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Fruit growth and development of neck orange at the optimal time for harvesting under the difference period of climate

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Abstract Fruit growth and development of neck orange at the optimal time for harvesting under the difference period of climate was reported. The experiment was conducted at the orchard in the Banna sub-district, Chana district, Songkhla province, Thailand starting from January, 2018 to September, 2019. The effect of the harvesting time around the year was divided to two time of the year, half year and half year later which was advanced significant difference of the harvesting time. The half year could develop as indicated fruit weight (g), peel weight (g), flesh weight (g), diameter of fruit (cm) and fruit circumference (cm) compared to the half year later. The fruit quality of the half year had higher total soluble solid (TSS), titratable acidity (TA), but TSS/TA ratio is lower. The fruit age at 5^{th}, 6^{th}, 7^{th}, 8^{th} and 9^{th} months was develop of fruit weight(g), peel weight (g), flesh weight (g), diameter of fruit (cm) and fruit circumference (cm), the result showed that fruit age at 8^{th} months could develop the highest of fruit weight (g), peel weight (g), flesh weight (g), diameter of fruit (cm) and fruit circumference (cm) and highest of fruit quality as indicated of TSS, TA and TSS/TA ratio.

Keywords: Tree age, Fruit age, Fruit development, Fruit quality, Neck orange

Introduction

Neck orange (*Citrus reticulata* Blanco) is the geographical indications (GI) product in Chana District, Thailand and a popular localized citrus in southern of Thailand. Recently, the demand for this fruit has gradually increased in the domestic market because of its unique fruit shape and flavor, on the other hand the area of neck orange plantation was decreasing. (Hansuek *et al*., 2018). The major problem of neck orange production area is the climate

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variability, which is induced by global warming effects, has become a global concern as it may have many consequences on the various system and sectors that may threaten human wellbeing (IPCC, 2001). Climate change has a major impact on the phonological cycle and agricultural productivity (Solomon and Shugart, 1993).The quality of neck orange depened on the difference of climate period of around a year and harvesting index (Wongchana and Pongmanawat, 2003).

The objectives of the study were aimed to determine the effects of the climate period around the year and age of fruit to fruit development and fruit quality of Neck orange (*Citrus reticulata* Blanco).

Materials and methods

Plant materials

The experiment was conducted at the orchard of Mr. Donkonee Lawman Banna sub-district, Chana district, Songkhla province, Thailand. 10-year–old field-grown neck orange trees were used in this study from January, 2018 to August, 2019. Plants under investigation were grown in the same location and were subject to rigorously similar cultural practices.

Treatments

2x5 factorial in completely randomized design (CRD) with single tree plots replicated five times was used. The treatments included 3 factors; A: the different climatic period around the year (half year, half year later, and B: the different age of neck orange fruit for harvesting (5^{th}, 6^{th}, 7^{th}, 8^{th} and 9^{th} months).

Data recording and analysis

On the 5^{th}, 6^{th}, 7^{th}, 8^{th} and 9^{th} months of the half year half year later of tree 10 -year–old of neck orange trees were collected fruit weight (g), peel weight(g), fresh weight (g), diameter of fruit (cm) and fruit circumference (cm), peel thickness, total soluble solid (^{o}Brix) and titratable acidity (%). The data analysis was used program-R and treatment means were statistically compared using Duncan’s Multiple Range Test (DMRT).

Results

Fruit growth and development

The fruit growth and development of the neck orange at different climate period around the year was indicated of fruit weight, peel weight and flesh weight were significant differences between the time of climate period around the year, half year was shown the highest of fruit weight (268.26 g), peel weight (78.57 g) and flesh weight (187.92 g), half year later was recorded the lowest of fruit weight (241.43 g), peel weight (63.73 g) and flesh weight (174.00 g) (Table 1). The fruit circumference and fruit diameter have shown not significant differences between the climate period around the year, half year was shown the circumference (24.92 cm and 24.76 cm) and fruit diameter (7.79 cm and 7.77 cm), the peel thickness has shown significant differences between the climate period around the year, half year later was shown the higher of peel thickness (0.45 cm) than half year (0.40 cm) (Table 2).

Table 1. Fruit growth development of neck orange at the difference age of tree, age of fruit and time of harvesting on fruit weight (g), peel weight (g) and flesh weight (g)

Treatments	Fruit weight (g)	Peel weight (g)	Flesh weight (g)
Harvesting time (A)			
half year	268.26a	78.57a	187.92a
half year later	241.43b	63.73b	174.00b
Age of fruit (B)			
5 months	172.30d	53.80c	118.75d
6 months	219.00c	54.80bc	158.25c
7 months	235.76c	70.84b	160.43c
8 months	293.54ab	74.65ab	208.57ab
9 months	310.39a	80.69a	218.82a
Probability level of Significance (ANOVA)			
Harvesting time (A)	0.0097	0.0003	0.0020
Age of fruit (B)	0.0001	0.0001	0.0001
AXB	0.1126	0.2878	0.2285
CV.(%)	20.12	27.62	23.72

Mean values with each column followed by a same letter are not significantly at $p \leq 0.05$ tested by DMRT.

Table 2. Fruit development of neck orange at the difference age of tree, age of fruit and time of harvesting on fruit circumference (cm), fruit diameter (cm) and peel thickness (cm)

Treatments	Fruit circumference (cm)	Fruit diameter (cm)	Peel thickness (cm)
Harvesting time (A)			
half year	24.92a	7.79a	0.40a
half year later	24.76a	7.77a	0.45b
Age of fruit (B)			
5 months	21.58d	6.76d	0.40b
6 months	24.17c	7.46c	0.41b
7 months	24.37b	7.51c	0.41b
8 months	25.78ab	8.32ab	0.45a
9 months	26.30a	8.87a	0.46a
Probability level of Significance (ANOVA)			
Harvesting time (A)	.06856	0.8686	0.0036
Age of fruit (B)	0.0001	0.0001	0.2146
AXB	0.4630	0.2010	0.1039
CV.(%)	7.73	7.81	21.78

Mean values with each column followed by a same letter are not significantly at $p \leq 0.05$ tested by DMRT.

The fruit growth and development of neck orange at different age of fruit at the harvest time was indicated of fruit weight, peel weight and flesh weight were significant differences among the different age of fruit.

The fruit growth and development of the neck orange at different age of fruit (5^{th}, 6^{th}, 7^{th}, 8^{th} and 9^{th} months) was indicated of fruit weight, peel weight and flesh weight were significant difference among of a different age of fruit the highest fruit weight was shown at the 8^{th} and 9^{th} mounts were 293.54 and 310.39 g, respectively, the peel weight were significant differences among the treatments. The flesh weight of a different age of fruit the highest flesh weight was shown at the 8^{th} and 9^{th} mounts was 74.65 and 80.69 g, respectively (Table 1). The fruit circumference, fruit diameter and peel thickness were significant differences among means of a different age of fruit at the 5^{th}, 6^{th}, 7^{th}, 8^{th} and 9^{th}

months, the highest of fruit circumference, fruit diameter and peel thickness was shown at 8th and 9th months, fruit circumference (25.78 and 26.30 cm), fruit diameter (8.32 and 8.87 cm) and peel thickness (0.45 and 0.46 cm) (Table 2).

Fruit quality

The fruit quality of neck orange at different climatic period of the year was indicated of TSS was shown significant differences among the treatments, the higher of TSS by the half year (8.67 ^{o}Brix) than a half year later (8.08 ^{o}Brix). The value of the TA was shown the significant differences, the lower of TA in the half year later (1.93%) than the half year later (2.11%) (Table 3).

Table 3. Fruit quality of neck orange at the difference age of tree, age of fruit and time of harvesting on total soluble solid (^{o}Brix), titratable acidity (%), TSS/TA

Treatments	**Total soluble solid (^{o}Brix)**	**Titratable acidity (%)**	**TSS/TA**
Harvesting time (A)			
half year	8.67a	1.93b	4.18
half year later	8.08b	2.11a	4.10
Age of fruit (B)			
5 months	7.70c	3.31a	2.32
6 months	8.00b	2.49b	3.21
7 months	8.39a	1.64c	5.11
8 months	8.43a	1.35c	6.24
9 months	8.87a	1.31c	6.77
Probability level of Significance (ANOVA)			
Harvesting time (A)	0.0004	0.0082	-
Age of fruit (B)	0.0020	0.0001	-
AXB	0.2373	2658	-
CV.(%)	9.50	14.17	-

Mean values with each column followed by a same letter are not significantly at $p \leq 0.05$ tested by DMRT.

The ratio of TSS/TA was shown at half year is higher than a half year later (4.18 and 4.10). The fruit quality of the neck orange at different age of fruit was indicated of TSS was shown significant differences among the treatments, the highest of TSS are 7^{th}, 8^{th} and 9^{th} months (8.39 8.43 and 8.87 ^{o}Brix), the lowest of TA is the treatment 5^{th} (7.70 ^{0}Brix).The value of TA at the different age of fruit is significant differences among the treatment 5^{th}, 6^{th}, 7^{th}, 8^{th} and 9^{th} months (3.31 2.49, 1.64, 1.35 and 1.31 %, respectively). Also the ratio of TSS/TA was shown higher when the fruit age is increase from 5^{th}, 6^{th}, 7^{th}, 8^{th} and 9^{th} months (2.32, 3.21, 5.11, 6.24 and 6.77 respectively) (Table 3).

Discussion

In the southern Thailand is the located for tropical fruit plantations. Recently, the phenology in many fruit trees, including of mangosteen, has been changed due to climatic variability. Therefore, the impact of climatic variability on phonological change, yield and quality of mangosteen (Apiratikorn and Sdoodee, 2012). Also the impact of climatic variability on phonological change, make the pummelo var. Tumtim Siam was produced 3 times of flowering and fruit set and then impacted to yield and quality, the highest fruit growth and development and fruit quality were shown on the fruit at harvest time of the beginning of the year and mid-year, the lower fruit growth and development and fruit quality were shown at the harvest time on the end of the year due to this period is the rainy season in the southern Thailand (Preecha and Na Nakorn, 2018). The result of this study the higher fruit quality is related to climate period around the year, at the half year is better than a half year later. The citrus fruit quality may be indicated by external features, such as rind color, size, and rind texture, and internal physical (seediness, juice contents) and biochemical characters like ascorbic acid, TSS, TA and TSS:TA ratio (Saleem *et al.,* 2008).

The harvesting time of fruit age of neck orange at 7^{th} and 8^{th} month had the highest quality in term of TSS, TA and TSS:TA ratio and highest of growth and development in term of fruit weight, peel weight and flesh weight, fruit circumference, fruit diameter and peel thickness, there are the same reported in the studies on growth and development of neck orange fruit (*Citrus reticulate* Blanco) of Wongchana and Pongmanawat (2003) and also the fruit age of pummelo var. Tumtim Siam had the highest quality for harvesting at 7^{th}, 7.5^{th} and 8^{th} mouths (Preecha and Na Nakorn, 2018). Also Cassin (1969) was calculated the heat unit index (or total effective temperature) between mid-bloom and maturity for early and late cv. West Africa, the West indies and

some other place, Less time was required for growth and maturation of the fruit in the tropics. The distinction between early and late cv. also tended to disappear; maturation time was reduced from six to eight months for early and seven to eleven months for late. It is concluded that the impact of climate period of the year to the time of harvesting of neck orange is the best time in the half year. The age of fruit at 7^{th} and 8^{th} moths had more fruit size and fruit quality than fruit age at 5^{th}, 6^{th} and 9^{th} months.

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