the production of large and high–quality fruits (Hussein *et al.*, 2019). Furthermore, thinning is most successful at increasing the remaining fruit size when it is performed immediately after the first fruit set. The intensity of thinning can directly impact the size of the fruit and exerts a considerable impact on tree revenue (Hussein *et al.*, 2019). In this study, we examined the efficacy of an eco–friendly BTF on three major mango cultivars in Vietnam.

Compared with thinning at later stages, thinning at bloom time generally results in higher fruit size at harvest (Deshmukh *et al*., 2017; De Oliveira *et al*., 2017; Njoroge and Reighard, 2008). In fact, several studies have found that bloom thinning exerts a significant impact on fruit size distribution at harvest, with larger fruit sizes being typically produced (Byers *et al*., 2003; Myers *et al*., 2002). In the present study, after two BTF treatments, the tested mango trees had clear fruit differentiation. Each cluster had an average of 1.3–2.3 fruits, depending on the mango cultivar. For the control trees, each cluster had an average of 1.7–3.5 fruits, which was higher than that observed after BTF treatment. We have previously shown that bloom thinning using various BTFs was effective in terms of increasing mango fruit size (Jahan *et al*., 2014). However, Sutton *et al*. (2020) reported that bloom thinning alone may not produce consistently favorable effects in terms of fruit size improvement. Hence, partial bloom thinning followed by fruit thinning may be a viable option. In the present study, using BTF as a fruit thinning treatment resulted in increased fruit weight and yield for all the tested mango cultivars. The market price of mango fruit is highly dependent on fruit size (Tharanathan *et al*., 2006); our findings demonstrated that BTF treatment also increased the total revenue per tree compared with that received from the control trees. Therefore, fruit thinning was shown as a process that can increase the market value of the mango fruit varieties evaluated in our study. Similarly, Son *et al*. (2021) reported that different eco-friendly BTFs could increase the market price of mango fruits by more than twofold the price of the control fruit. In another study, Son *et al*. (2020a) reported a significant increase in yield with no negative effects after BTF treatment in "Fuji" and "Arisu" apple fruits.

In the present study, we observed a difference between the number of fruits per tree before bagging and the number of fruits per tree at harvest. This is because the bagging process does not bag all mango fruits but only those that are large enough to be bagged, and because several smaller fruits are not harvested if they are slow-growing, fall off during growth, or are not marketable. The higher yields at harvest time in the treated plots are due to the higher ratio of fruit size in the treated plots, although the untreated plots also had higher fruit numbers.

An increased ratio of large fruits results in an increase in total yield, which in turn leads to an increase in revenue per unit area. Moreover, the physiological impairment of mango trees and the changes in fruit characteristics due to BTF treatment were not different from those in the untreated plots in most of the treatments, suggesting that BTF has a positive potential for increasing production and producing high–quality mango fruits.

Although other eco–friendly thinning agents have been used on various fruit trees, only a few have produced consistent results with minimal or no phytotoxicity (Schmidt *et al*., 2011; Webster, 2002). For instance, Lordan *et al*. (2018) reported that olive oil, potassium soap, and lime sulfur exerted a considerable thinning effect that increased the fruit size of Red Chief and Golden Smoothee apple cultivars. Alrashedi and Singh (2016) used combinations of lime sulfur and olive oil, but it caused leaf burning. In the present study, we observed no phytotoxicity symptoms in the tested mango cultivars after BTF treatment. Other studies using various vegetable oils (corn, rape, and olive) have found that such treatments can reduce fruit set and increase fruit size (Ju *et al*., 2001; Pfeiffer and Ruess, 2002). However, Dussi *et al*. (2008) reported that lime sulfur (10%) and sulfur (80%) applied at 80% of full bloom exerted little effect on reducing the fruit set of "Williams" pears in Argentina and Oregon, USA. In contrast, Garriz *et al*. (2019) concluded that application of 7% lime sulfur at 30% of full bloom was effective for thinning and enhancing fruit quality in "Abbé Fetel" pears in Argentina.

Consumer acceptance of fruit is affected by its perceived flavor (Echeverría *et al*., 2012; Belisle *et al*., 2018). The perceived sweetness of mango fruit is highly variable and influenced by both its sugar level and acidity (Belisle *et al*., 2018; Lebaka *et al*., 2021). In the present study, fruit thinning with BTF treatment exerted no effect on fruit acidity, SSC, vitamin A content, and vitamin C content at harvest. This result is consistent with our previous study, which showed similar effects of BTF treatment on fruit SSC and acidity (Son *et al*., 2020a).

CONCLUSIONS

The process of flower thinning can impact both the amount and quality of the fruit that is ultimately harvested. Our experimental results clearly indicated that the application of BTF led to a reduction in crop load, fruit set, and number of fruits per tree, demonstrating its thinning impact. The use of bloom thinning as a strategy to achieve the desired fruit quantity per tree has the potential to be a valuable approach to optimize both fruit size and overall production. The BTF treatment group and the control group showed no statistically significant changes in physiological impairment or fruit quality. Therefore, our study indicated that BTF spray treatment exerted a positive impact on several parameters, including increased ratio of large fruits, average production, and market price, across all the tested mango cultivars of Vietnam.

AUTHOR CONTRIBUTIONS

M. M. Mostafiz and T. K. Son designed the study, performed the formulation experiments, analyzed the data, the statistical analysis and wrote the paper. N. T. Thanh and N. D. Can performed the field experiments and provided facilities and resources. K. Sakai participated in organizing the research results and editing the paper. K. Y. Lee and T. K. Son designed the study, supervised the work, wrote the paper and provided facilities and resources. All authors assisted in editing of the manuscript and approved the final version.

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