International Journal of Agricultural Technology 2018 Vol. 14(7): 1685-1692
Available online http://www.ijat-aatsea.com
ISSN: 2630-0613 (Print) 2630-0192 (Online)

Fruit growth and development of pummelo cv. tubtim siam at the difference tree age and fruit age for the optimal harvesting time under the climate variation

Preecha, C. and Na Nakorn, S.*

Department of Plant Science, Faculty of Agriculture, Rajamangala University of Technology Srivijaya, Nakhon Si Thammarat Campus, Thailand.

Preecha, C. and Na Nakorn, S. (2018). Fruit growth and development of pummelo cv. tubtim siam at the difference tree age and fruit age for the optimal harvesting time under the climate variation. International Journal of Agricultural Technology 14(7): 1685-1692.

Abstract The fruit growth and development of pummelo cv. Tubtim Siam at the difference tree age and fruit age for the optimal harvesting time under the climate variation was reported. The experiment was conducted at the orchard in the Klongnoi sub-district, Pak Panang district, Nakhon Si Thammarat province, Thailand starting from January, 2017 to September, 2018. The effect of the harvesting time around the year was divided to beginning of the year, mid year and end of the year which was advanced significant difference of the harvesting time. The beginning of the year and mid year could develop as indicated fruit weight(g), peel weight (g), pummelo fresh (g), diameter of fruit (cm) and fruit circumference (cm) compared to the during the time end of year. The fruit quality of the beginning of the year and mid year revealed the most higher total soluble solid (TSS), titratable acidity (TA) and TSS/TA ratio. The effect of tree age 10 and 15-year-old trees could develop as indicated fruit weight(g), peel weight (g), pummelo fresh(g) that was advanced significant difference compared to the 5-year-old trees, but the diameter of fruit (cm), fruit circumference (cm) and peel thickness was not significant difference of all treatments. The fruit quality of tree age 10 and 15-year-old trees most higher total soluble solid (TSS), titratable acidity (TA) and TSS/TA ratio than 5-year-old trees were reported. The fruit age at 6^{th} 6.5^{th} 7^{th} 7.5^{th} and 8^{th} month was develop of fruit weight(g), peel weight (g), pummelo fresh(g), diameter of fruit (cm) and fruit circumference (cm), the result showed that fruit age at 6.5^{th} , 7^{th} and 7.5^{th} month could develop the highest of fruit weight(g), peel weight (g), pummelo fresh(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, pummelo

Introduction

Tabtim Siam pummelo is the geographical indications (GI) product in Pak Panang Basin, Pak Panang District, Thailand and a popular new pummelo cultivar in the premium fresh-fruit marketplace. The external appearances of Tabtim Siam pummelo fruit and leaves should have the dark green colour and cover with soft hair, the internal appearances of Tabtim Siam pummelo thin light pink peel with tight row of small dark pink to red pummelo fresh, juicy with a sour - sweet taste (Kaewtubtim and

* **Corresponding Author:** Na Nakorn, S.; **Email:** nanakornsp@yahoo.com

Issarakraisila, 2011). All of production for domestic consumption and exporting. Recently, the demand for this fruit has gradually increased in both domestic and international markets, especially in China, Taiwan, Malaysia, Singapore and Brunei. Nowadays, the price of Tabtim Siam pummelo from the hand of the farmer is 150-250 bath/fruit, the farmer's orchard expands to plantation increasing continuously for commercial purpose. The major problem of Tabtim Siam pummelo in the production area is the climate 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 effected of climate variation make of the Tabtim Siam pummelo had a fruit set 3 times around the year, a quality of fruit at each period of the year is not stable. Nowadays, only a limited information on the climate variability of Tabtim Siam pummelo production in Thailand has been published based on fruit growth and quality.The farmer they lack of data on the effects of the climate variation to tree age and fruit age on fruit development and fruit quality for making a decision by harvesting time of the Tabtim Siam pummelo. The fruit quality is very important for consumption and marketability of inside and outside the country. In Tabtim Siam pummelo external fruit quality parameters include fruit weight, peel weight, pummelo fresh, diameter of fruit and fruit circumference, whereas internal fruit quality includes TSS,TA and TSS:TA.

The objectives of the study were aimed to determine the effects of the climate variation to fruit development and fruit quality of Pummelo var. Tabtim Siam.

Materials and methods

Plant materials

The experiment was conducted at the orchard of Mr.Wirat Suksang, Mr.Kitcharat Na Nakorn and Mr.Sorawit Kanwinplang, Klongnoi sub-district, Pakpanang district, Nakhon Si Thammarat province, Thailand. 5, 10 and 15-year–old field-grown Tabtimsiam pummelo trees were used in this study from January, 2017 to September, 2018. Plants under investigation were grown in the same location and were subject to rigorously similar cultural practices.

Treatments

3x3x5 factorial in completely randomized design (CRD) with single tree plots replicated five times was used. The treatments included 3 factors;

A : the differenttime of harvesting (beginning of the year, mid year and end of year) B: the difference age of pummelo trees (5, 10 and 15-year–old trees) and C : the different age of pummelo fruit for harvesting (6^{th} 6.5^{th} 7^{th} 7.5^{th} and 8^{th} month).

Data recording and analysis

At the 6^{th} 6.5^{th} 7^{th} $7.5^{th}$and 8^{th} month from the beginning of the year, mid year and end of the year from a different age of tree 5, 10 and 15-year–old trees were collected fruit weight (g), peel weight(g), pummelo fresh(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 pummelo var. Tubtim Siam at different time of harvesting was indicated of fruit weight, peel weight and pummelo flesh were significant differences among the time of harvesting around the year, beginning of the year and mid year was shown the highest of fruit weight (1962.65 g and 1924.08 g), peel weight (620.27 g and 585.88 g) and pummelo flesh (1406.69 g and 1330.67 g), Harvesting time at the end of the year was recorded the lowest of fruit weight (1760.05 g), peel weight (564.45 g) and pummelo flesh (1228.21 g) Table 1. The fruit circumference and fruit diameter have shown significant differences between the period time of harvesting around the year, beginning of the year and mid year was shown the highest circumference (54.25 cm and 54.17 cm) and fruit diameter (17.71 cm and 17.45 cm). Harvesting time at the end of the year was recorded the lowest of fruit circumference and fruit diameter (52.98 cm and 17.04 cm) Table 1, Harvesting time at the 3 times of the year was recorded the peel thickness has shown not significant differences between the time harvesting around of the year (Table 2).

The fruit growth and development of the pummelo var. Tubtim Siam at different age of the tree was indicated of fruit weight, peel weight and pummelo flesh were significant differences among the tree age, 15- year-old and 10- year-old tree was shown the highest of fruit weight (2033.57 g and 1927.28 g), peel weight (620.27 g and 587.10 g) and pummelo flesh (1412.49 g and 1337.81 g), 5- year-old of tree has the lowest of fruit weight (1779.63 g), peel weight (561.53 g) and pummelo flesh (1215.23 g) (Table 1). The fruit circumference and diameter have shown significant differences among the tree age, 15- year-old and 10-year-old tree was shown the highest of fruit circumference and fruit diameter (55.09 cm/54.78 cm) and fruit

circumference (17.56 cm/17.53 cm), 5- year-old tree has the lowest of fruit circumference and fruit diameter(53.53 cm and 17.10 cm), the peel thickness it is not significant differences among the tree ages(1.50 1.49 and 1.48 cm, respectively) Table 2.

Table 1. Fruit growth development of pummelo var. Tubtimsayam at the difference age of tree, age of fruit and time of harvesting on fruit weight (g), peel weight (g) and pummelo fresh (g)

Treatments	Fruit weight (g)	Peel weight (g)	Pummelo fresh (g)
Harvesting time) A)			
beginning of year	1962.65a	620.27a	1406.69a
mid year	1924.08a	585.88ab	1330.67a
end of year	1760.05b	564.45b	1228.21b
Age of tree) B(			
5year-old	1779.63b	561.53b	1215.23b
10year-old	1927.28a	587.10ab	1337.81a
15year-old	2033.57a	620.27a	1412.49a
Age of fruit (C)			
6 months	1786.24b	584.22	1199.09b
6.5months	1940.84a	604.36	1333.09a
7months	1900.04ab	584.93	1314.82ab
7.5months	1987.33a	583.20	1402.49a
8months	1969.40a	594.29	1373.36a
Probability level of significance (ANOVA)			
Harvesting time) A)	0.0012	0.0279	0.0013
Age of tree) B(	0.2254	0.3504	0.0253
Age of fruit (C)	0.4633	0.7918	0.2960
AxB	0.5921	0.3884	0.1695
AxC	0.5589	0.7201	0.5537
BxC	0.4407	0.4696	0.2725
AxBxC	0.9809	0.9700	0.5574
CV)%(	18.77	24.28	22.30

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 the pummelo var. Tubtim Siam at different age of fruit (6 6.5 7 7.5 and 8 months) was indicated of fruit weight, peel weight and pummelo flesh weight were significant differenct among of difference age of fruit the highest fruit weight was shown at the 6.5^{th} 7^{th} 7.5^{th} and 8^{th} mounts were 1940.84 1900.04 1987.33 and 1969.40 g, respectively, the peel weight were not significant differences among the treatments. The pummelo flesh weight of different age of fruit the highest pummelo flesh weight was shown at the 6.5^{th} 7^{th} 7.5^{th} and ^{8th} mount were 1333.09 1314.82 1402.49 and 1373.36 g, respectively(Table 1). The fruit circumference, fruit diameter and peel thickness were not significant differences among means of a difference age of fruit at the 6^{th} 6.5^{th} 7^{th} 7.5^{th} and 8^{th} mounts (Table 2).

Table 2. Fruit development of pummelo var. Tubtimsayam 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)			
beginning of year	54.25a	17.71a	1.53
mid year	54.17a	17.45a	1.50
end of year	52.98b	17.04b	1.45
Age of tree) B(			
5 year-old	53.53b	17.10b	1.480
10 year-old	54.78a	17.53a	1.49
15 year-old	55.09a	17.56a	1.50
Age of fruit (C)			
6 months	53.83	17.47	1.54
6.5 months	54.25	17.47	1.54
7 months	54.07	17.43	1.5
7.5 months	54.43	17.36	1.45
8 months	52.41	17.26	1.43
Probability level of significance (ANOVA)			
Harvesting time) A)	0.2277	0..0047	0.5138
Age of tree) B(	0.2395	0.0450	0.9500
Age of fruit (C)	0.3292	0.9145	0.5804
AxB	0.3909	0.2042	0.2489
AxC	0.5986	0.9567	0.9152
BxC	0.5862	0.7519	0.9053
AxBxC	0.8880	0.9825	0.8241
CV)%(	9.36	7.13	16.40

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

Fruit quality

The fruit quality of the pummelo var. Tubtim Siam at different time of harvesting was indicated of TSS was shown significant differences among the treatments, the highest of TSS of the beginning of the year and mid year (10.02 and 10.00 ^{0}Brix), the end of the year has the lowest of TSS (9.87^{0}Brix), The value of TA among the different time of harvesting was shown the significant differences, the lowest of TA at the beginning of the year (0.48%) and the highest of TA at the mid year and the end of the year (0.50 and 0.51%, respectively) Table 3.

The fruit quality of the pummelo var. Tubtim Siam at different age of the tree was indicated of TSS was shown significant differences among the treatments, the highest of TSS of 15- year-old and 10-year-old tree (10.02 and 10.03 ^{0}Brix), 5- year-old tree has the lowest of TSS (9.84^{0}Brix), The value of TA among the different age of the tree are not significant differences (0.51 0.50 and 0.49 %, respectively) Table 3.

The fruit quality of the pummelo var. Tubtim Siam at different age of the tree was indicated of TSS was shown significant differences among

the treatments, the highest of TSS of 15- year-old and 10-year-old tree (10.02 and 10.03 ^{0}Brix), 5- year-old tree has the lowest of TSS (9.84^{0}Brix), The value of TA among the different age of the tree are not significant differences (0.51 0.50 and 0.49 %, respectively) Table 3.

Table 3. Fruit quality of pummelo var. Tubtimsayam at the difference age of tree, age of fruit and time of harvesting on total soluble solid (^{0}Brix), titratable acidity (%),TSS/TA

Treatments	**Total soluble solid (^{0}Brix)**	**Titratable acidity (%)**	**TSS/TA**
Harvesting time) A)			
beginning of year	10.02a	0.48b	20.87
mid year	10.00a	0.50a	20.00
end of year	9.87b	0.51a	19.35
Age of tree) B(			
5 year-old	9.84b	0.49	16.96
10 year-old	10.03a	0.50	20.06
15 year-old	10.02a	0.51	19.64
Age of fruit (C)			
6 months	9.70b	0.58a	16.72
6.5 months	10.06ab	0.53ab	18.98
7 months	9.94ab	0.47b	21.14
7.5 months	10.29a	0.49b	21.00
8 months	9.84ab	0.47b	20.93
Probability level of significance (ANOVA)			
Harvesting time) A)	0.0112	0.0147	-
Age of tree) B(	0.0224	0.6917	-
Age of fruit (C)	0.0232	0. 0145	-
AxB	0.5462	0. 7496	-
AxC	0.9866	0.7678	-
BxC	0.8981	0.5308	-
AxBxC	0.9834	0.8906	-
CV)%(	12.88	13.44	-

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

Discussion

In the southern Thailand is the located for tropical fruit plantations. Recently, the phenology in many fruit tree, 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 of pummelo var. Tumtim Siam in this study, the highest fruit growth and development and fruit quality was shown on the fruit at harvesting time of the beginning of the year and mid year, the lower fruit growth and development and fruit quality was shown at the harvesting time on the end of the year due to this period is the rainy season in the southern Thailand.

Effects of tree age of pummelo var. Tumtimsiam on fruit weight, peel weight, pummelo fresh, peel thickness, fruit diameter and fruit circumference, the data were shown significant difference the average means of among tree age on fruit weight, pummelo fresh, fruit diameter and fruit circumference were increasing related to the tree ages increase. The difference tree age was effected to fruit development in term of fruit size, tree age and fruit size had significant influence on fruit weight, peel weight, pummelo fresh, peel thickness, fruit diameter and fruit circumference. Large sized fruit from 10-year-old trees and 15-year-old trees had more the biggest fruit size while, less fruit size was obtained from 5-year-old trees, because, the young tree is smaller canopy, lesser number of leaves and all of these factors related to the photosynthesis rate (Kramer and Kozlowski,1979). Flore and Lakso (1989) was explained that the leaves are the main source of photosynthesis in plants, but CO_2 assimilation can also take place in stems, flowers and fruit. Photosynthetic rates are generally low in young unexpanded leaves, and increase up to full leaf expansion or soon after the leaves become fully expanded. Effects of tree age of pummelo var. Tumtim Siam on fruit quality, it is very important for consumption and marketability, fruit from 10-year-old trees and 15-year-old trees had more higher TSS and lower TA than fruit from 5-year-old trees. In citrus external fruit quality parameters include colour, size, rind smoothness and blemishes whereas internal fruit quality includes TSS, TSS:TA. In *Prunus salicina*, 5-10 year old trees had higher ascorbic acid concentrations than 20-30 year old trees, however taste, acidity and soluble solid contents did not significantly vary with the tree age (Dong Hui *et al*., 2005).

The effect of fruit age of pummelo var. Tumtim Siam was harvested at 6^{th} 6.5^{th} 7^{th} 7.5^{th} and 8^{th} mouth on fruit development as indicated of fruit weight, peel weight, pummelo fresh, peel thickness, fruit diameter and fruit circumference. The optimal time for harvesting of pummelo var. Tumtim Siam depend on the fruit size and fruit quality, the size of fruit and fruit quality were related to fruit age at 6^{th} 6.5^{th} 7^{th} 7.5^{th} and 8^{th} mouth. The optimal time for harvesting from this experiment showed that at 6.5^{th} 7^{th} and 7.5^{th} mouths due to the fruit size as indicated by weight, peel weight, pummelo fresh, peel thickness, fruit diameter and fruit circumference were increased and the internal physical was determined TSS,TA and TSS:TA ratio also increase. Flavor and taste are related to the level of total soluble solids (TSS), titratable acidity (TA), and the amount of aromatic or bitter flavors in the fruit. Ahmed *et al*. (2006b) ; Saleem *et al.* (2008c) explained that citrus fruit quality may be indicated by external features, such as rind colour, size, and rind texture, and internal physical (seediness, juice contents) and biochemical characters like ascorbic acid, TSS, TA and TSS:TA ratio. Na Nakorn *et al*. (2015) was reported that total soluble solid was increased when the fruit developed from the 1^{st} month to 7.5^{th} month and the titratable acidity has the values deceasing opposite with the total soluble solid when

the fruit developed from the 1st month to 7.5th month. Tree age affected acidity and TSS content of 'Satsuma' mandarin and juice content, TSS, acidity and ripeness index of oranges (Matsumato *et al.*, 1972; Frometa and Echazabal, 1988). Bramlage (1993) reported that pome fruit harvested from young trees was highly susceptible to postharvest disorders.

It is concluded that the impact of climate variation to the time of harvesting of pummelo var. Tumtim Siam is the best time at the beginning and mid year. The effects of tree age at 10-year-old trees and 15-year-old trees of pummelo var. Tumtimsiam had more fruit size and fruit quality than 5-year-old trees. The age of fruit at 6.5 7th 7.5th and 8th moth also had more fruit size and fruit quality than fruit age at 6th month.

Acknowledgements

The authors are thankful to Mr. Wirat Sakseang, Mr.Kicharat Na Nakorn and Mr. Sorawit Kanwinpaung, the holder of pummelo orchard for encouragement during the study. We gratefully acknowledge the financial support from the Nation Research Council of Thailand.

References

Apiratikorn, S. and Sdoodee, S. (2012). The impact of climatic variability on phonological change, yield and fruit quality of mangosteen in Patthalung province, Southern Thailand. Kasetsart Journal. 46:1-9.

Ahmad, S., Thompson, A. K., Perviez, M. A., Anwar, N. and Ahmad. F. (2006a). Effect of fruit size and temperature on the shelflife and quality of ripe banana fruit. Journal of Agricultural Research. pp. 45.

Bramlage, W. J. (1993). Interaction of orchard factors and mineral nutrition on quality of pome fruit. Acta Horticulturae. 326:15-28.

Dou, H., Jones, S., Obreza, T. and Rouse, B. (2005). Influence of various phosphorous and potassium rates on juice vitamin C, β-carotene, lycopene and sugar concentrations of Flame grapefruit. Proceedings of the Florida State Horticultural Society. 118:372-375.

Frometa, E. and Echazabal, J. (1988). Influence of age and cultivar on juice characteristics of early oranges. Agrotecnia de Cuba. 20:71-75.

IPPC (2001). Climate change 2001. In Impact, Adaptation and Vulnerability. Contribution of Workshop Group II to the Third Assessment Report of the International Panel on Climate Change (IPPC). Cambridge University Press, Cambridge, UK.

Kaewtubtim, M. and Issarakraisila. (2011). Effects of nitrogen and zinc on fruit quality of pummelo cv. Tubtim Sayam .In Commission on Higher Education Congress IV University Staff Development Consortium. pp. 44.

Kramer, P. J. and Kozlowski, T. T. (1979). Physiology of woody plants. Academic Press, New York, pp.811.

Matsumoto, K., Chikaizumi, S., Oku, H. I. and Watanabe, J. (1972). Studies on the contribution of environmental and internal factors affecting the edible quality and exterior appearance of Satsuma mandarin fruits. Journal of the Japanese Society for Horticultural Science. 41:171-178.

Na Nakorn, S. and Chalumpak, C. (2016).Effect of tree age and fruit age on fruit development and fruit quality of Pummelo var. Tabtimsiam. International Journal of Agricultural Technology. 12:541-549.

Na Nakorn, S., Chalumpak, C., and Sangwiroonton, K. (2015). Effect of crop load on fruit development and fruit quality of pummelo var. Tabtimsiam. Journal of Agricultural Technology. 11:2211-2217.

Saleem, B. A., Malik, A. U. Pervez, M. A., Khan, A. S. and Khan, M. N. (2008c). Spring application of growth regulators affects fruit quality of 'Blood red' sweet orange. Pakistan Journal of Botany. 40:1013-1023.

Solomom, A. M., and Shugart, H. H. (1993). Vegetation Dynamics&Global Change.Chamman and Hall, New York, USA. pp. 338.

(Received: 7 September 2018, accepted: 3 November 2018)