Effect of hand pollination to increase yield of papaya (*Carica papaya*) cv. 'Yellow Krang' grown in Thailand

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ABSTRACT

This research aimed to determine if the time of the year and the practice of hand pollination affected the yield of papaya. The experiment was done on papaya cultivar 'Yellow Krang' grown in northeastern Thailand. The experiment was arranged in a 12 × 2 factorial in a randomized complete block design with 5 replications and 10 trees per replication. The first factor tested was the time of the year. Seeds were planted each month, from January to December 2017. The second factor was pollination method, i.e., hand pollination versus natural pollination. The results showed that the number of days to flowering (range 90.8–110.2 days), flesh thickness of fruit (range 1.3–2.4 cm), flesh firmness (range 0.44–0.76 kg/cm^2) and perceived crispness of the fruit (range 4.3–4.8 on a scale of 1–5) were similar across all months of the year, and no significant differences in these variables were observed between fruit obtained from natural pollination and those from hand pollination. However, there were statistically significant differences (0.05) in mean number of flowers per tree, percentage of fruit set, number of fruit per tree, and mean fruit weight between the trees planted in different months and comparing hand to natural pollination. Trees that began flowering in the cooler months, between October and January, bore the most flowers per tree (180.1–189.6 flowers over the data collection period of 3 months), while those that began flowering in the hottest month of April bore fewer flowers (mean 124.2 flowers per tree over 3 months). Notably, the percentage of fruit set was 90.1–100% in trees that were hand pollinated, compared to 56.2–98.2% for naturally pollinated trees. The number of fruit per tree from hand pollinated trees was 241.5–305.6, more than double the number of fruit harvested from naturally pollinated trees (62.7–132.2). The mean fruit weight from hand-pollinated trees was also greater, ranging from 1.20–2.56 kg, compared to a range of 0.72–1.84 kg from naturally pollinated trees. Pollination success is dependent on many factors including cultivar, existence/population density of insect pollinators, temperature, humidity, and precipitation. A hand pollination technique might hold promise for increasing yield of 'Yellow Krang' papaya for growers with the time to invest in this procedure.

Keywords: Fruit quality, flowering, fruit set, pollination success, seasonality

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INTRODUCTION

Believed to be introduced to Thailand in the seventeenth century (Sompak *et al.,* 2014), papaya (*Carica papaya*) has become a familiar crop that is associated with the culinary culture of Thailand. It is popular as an easy plant to grow in backyard gardens for household consumption (Magoon, 1980). Demand for both unripe and ripe papaya in Thailand is growing, for eating and industrial applications in the meat tenderizing, textile, tannery, and canning industries (Janthasri, 2007). "Som tam" is a dish made from unripe papaya that is very popular, especially in northeast Thailand. The 'Yellow Krang' and 'Red Krang' cultivars grown in Maha Sarakham province and the 'Khaeg Nuan' cultivar grown in Kalasin province are particularly sought after by som tam makers because the unripe flesh of these cultivars is crisper and more flavorful than other cultivars.

Cultivated papaya is polygamous with three basic floral types: pistillate, staminate, and hermaphrodite (which may be subdivided into pentandria hermaphrodite, carpelloid hermaphrodite, elongate hermaphrodite, and barren hermaphrodite). The sex is genetically determined, but in some cases, male and hermaphrodite trees may undergo sex reversal due to environmental factors (Chan, 2009). In Thailand, it is a common practice among farmers to plant 3 papaya seedlings in each spot, and when they start to flower, select just the strongest one with hermaphrodite flowers and pull out the other 2 in order to avoid wasting resources on trees that produce only male flowers (Janthasri, 2007). Hermaphrodite flowers produce more marketable fruit than pistillate flowers (Phuangrat *et al.,* 2013). Previous studies have indicated that wind, honeybees, butterflies, and moths may be the main pollination vectors, although some cultivars are also self-pollinating (Chan, 2009). Hand pollination has been found to improve fruit quality in some other fruit crops, which we suspect might be due to greater numbers of pollen grains reaching the stigma and successfully elongating pollen tubes to reach ovaries. However, the outcome of hand pollination on the yield and fruit quality in papaya has not yet been studied.

Unfortunately, the papaya ringspot virus (PRSV) has taken a heavy toll on papaya production in Thailand and many other parts of the world, leading to market shortages at some times of the year. With aphids as the main vector, the virus spreads quickly and severe infections make the fruit unsalable (Reddy and Gowda, 2014). Some PRSV-tolerant papaya varieties are now available (Somsri, 2014) but at present, the amount of papaya produced in northeast Thailand is still not enough to meet consumer demand and additional papaya must be transported from growing areas in central Thailand (Janthasri, 2004). Papaya can flower and bear fruit throughout the year, but as previous research has shown that temperature and relative humidity can affect papaya flowering and fruit set (Cohen *et al*., 1989; Deuramae and Janthasri, 2014), it is expected that growers in northeast Thailand will have variable harvests at different times of the year depending on the season. So far, no studies have been done to evaluate papaya production and quality in each month of the year. If growers had more information on the best times to plant papaya seeds and the times when the most fruit can be harvested, they could better plan their production schedules. The current study of papaya flowering throughout the year in Maha Sarakham province may help farmers plan their planting schedules more effectively and alleviate the problem of shortages in the market.

The objectives of this research were to study the rate of flowering during each month of the year for 'Yellow Krang' cultivar papayas grown in Maha Sarakham province and to compare the percentage of fruit set from naturally pollinated versus hand-pollinated flowers during each month as well as the size and quality of papaya fruit resulting from natural pollination and hand pollination and fruit maturing at different times of the year.

MATERIALS AND METHODS

Experimental Design

The experiment was designed in a 12 × 2 factorial design in a randomized complete block design with 5 replications and 10 trees per replication. The first factor tested was the time of the year.

Seeds were planted each month, from January to December 2017. The second factor was the pollination method: hand pollination versus natural pollination.

Soil Analysis

Soil analysis was performed before the experiment commenced. Soil composition was determined using a hydrometer. Soil pH was measured using a pH meter. Soil organic matter content was evaluated using the wet oxidation method of Walkley and Black (Walkley and Black, 1934). Phosphorus content was determined following the modified Bray II method (Bray and Kurtz, 1945). An atomic absorption spectrophotometer was used to measure potassium, calcium, and magnesium contents.

Planting

A farmer's field was selected in Baan Nong Go, Borabue district, Maha Sarakham province (16°07'N and 103°22'E). The planting schedule was planned so that papaya trees would be flowering all year long (Table 1). 'Yellow Krang' cultivar papaya seeds were planted with one seed per bag planted at a depth of 1 cm in 2 × 6-inch plastic bags filled with potting material consisting of 2 parts topsoil to 3 parts burnt rice husks to 1 part compost. The potting material was disinfected with calcium oxide, and metalaxyl was applied (at a concentration of 30 g/20 L of water) to prevent damping off. When the seedlings were 20 days old, 25-5-5 fertilizer was added (dissolved at a concentration of 30 g/20 L of water). The seedlings were transplanted to the field at 45 days old. Ten of the healthiest trees were selected for each treatment (natural pollination or hand pollination) and marked. The trees were fertilized every 15 days with 1 kg of 15-15-15 fertilizer applied per tree, and after they started flowering, they were given 13-13-21 fertilizer at the rate of 1 g per tree or 5 kg of manure or compost per tree. The trees were watered every 3 days. Diseases and insect pests were managed when necessary, such as by using carbosulfan against aphids or benomyl against anthracnose.

Table 1 Papaya planting schedule

Transplanting time (45-day-old seedlings)	Flowering month (100-day-old trees)
January	April
February	May
March	June
April	July
May	August
June	September
July	October
August	November
September	December
October	January
November	February
December	March

Pollination

For the hand pollination treatment, flowers were observed, and at the stage when the ends of the petals of the hermaphrodite flowers were beginning to curve but had not fully opened, the whole hermaphrodite flower that would serve as the pollen donor was plucked from the parent plant and the petals were removed, leaving only the fully mature anthers (when tapped onto the palm of one's hand, light yellow powder was observable). Selected

hermaphrodite flowers on the pollen acceptor plants were emasculated by using forceps to remove all the anthers, and then donated pollen was brushed lightly onto the stigma, and the flower was labeled. Hand pollination was performed during the period 6:30 to 10:00.

For the natural pollination treatment, hermaphrodite flowers were labeled and left to pollinate naturally. There were 10 trees per treatment per month, and 20 hermaphrodite flowers on each tree were labeled for either hand or open pollination. The date of labeling/pollination was recorded, along with the date of observed fruit set (after the petals were shed and the pistil started to elongate and darken).

Data Recording

Flowering

Number of days to flowering (from the seed planting date to the date of the first flower buds were observed), number of flowers per tree (counted from when the papaya trees were 4 months old until they were 6 months old), number of flowers of each type (hermaphrodite, female, and male) and percent fruit set (stigma swollen to about the size of a thumb, calculated from 20 labeled hermaphrodite flowers).

Quality of unripe papaya

The number of fruit per tree and weight per fruit (in kg) were recorded when each set of fruit was 6 months mature (unripe stage). Five fruit were randomly selected from each tree for quality measurement. Flesh thickness (in cm) was measured at the thickest and thinnest sections when the fruit was cut lengthwise, and the values were averaged. Flesh firmness was tested using a firmness tester (Effegi, Italy) set at a 10 mm plunger diameter. Crispness was rated subjectively using a panel of 100 untrained taste testers (average consumers comprising mainly university students and staff), who rated the 6-month-old unripe fruit on a scale of 1 to 5 (1 = not crispy, 2 = slightly crispy, 3 = medium crispy, 4 = very crispy, and 5 = crispiest).

Data Analysis

Analysis of variance (ANOVA) was used to analyze the data and Duncan's new multiple range test (DMRT) was used for multiple comparisons between treatments using MSTAT software (Bricker, 1989).

RESULTS AND DISCUSSION

An analysis of the soil at the test field showed that it was sandy, basic, and had lower organic content than average. Nutrient analysis showed that it had medium amounts of phosphorus and potassium and very high calcium content (Table 2). Higher than sufficient amounts of nutrients in the soil can be toxic to plants and negatively affect their growth (Purcifull *et al*., 1984). The symptoms of excess calcium in papaya are slow growth, pale-colored leaves, and white specks. White specks were observed on some of the fruit in this study, which could have been due to the high calcium content of the soil (Chumsang and Janthasri, 2013).

Table 2 Properties of soil at the test site

Characteristic	Unit	Soil analysis result
Sand [1]	%	61.24
Silt [1]	%	32.57
Clay [1]	%	9.16
pH [2]	-	5.22
Organic matter [3]	%	1.43
Phosphorus [4]	mg/kg	65.81
Potassium [5]	mg/kg	72.50
Calcium [5]	mg/kg	2,380.11
Magnesium [5]	mg/kg	120.70

Note: [1] analyzed by hydrometer (modified), [2] pH (soil : water = 1 : 1) measured by pH meter, [3] analyzed by wet oxidation (Walkley and Black, 1934), [4] analyzed by modified Bray II extraction (Bray and Kurtz, 1945), [5] extracted with NH_4OAc and analyzed by atomic absorption spectrophotometer

There was a statistically significant difference at 0.05 in the number of days to flowering of papayas started from seed in different months of the year (Table 3). Papayas planted in January and February and started flowering in April and May took a longer time to begin blooming (110.2 and 105.4 days, respectively) compared to those that were planted in June-October and started flowering in September-January that bloomed more quickly (90.8–93.4 days). Normally, 'Yellow Krang' papaya plants start to flower when they are about 3 and a half months old. During the rainy season and cool season in Thailand, temperatures tend to be relatively low (20–28°C) and this might stimulate quicker flowering. April and May are usually the hottest time of the year, with temperatures up to 38–42°C, and relative humidity (RH) also drops when there is no rain, so these conditions could retard flowering. These results are consistent with a study by Deuramae and Janthasri (2014) on sex expression in papaya, which was also done in Thailand, and found that papaya flowering was 10–15 days later during March and April and was quickest (85–90 days from planting date) during December to February. By comparison, Subhadrabandhu and Nontaswatsri (1997) found in a study on the hybridization of 3 papaya cultivars ('Khaek Dam', 'Tainung#5' and 'Eksotika#20') that the mean number of days to flowering differed among the cultivars. 'Tainung' plants were the quickest to flower at 107 days and 'Eksotika' plants took the longest at 152 days, while the number of days to flowering in the hybrid progeny tended to be shorter, with a range of 106 to 137 days. In a study comparing greenhouse versus open field conditions for growing 'Red Lady' cultivar papaya in a PRSV-infected area of India, Ganeshan (1986) reported that the mean number of days taken for the first flowering was 84.7 days in the greenhouse and 95.7 days in the open field.

Table 3 Month of flowering and means for number of days to flowering and number of flowers per tree (n=10) of 'Yellow Krang' papaya plants planted in each month of the year

Transplanting time (45-day-old seedling)	Flowering month (100-day-old trees)	Number of days to flowering	Number of flowers per tree (month 4 – month 6)
January	April	110.2^{a}	124.2^{c}
February	May	105.4^{a}	132.4^{bc}
March	June	97.9^{ab}	147.9^{b}
April	July	95.1^{ab}	152.4^{b}
May	August	95.3^{ab}	159.6^{ab}
June	September	92.7^{b}	172.2^{ab}
July	October	93.4^{b}	180.1^{a}
August	November	92.1^{b}	185.1^{a}
September	December	91.5^{b}	189.6^{a}
October	January	90.8^{b}	187.8^{a}
November	February	96.4^{ab}	174.2^{ab}
December	March	95.2^{ab}	143.7^{b}
CV (%)		5.62	3.74

Note: ^{a,b,c} Means in the same column with different superscripts differ at 95% confidence by Duncan's new multiple range test. CV = coefficient of variation.

There was a statistically significant difference in the mean number of flowers per tree when compared from month to month ($P < 0.05$). The greatest mean number of flowers (180.1–189.6 per tree) was observed in the period from October to January, and the lowest mean number of flowers (124.2 per tree) was observed in April (Table 3). Towards the end of the rainy season and the beginning of the cool season was the time 'Yellow Krang' papaya trees produced the most flowers because the temperature and RH were suitable (25–30°C; RH: 85–90%). Janthasri (2014) recently studied papaya flowering in Thailand and found that temperature and RH affected flowering and pollination. She reported that low temperatures and high RH promoted flowering, while high temperatures and high RH promoted fruit growth. In that study, high rates of flowering occurred during the rainy season, but this did not result in a high rate of fruit set because rainy conditions tend to obstruct pollination (Janthasri *et al.,* 2014). Earlier, a study on papaya pollen viability and storage was carried out in Israel by Cohen *et al*. (1989) and the findings indicated that pollen viability (tested *in vitro*) was much higher during the summer months when the temperature was above 25°C and lower, even down to nil, during the cooler months.

Hand pollination made a significant difference in fruit set, number of fruit per tree, and fruit weight. When the papaya trees were hand pollinated, the rate of fruit set was 90.1–100%, the number of fruit per tree was 241.5–305.6 and the average fruit weight was 1.20–2.56 kg. By comparison, when left to pollinate naturally, the fruit set was 56.2–98.2%, the number of fruit per tree was only 62.7–132.2 and the average fruit weight was 0.72–1.84 kg. Hand pollination was most successful in the period July through February. The fruit set was highest in December and January, both for naturally pollinated and hand-pollinated trees (Table 4). This is consistent with the findings of Janthasri *et al.* (2014), who reported that hand pollination of papaya resulted in a greater percentage of fruit set and more fruit produced per tree compared to open pollination, but they did not find any significant difference in fruit weight. They also reported higher fruit set during the cool season compared to the rainy season or hot season. Similarly, Deuramae and Janthasri (2014) reported that when papaya plants in Thailand flowered in the period from July to September (rainy season), they had low fruit set at only 32%, whereas when the trees flowered in the period from December to February the fruit set was much higher at 85%. Interestingly, in comparison, Das *et al.* (2014) did not obtain as high a percentage of fruit set as in the present study through hand pollination. When they pollinated 'Sunrise Solo' cultivar with pollen from 'Washington' cultivar, the fruit set was 76%, and when they did the reciprocal cross the fruit set was 73.7%, both of which figures are within the range of the fruit set obtained from natural pollination in the present study.

'Yellow Krang' cultivar is gaining popularity partly due to its high yield. This was confirmed by the maximum yield in the present study of more than 130 fruit per tree for naturally pollinated trees and over 300 fruit per tree from hand-pollinated trees. In comparison, the 'Maradol' cultivar that is widely grown in the Caribbean and Central America has been reported to produce a mean of only 23.8 fruit per plant (Vázquez Calderón *et al*., 2014) while the F2 progeny that came from a cross between 'Maradol' and a local Mexican line of wild *C. papaya* were reported to yield from 6 to 94 fruit per plant (Vázquez Calderón *et al*., 2014). In a study on the crossing ability of 3 papaya cultivars by Subhadrabandhu and Nontaswatsri (1997), the means number of fruit per plant (open pollinated) for the cultivars 'Khaek Dam', 'Eksotika#20' and 'Tianung#5' and their hybrids were recorded, ranging from 30 up to 91. Comparing other fruit, Janthasri and Adiwetin (2006) did a study on dragon fruit (*Hylocereus undatus*) flowering and pollination at different times of the year in Thailand and found that the plants produced more flowers during the rainy season, but the successful pollination rate was only 42% at that time, while during the cool season the flowering rate was much lower, but the successful pollination rate was up to 90%. The low fruit set during the rainy season was attributed to heavy rainfall causing little or no pollen to adhere to the stigmas.

Table 4 Percentage of fruit set, number of fruit per tree, fruit weight and yield of 'Yellow Krang' papaya plants pollinated by hand or by nature during each month of the year

Flowering month (100-day-old trees)	Pollination method	Pollination success (%)	Number of fruit per tree	Mean fruit weight (kg)	Yield per tree (kg)
April	Natural pollination	56.2^{c}	62.7^{c}	0.80^{c}	50.2
	Hand pollination	90.3^{ab}	250.4^{ab}	1.20^{b}	300.5
May	Natural pollination	59.5^{c}	68.1^{c}	0.75^{c}	51.1
	Hand pollination	90.1^{ab}	241.5^{ab}	1.50^{b}	362.3
June	Natural pollination	62.8^{c}	74.2^{c}	0.91^{c}	67.5
	Hand pollination	97.3^{a}	268.9^{ab}	1.30^{b}	349.6
July	Natural pollination	79.4^{b}	87.8^{c}	0.72^{c}	63.2
	Hand pollination	100.0^{a}	294.5^{a}	1.42^{b}	418.2
August	Natural pollination	82.4^{b}	84.2^{c}	1.10^{b}	92.6
	Hand pollination	100.0^{a}	305.6^{a}	1.73^{ab}	528.7
September	Natural pollination	80.2^{b}	78.2^{c}	1.41^{b}	110.3
	Hand pollination	98.8^{a}	251.7^{ab}	2.04^{a}	513.5
October	Natural pollination	89.6^{ab}	92.3^{c}	1.59^{ab}	146.8
	Hand pollination	100.0^{a}	270.9^{ab}	1.91^{ab}	517.4
November	Natural pollination	92.8^{ab}	110.8^{b}	1.83^{ab}	202.8
	Hand pollination	100.0^{a}	275.7^{ab}	2.27^{a}	625.8
December	Natural pollination	97.7^{a}	125.3^{b}	1.84^{ab}	230.6
	Hand pollination	100.0^{a}	290.4^{a}	2.25^{a}	653.4
January	Natural pollination	98.2^{a}	132.2^{b}	1.52^{ab}	200.9
	Hand pollination	100.0^{a}	298.9^{a}	2.38^{a}	711.4
February	Natural pollination	90.2^{ab}	108.4^{b}	1.71^{ab}	185.4
	Hand pollination	100.0^{ab}	284.7^{a}	2.56^{a}	728.8
March	Natural pollination	89.8^{ab}	94.2^{c}	1.28^{b}	120.6
	Hand pollination	97.4^{a}	264.5^{ab}	2.21^{a}	584.6
CV%		6.27	8.50	5.59	-

Note: ^{a,b,c} Means in the same column with different superscripts differ at 95% confidence by Duncan's new multiple range test. CV = coefficient of variation.

Flesh firmness, flesh thickness, and perceived crispness were not found to differ significantly between fruit harvested in different months of the year or between those from naturally pollinated and hand pollinated trees (Table 5). For both treatments and across all months of the year, the average flesh firmness recorded ranged from 0.44–0.76 (kg/cm^2) while flesh thickness was between 1.3–2.4 cm and perceived crispness rated by tasters was in the range of 4.3–4.8 (very crispy to crispiest on a scale of 1 to 5). Likewise, Janloon *et al.* (2014) compared the quality of 'Yellow Krang' papaya produced in 3 provinces in Thailand (Roi Et, Maha Sarakham, and Khon Kaen) and found that there were statistically significant differences in flesh firmness, flesh thickness, and perceived crispness in the fruit from the different growing areas, but the variable of flesh thickness was correlated to fruit size. Subhadrabandhu and Nontaswatsri (1997) reported that the mean flesh thickness was 2.9 cm for 'Khaek Dam' cultivar, 2.7 cm for 'Tainung#5' cultivar and 1.9 cm for 'Eksotika#20' cultivar, while the mean flesh firmness of 'Khaek Dam', 'Tainung #5,' and 'Eksotika#20' cultivars was 10.2, 11.5, and 12.9 kg/cm^2, respectively.

Several other fruit crops, such as durian (Honsho *et al.,* 2004) and cherimoya (Rosell *et al.,* 2006) produce more fruit when pollinated by hand. In the current study, not only the number of fruit per tree was higher from hand pollination compared to natural pollination but also the mean fruit weight of hand-pollinated fruit was greater. When the annual yield of the trees in this study is calculated by multiplying the number of fruit per tree by the mean fruit weight, it can be observed that when the figures for all 12 months are averaged, the mean yield from hand-pollinated trees was 524.51 kg of fruit per tree compared to 126.82 kg of fruit per tree from naturally pollinated trees. This implies significant economic gains for farmers who consider adopting hand pollination practices. Further study could be done to establish if the economic returns are worth the extra input of labor time. The conclusion also could not be generalized to other cultivars and other growing areas without further evidence.

The higher rate of fruit set from the hand pollination treatment group indicates that the hand pollination practice used by the researchers was more effective than the action of self-pollination, wind, or insect pollinators at the test site. The lower percentage of fruit set in the natural pollination treatment group could be due to a lack of effective insect pollinators. Finding ways to increase the populations of insect pollinators might be another approach to increasing papaya yields.

Table 5 Flesh firmness, flesh thickness and flesh crispness of 'Yellow Krang' papaya fruit from natural pollination or hand pollination

Month of flowering (100-day-old trees)	Pollination method	Flesh firmness (kg/cm²)	Mean flesh thickness (cm)	Perceived crispness
April	Natural pollination	0.46^{c}	1.6^{ab}	4.6^{ab}
	Hand pollination	0.44^{c}	1.8^{ab}	4.6^{ab}
May	Natural pollination	0.68^{ab}	1.3^{b}	4.5^{b}
	Hand pollination	0.60^{ab}	1.5^{b}	4.8^{a}
June	Natural pollination	0.74^{a}	1.7^{ab}	4.6^{ab}
	Hand pollination	0.70^{a}	2.1^{a}	4.6^{ab}
July	Natural pollination	0.76^{a}	1.6^{ab}	4.7^{a}
	Hand pollination	0.72^{a}	2.0^{ab}	4.8^{a}
August	Natural pollination	0.68^{ab}	1.8^{ab}	4.4^{b}
	Hand pollination	0.61^{ab}	2.3^{a}	4.5^{b}
September	Natural pollination	0.58^{b}	1.6^{ab}	4.3^{b}
	Hand pollination	0.50^{b}	2.4^{a}	4.7^{a}
October	Natural pollination	0.55^{b}	1.5^{b}	4.6^{ab}
	Hand pollination	0.54^{b}	2.3^{a}	4.6^{ab}
November	Natural pollination	0.59^{b}	1.6^{b}	4.8^{a}
	Hand pollination	0.53^{b}	2.1^{a}	4.8^{a}
December	Natural pollination	0.55^{b}	1.4^{b}	4.7^{a}
	Hand pollination	0.49^{bc}	2.2^{a}	4.8^{a}
January	Natural pollination	0.51^{bc}	1.4^{b}	4.7^{a}
	Hand pollination	0.47^{bc}	2.3^{a}	4.8^{a}
February	Natural pollination	0.51^{bc}	1.3^{b}	4.6^{ab}
	Hand pollination	0.46^{c}	1.8^{ab}	4.7^{a}
March	Natural pollination	0.54^{b}	1.9^{ab}	4.7^{a}
	Hand pollination	0.48^{bc}	2.2^{a}	4.8^{a}
CV (%)		4.31	4.72	3.74

Note: Flesh thickness was measured at the thickest and thinnest sections when the fruit was cut lengthwise and averaged. Flesh firmness was tested using a firmness tester (Effegi, Italy). Crispness was rated using a panel of 100 untrained taste testers, who rated the 6-month-old unripe fruit on a scale of 1 to 5 (1 = not crispy, 2 = slightly crispy, 3 = medium crispy, 4 = very crispy, 5 = crispiest). ^{a,b,c} Means in the same column with different superscripts differ at 95% confidence by Duncan's new multiple range test. CV = coefficient of variation.

CONCLUSION

'Yellow Krang' papaya grown in northeast Thailand tends to produce the greatest number of flowers in the rainy period of July, August, September, and October, and tends to produce the greatest number of fruit in the cooler months of November, December, January, and February. Hand pollination resulted in a higher number of fruit set, a greater number of fruit growing to harvest size, and larger fruit compared to natural pollination. Fruits from hand pollination were slightly thicker and less firm than those from natural pollination, and sample consumers tended to rate them as the same or slightly crisper in terms of crispness.

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