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Research Article

The Effects of Climatic Variability on Mangosteen Flowering Date in Southern and Eastern of Thailand

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Abstract: Mangosteen (*Garcinia mangostana* L.) is one of the economically important fruits of Thailand. However, it has been evident that climate change affects the yield and quality of mangosteen fruits. As a result, this may have an impact on economic of mangosteen growers. Therefore, the objectives of this study are: 1) to investigate the effects of climatic variability on mangosteen flowering date in 2 production areas (Nakhon Si Thammarat and Chanthaburi provinces) and 2) to analyze the correlation between the climatic factors and the flowering dates of mangosteen. The results showed that the climatic variability occurred during 1982-2012 both in Nakhon Si Thammarat and Chanthaburi provinces. The average flowering date of mangosteen during the off-season period significantly delayed by 5.10 days/year ($p \leq 0.01$). A drying periods before flowering and maximum temperatures affected mangosteen flowering. A model using these climatic factors was developed to predict the flowering date of mangosteen. The model could predict the flowering date with 52.30% accuracy and the estimated standard error was 9.53.

Keywords: Climate change, climatic factors, climatic variability, flowering date

INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) is an important export fruit of Thailand. The statistical data showed that mangosteen production in Thailand was 215,182 ton and the revenue from exporting was around USD 132 million in 2013 (Office of Agricultural Economics, 2013). The main cultivation areas of mangosteen are in the Eastern and Southern of Thailand. These areas are suitable for growing mangosteen because of humid climate. Normally, the flowering period of mangosteen in the Eastern area is between November and December and the harvesting period is between May and June. However, the mangosteen cultivation in the Southern region may vary to production period. There are two production periods e.g., in-season and off-season periods. In case of the in-season period, the flowering period is during February and April and the harvesting period is during July and September. But the off-season period, the flowering period is between June and September and the harvesting period is between December and February (Puttakan, 1993; Manakasem, 1995; Suamag, 2005). However, some studies showed that climatic variability affected not only the flowering period in the off-season period of mangosteen in Phatthalung province but also the flowering period in the off-season period of longkong (*Lansium domesticum* Corr.) in Southern Thailand (Uraipan, 2009; Apiratikorn *et al*., 2012). Uraipan (2009) also reported that the change of rainfall distribution pattern might delay the flowering date of longkong. In addition, Apiratikorn *et al.* (2014) found that there was a significant delay in the flowering date of mangosteen during 2003-2012.

Some studies in climatic variability and climate change domain suggest that greenhouse gas emissions from human activities cause global warming (IPCC, 2007). Thailand has experienced the impact of climate change due to the data from the Meteorological Department illustrated that an annual mean of average temperature keeps increasing during 1955 to 2009. Nevertheless, there was insignificant change of annual rainfall in the same period (The Thailand Research Fund, 2011). Changes mentioned above have an impact on the agricultural production, including flowering induction, fruit setting, fruit development, harvesting and quality of tropical fruits (Dewi, 2009; Vorakuldumrongchai *et al*., 2010; Sthapit *et al*., 2012). The objectives of this research were:

- To investigate the impact of climatic variability on the flowering dates of mangosteen at Nakhon Si Thammarat (Southern Thailand) and Chanthaburi province (Eastern Thailand)

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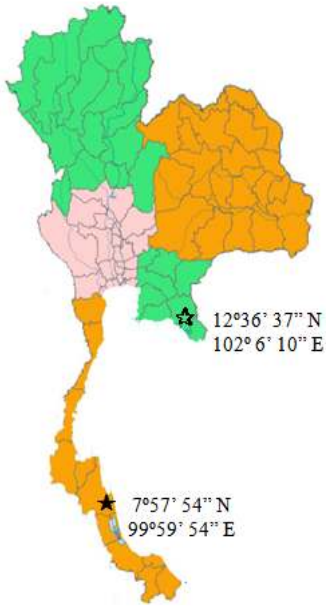


Fig. 1: Map of Thailand showed the studied areas
☆: Chanthaburi province; ★: Cha-uat district, Nakhon Si Thammarat province

- To analyze the climatic factors that correlate with the flowering dates of mangosteen

MATERIALS AND METHODS

Two experimental sites of the mangosteen production in Cha-uat district (7°57' 54" N, 99°59' 54" E with altitude of 7 m above the sea), Nakhon Si Thammarat province (Southern) and Chanthaburi province (12°36' 37" N, 102° 6' 10" E with altitude of 4 m above the sea) Eastern (Fig. 1) were used for data collection. The data set of the flowering date of mangosteen was obtained from the orchard owners in the above areas and the Office of Agricultural Economics from 2000 to 2013.

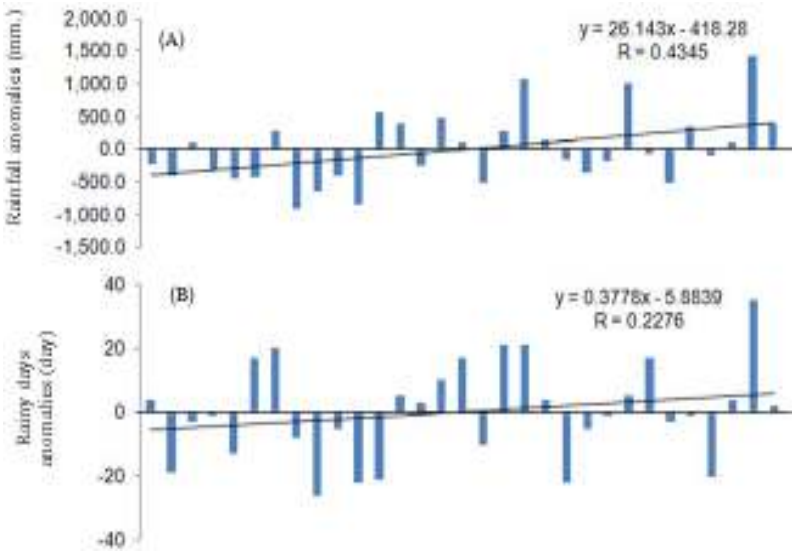
The meteorological data were obtained from Nakhon Si Thammarat Meteorological Station, Water Management Center for Southern Region Phattalung province where is adjacent to Nakhon Si Thammarat province and Thai Meteorological Department (TMD). The daily rainfall, the maximum and the minimum temperatures and the number of rainy days were plotted and used for the assessment of climate change scenario.

A multiple regression analysis was applied to determine the correlation between the climatic factors and the flowering dates of mangosteen.

RESULTS

The annual rainfall, number of rainy day, maximum temperature and minimum temperature in Cha-uat district of Nakhon Si Thammarat province, Southern Thailand during 1982-2012 showed anomalies from the long term average with increasing trends of annual rainfall, the maximum temperature and the minimum temperature (Fig. 2). However, the average annual anomalies of the number of rainy days did not indicate the increasing trend. There was no long term trend of annual rainfall, but number of rainy days, maximum temperature and minimum temperature tended to increase over the years in Chantaburi province, Eastern Thailand (Fig. 3).

The off-season mangosteen flowering date data were observed in Cha-uat district, Nakhon Si Thammarat province during 2000-2013. On average, the flowering date increased by 5.10 days/annum (Fig. 4). However, the in-season data of Chanthaburi province did not show a significant increasing trend (Fig. 5).



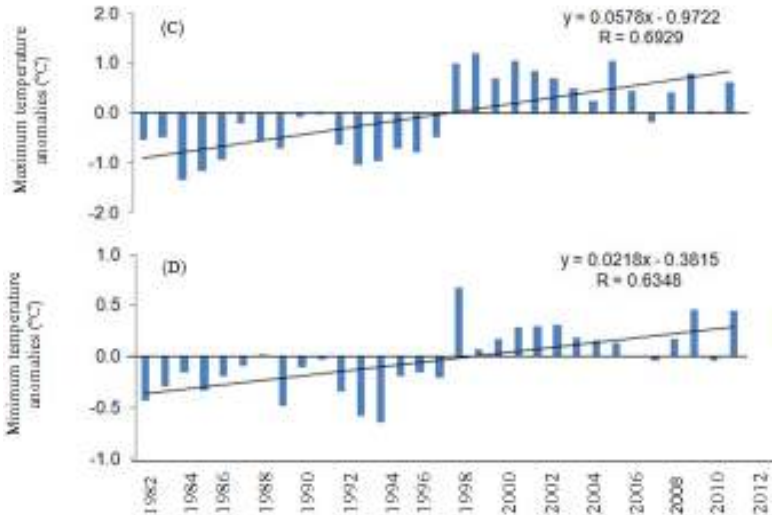


Fig. 2: Annual anomalies from the long term average of; (A): Rainfall; (B): Number of rainy days; (C): Maximum temperature; (D): Minimum temperature during 1982-2012 in Cha-uat district, Nakhon Si Thammarat province, southern Thailand

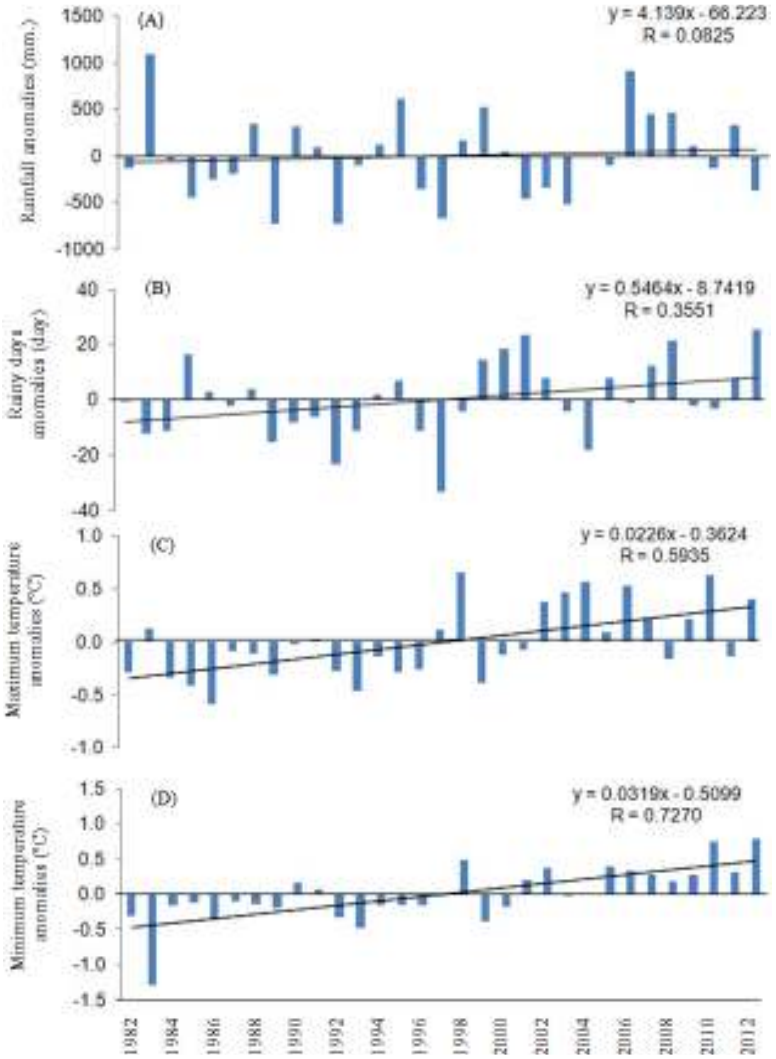


Fig. 3: Annual anomalies from the long term average of; (A): Rainfall; (B): Number of rainy days; (C): Maximum temperature; (D): Minimum temperature during 1982-2012 in Chanthaburi province, eastern Thailand

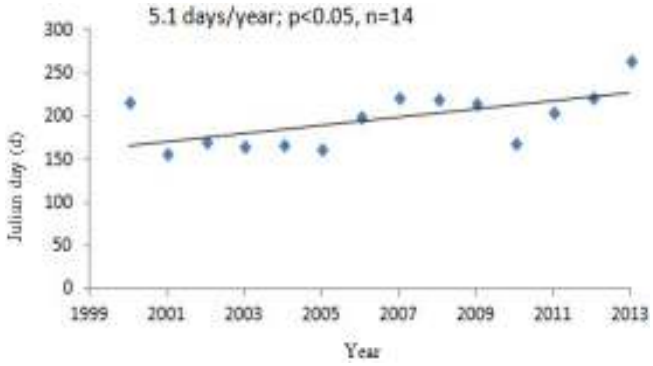


Fig. 4: Trend of average mangosteen flowering date during 2000-2013 in Cha-uat district, Nakhon Si Thammarat province (southern Thailand)

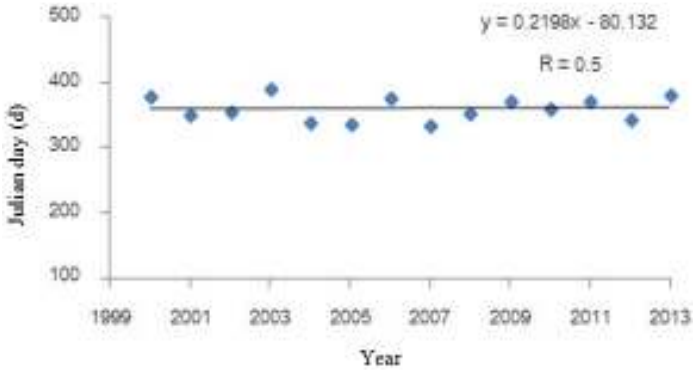


Fig. 5: Trend of average mangosteen flowering date during 2000-2013 in Chanthaburi province (eastern Thailand)

Table 1: The details of multiple regression analysis

Climatic factors	b	$S.E._b$	β	t	Sig.
Dry	0.41982	0.07562	0.61011	5.55156	0.00000
Maxtemp	1.97076	0.97689	0.22171	2.01737	0.04951
R = 0.72342	R^2 = 0.52334		F = 25.25239*		
$S.E._{est}$ = 9.53266	R^2_{adj} = 0.50262		a = -23.46134		

*: Significant at 0.05 level of probability; S.E.: Standard error

Table 1 shows the correlation analysis between the climatic factors and the flowering date using the multiple linear regression. The correlation coefficient was 0.72, the power of forecasting was 52.30% at 0.05 level of statistical significant and the estimated standard error was 9.53. The factors affected the mangosteen flowering date were obtained using stepwise multiple linear regression. The result showed that dry period and maximum temperature have affected the flowering date and could predict the flowering date 52.30% of the accuracy prediction and the estimated standard error was 9.53 (Table 1).

The multiple linear regression model shown as following:

Fdate = -23.46 + 0.42 Dry + 1.97 Maxtemp

This model showed that if dry period increased 1 day, the flowering date increased or delayed 0.42 day.

DISCUSSION

This study indicated that the variability of the climate occurred in Nakhon Si Thammarat as well as Chanthaburi provinces during 1982-2012. Boonklong *et al*. (2006) studied the climatic pattern in Eastern and Southern Thailand during 1976-2005. There were increasing trends in the number of rainy days and the minimum temperature in Eastern Thailand. However, there was no such trend found in Southern (Boonklong *et al*., 2006). Apiratikorn *et al*. (2012) also found increasing trends in the annual rainfall, the maximum temperature, the average temperature and the minimum temperature. However, there was the decreasing trend in the number of rainy days in Phatthalung province where is adjacent to Nakhon Si Thammarat province during 1981-2010. In addition, Apiratikorn *et al*. (2014) found that the annual rainfall and number of rainy days, relative humidity and the maximum and the minimum

temperatures in Hat Yai, Songkhla province tended to increase during 1980-2012.

The climate change impacts plant phenology because the temperature influences the timing of development both only temperature and temperature with other factors (Cleland *et al*., 2007). Many studies suggested that the climate change could shift the flowering dates of fruit trees. Georgiades *et al*. (2013) found that the flowering of *Leptospermum laevegatum* occurred earlier than usual because of the increase of temperature. Keatley and Hudson (2007) reported that Australian plants delayed flowering by 0.9 days/year because of climate change during 1983-2006. Uraipan (2009) suggested that the off-season flowering date of longkong in Southern Thailand might be delayed by the change of rainfall distribution pattern. Apiratikorn *et al*. (2012) found that there was no flowering in mangosteen in Phattalung province during the off-season period of 2010. In addition, Apiratikorn *et al*. (2014) pointed out that the flowering period of mangosteen and longkong in Songkhla province significantly delayed due to climate change. Boonklong *et al*. (2006) also found that mangosteen in Southern Thailand tended to increase flowering during the off-season period.

Although temperature is the main factor that impacts the phenological development of tropical fruit trees, this study showed that dry period before flowering influenced the mangosteen flowering date. If the dry period increased, the flowering date tended to delay. Chutinunthakun (2001), Sdoodee and Chiarawipa (2005) and Apiratikorn *et al*. (2012) suggested that mangosteen required the dry period before flowering. Yaacob and Tindall (1995) also reported that the mangosteen flowering period was induced by the short dry period of 15-30 days. In Southern, there are two flowering periods and the farmers in the studied area (Cha-uat district) prefer to grow the off-season mangosteen because of the higher price. The off-season of mangosteen is beneficial to farmers because it generates more income than in-season mangosteen production, especially in Nakhon Si Thammarat province where the potential for off-season mangosteen production was possible. However the climate change tended to shift the mangosteen flowering dates. The flowering of mangosteen in Nakhon Si Thammarat has delayed to heavy rain period. As a consequence, the harvesting period may occur during the rainy season in which excess moisture could damage mangosteen fruits. If the farmers are aware of the impact of the climate change on the phenology of mangosteen, they will be able to manage properly. The regression model was developed; this can predict the relationship between the flowering date of mangosteen and climatic factors. Moreover, this study appears to be contributed to the management of mangosteen production. The model will be used as a guideline for the farmers in the orchard management.

CONCLUSION

They provide a trend of climate change (the annual rainfall, the maximum and the minimum temperature) in Nakhon Si Thammarat and Chanthaburi provinces. Evidence clearly showed that the flowering dates of mangosteen in Nakhon Si Thammarat, Southern Thailand, have shifted. However, there was no shift of the flowering dates of mangosteen in Eastern Thailand. The regression model will be able to predict the flowering dates of mangosteen.

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