The Impact of Climatic Variability on Phenological Change, Yield and Fruit Quality of Mangosteen in Phatthalung Province, Southern Thailand

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ABSTRACT

Southern Thailand is a traditional area for tropical fruit plantations. Recently, the phenology in many fruit trees, including mangosteen, has been changed due to climatic variability. Therefore, the impact of climatic variability on phenological change, yield and quality of mangosteen needs to be investigated. In 2008, a study was established in an orchard in Phatthalung province, southern Thailand. Eighteen-year old mangosteen trees with 8 × 8 m spacing were used to investigate flowering during the in-season, off-season and even, alternate bearing during three consecutive years (2008–2010). The 30-year weather data from 1981 to 2010 showed trends of change in the annual rainfall, the number of rainy days, and the maximum and minimum temperature. A marked change in rainfall distribution affected the phenological change in flowering, productivity and fruit quality. In 2008 and 2009, the mangosteen trees experienced the required dry period that regulates floral induction before flowering. Thus, flowering was found in both the in-season and off-season. However, in 2010, a prolonged drought in summer followed by rain during July–August caused leaf flushing instead of flowering and this resulted in no off-season fruit production. This indicated that climatic variability resulted in a phenological change of mangosteen in Phatthalung province, southern Thailand where there is usually off-season production. In addition, climatic variability affected the fruit yield and fruit quality of mangosteen.

Keywords: climatic variability, phenology, yield, fruit quality, mangosteen (*Garcinia mangostana* L.)

INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) is an important tropical fruit tree (Wiebel, 1993; Issarakraisila and Settapakdee, 2008) and has high potential as a fruit for export from Thailand (Almeyda and Martin, 1976). It is well known in Southeast Asia and the major production comes from Thailand, Malaysia, Indonesia and the Philippines. Mangosteen fruit has a high economic value, thus it has good prospects to be developed into an excellent export commodity. Recently, the Thailand government has placed a high priority on developing mangosteen for export. Statistical data showed that in 2009, mangosteen production in Thailand was 270,554 t. In 2010, the volume of mangosteen fruits exported was around THB 2,000 million (Office of Agricultural Economics, 2010). Large mangosteen fruit (weight > 70 g) is required for export (Department of Agriculture, 2008).

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Mangosteen has adapted to a well distributed rainfall (Yaacob and Tindall, 1995; Osman and Milan, 2006), of 1,200 mm annually.

Climate change, which is induced by global warming effects, has become a global concern as it may have many consequences on various systems and sectors that may threaten human wellbeing (IPCC, 2001). Climate change has a major impact on the phenological cycle and agricultural productivity (Solomon and Shugart, 1993). The critical agro-meteorological variables associated with agricultural production are precipitation, air temperature and drought period (Boonklong *et al.*, 2006). In general, tropical-fruit production is normally limited by the available soil moisture and many fruit trees, such as mango and litchi, require a dry period to stop vegetative growth and induce flowering (Nakasone and Paull, 1998; Salakpetch, 2006; Sdoodee, 2007). The duration of this period for mangosteen is approximately 20 d (Salakpetch, 2000). The stage of growth and development at which water stress occurs greatly affects the final yield. Many factors influence the amount of rainfall available to plants including evaporation, transpiration rates, surface runoff and soil water-holding capacity through the soil profile beyond the rooting area (Kirkham, 2005). Excessive rainfall also causes major problems with flowering, pests, diseases and fruit quality (SCUC, 2006).

The objective of the current study was to investigate the impact of climatic variability on the phenological change, yield and fruit quality of mangosteen in Phatthalung province, southern Thailand.

MATERIALS AND METHODS

The experiment was conducted using 18-year old mangosteen trees with spacing 8 × 8 m in a farmer's orchard. A sample of 10 similar trees was selected for the experiment in Phatthalung province, southern Thailand (latitude N 7°35'14.4", longitude E 99°59'56.9", altitude 44 m above sea level). Development of the sample trees was continuously recorded from 2008 to 2010. The soil in the orchard was a sandy clay loam, with total N of 0.09 %, a pH of 5.34, organic matter of 1.65 %, available P (BrayII) of 27.28 mg.kg^{-1} and exchangeable (NH_4OA_c) K, Ca and Mg of 0.16, 0.36 and 0.29%, respectively. All trees were fertilized after harvest with a 16:16:16 ($N:P_2O_5:K_2O$) granular fertilizer plus minor elements plus cow manure, with 8:24:24 ($N:P_2O_5:K_2O$) fertilizer 2 mth later, and 13:13:21 ($N:P_2O_5:K_2O$) during fruit growth and development. Pruning was carried out after the first fertilizer application. During summer (around February), soil drying occurred because of the high evaporation and no watering during this period. This caused wilting of the mangosteen trees with looping leaves and wrinkled petioles. Then, irrigation using a sprinkler system was applied to saturate the soil and induce flowering. After fruit setting, irrigation was applied by a sprinkler system at 80 % of the daily evaporation as recommended by Salakpetch (2000). Mangosteen fruit was harvested from the orchard for further analysis of fruit quality.

Climatic data

Weather data collected from 1981 to 2010 at the Phatthalung Meteorological Station located 15 km from the experimental plot was analyzed. Data on rainfall, maximum and minimum temperature, and evaporation were used for the assessment of climate change scenarios and plotted. Data on the rainfall, number of rainy days and anomalies from the average for the maximum, minimum and average temperature were plotted.

Phenological development, yield and fruit quality

The phenological development of mangosteen trees was monitored from 2008 to 2010. Dates were recorded of flower bud appearance and flower bud to full bloom and/or fruit set. The onset of the stress period was recorded from the last date of rainfall until the appearance of flower buds. The total yield per tree was determined after harvest. The fruit quality of mangosteen under the influence of weather conditions was investigated. After harvest, the mangosteen fruit was transported to the laboratory within 2 hr for quality assessment. Thirty sample fruit per tree were used in the quality analysis that involved fruit weight, peel thickness, total soluble solids (TSS) and titratable acidity (TA). The percentages of incidence of translucent flesh disorder (TFD) and gamboge disorder (GD) were also assessed.

Means were compared using Duncan's multiple range test at the 5% level of significance.

RESULTS

Climatic variability

The annual rainfall and number of rainy day in Phatthalung province (Figure 1) during the 30 year period (1981–2010) showed anomalies from the long term averages with a trend of increasing annual rainfall but a decreasing trend in the number of rainy days, while the maximum temperature, average temperature and minimum temperature showed a gradually increasing trend (Figure 2).

The annual rainfall in 2008, 2009 and 2010 was 2,508.3, 2,168.8 and 2,171.6 mm, respectively. In 2008, the dry period occurred from March until the end of August to September. In 2009, there were two dry periods; first, a short dry period occurred in February, followed by a second, longer dry period from June to September. In 2010, a prolonged drought period occurred from January to June, followed by rain in July and August (Figure 3).

Phenological development

Figure 3 indicates the effects of the dry period on the phenological changes in mangosteen. In 2008, in-season flowering occurred on 15 March

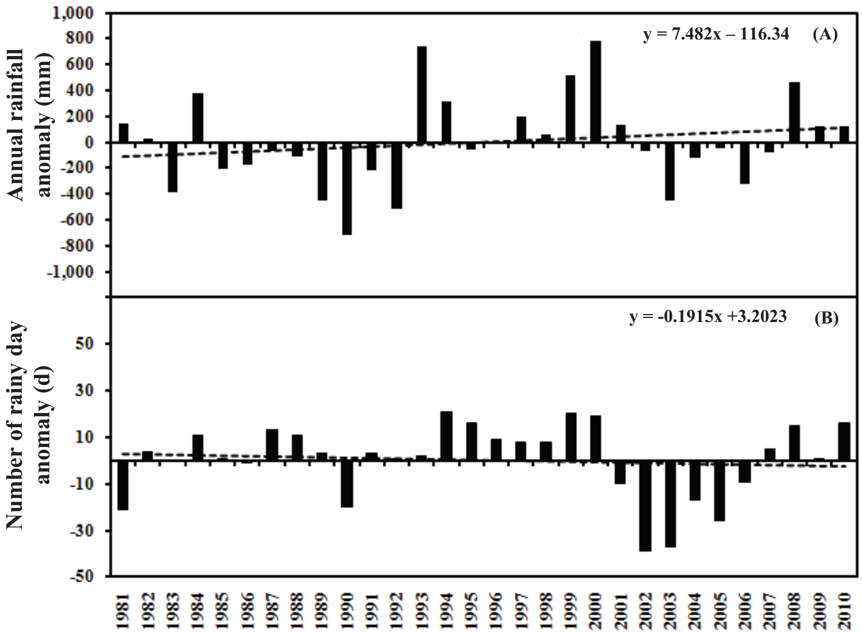

Figure 1 Anomalies based on deviation from the long term average in Phatthalung province during 1981-2010 for: (A) rainfall; and (B) number of rainy days.

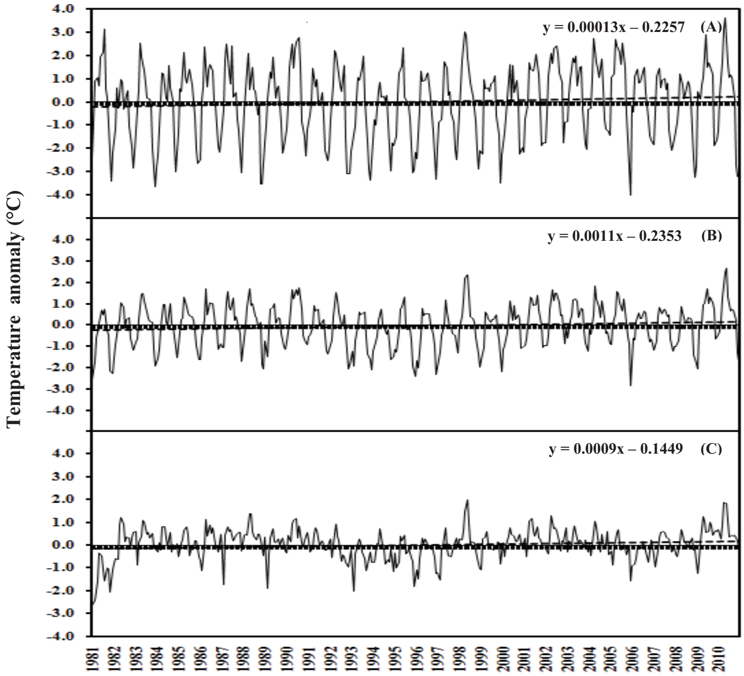

Figure 2 Anomalies based on deviation from the long term average in Phatthalung province during the period 1981–2010 for: (A) maximum temperature; (B) average temperature; and (C) minimum temperature.

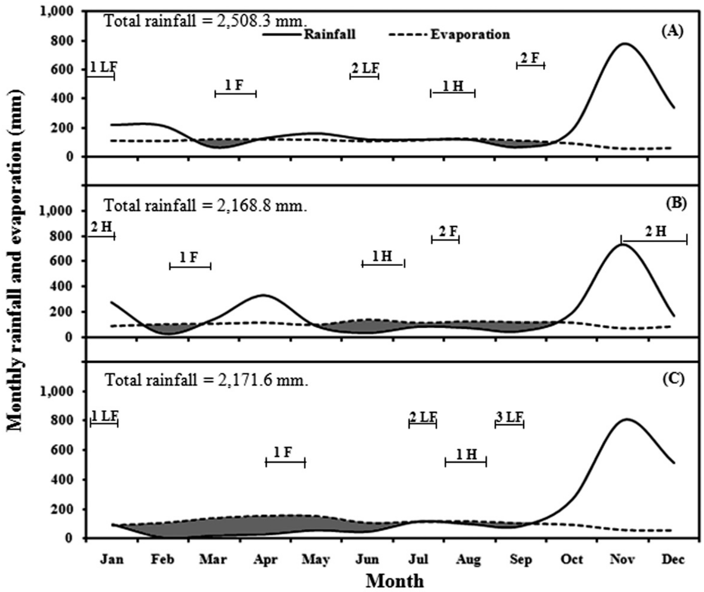

Figure 3 Monthly rainfall (–), evaporation (--) and phenological development of mangosteen in Phatthalung province in: (A) 2008; (B) 2009; and (C) and 2010 (■ = Water deficit period, 1F, 2F = First and second flowering periods, respectively; LF1, LF2 = First and second leaf flushing periods, respectively; H1, H2 = First and second harvest periods, respectively).

and harvesting time was from 27 June to 31 July. Off-season flowering occurred from 9 September to the end of September and fruit was harvested at the end of December 2008 until 25 January 2009. In 2009, in-season flowering started on 23 February and the harvest period was from 13 June to 7 July. Off-season flowering started from 18 July and mangosteen fruit was harvested from 12 November until the end of December. In 2010, in-season flowering started from 17 April and fruit was harvested from 7 August to 7 September. Data on flowering, harvesting time, harvest duration and the period of fruit development during the three consecutive years are shown in Table 1.

Yield and fruit quality

Mangosteen yields differed significantly in the various seasons (Figure 4). In 2009, there was clearly a significantly high in-season mangosteen yield, while a low yield was observed in the in-season of 2008. The fruit quality of mangosteen was significantly different in various seasons. In particular, in 2009, the in-season mangosteen fruit size was significantly large, while the smallest fruit size was found in 2008. Peel thickness also showed significant differences among seasons. There were no significant differences in TSS and TA in any season. The percentage of fruit disorders was markedly different among the seasons. In 2009, the highest incidence of TFD and GD was found in off-season mangosteen (Table 2).

Table 1 Flowering and harvest duration of mangosteen in Phatthalung province, Thailand.

Year	Harvesting season	Start of flowering time	Beginning of harvest period	Harvest duration (d)	Blooming to harvest duration (d)
2008	In-season	15 March	27 June	34	91
	Off-season	9 September	30 December	27	102
2009	In-season	23 February	13 June	24	85
	Off-season	18 July	12 November	30	99
2010	In-season	17 April	7 August	29	84

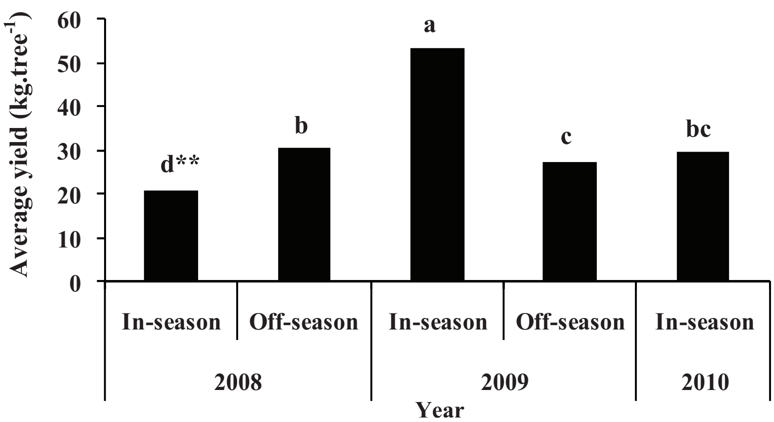

Figure 4 Average fruit yield of mangosteen compared among the seasons in Phatthalung Province during the period 2008–2010. ** = Bars with different letters are significantly different ($P \leq 0.05$) by Duncan's multiple range test.

Table 2 Average fruit weight, peel thickness, total soluble solid (TSS), titratable acidity (TA) and percentage of disorders [translucent flesh disorder (TFD) and gamboges (GD)] of mangosteen fruit in Phatthalung province during the period 2008–2010.

Year	Season	Fruit quality					
		Fruit weight (g fruit^{-1})	Peel thickness (mm)	TSS (°Brix)	TA (%)	Fruit disorder (%)	
						TFD	GD
2008	In-season	58.90 ^{e}	7.36 ^{c}	17.00	0.70	14.35 ^{c}	18.25 ^{d}
	Off-season	88.10 ^{b}	7.20 ^{c}	17.84	0.77	18.95 ^{b}	16.66 ^{e}
2009	In-season	105.77 ^{a}	8.53 ^{a}	17.38	0.82	12.94 ^{e}	19.82 ^{b}
	Off-season	83.27 ^{c}	7.54 ^{c}	17.61	0.76	21.36 ^{a}	23.72 ^{a}
2010	In-season	74.67 ^{d}	8.13 ^{b}	17.67	0.74	13.33 ^{d}	19.33 ^{c}
F-test		*	*	ns	ns	*	*
CV (%)		2.36	2.56	2.47	6.36	6.40	7.20

* = Means with different letters are significantly different ($P \geq 0.05$) by Duncan's multiple range test. ns = Nonsignificant difference. CV = Covariance.

DISCUSSION

Although, the annual rainfall in Phatthalung province over 30 years (1981–2010) increased, the number of rainy day decreased. This incidence was also reported by Boonklong (2005). There was an increasing trend in annual rainfall, maximum temperature, average temperature and minimum temperature; however, there was a decreasing trend in the number of rainy days. These observations indicated that Phatthalung had been experiencing climatic variability. The pattern of monthly rainfall and evaporation in 2010 showed a prolonged drought, while intense flooding also occurred at the end of 2010. This indicated that dry periods in January–March and June–August were required to stimulate flowering in the in-season and off-season, respectively. Sdoodee and Chiarawipa (2005) reported that the drought period usually occurred from February to March and a short dry period occurred during July and August in southern Thailand. These results supported other studies reporting that mangosteen trees need a dry period to induce flowering (for example, Nakasone and Paull, 1998; Chutinunthakun, 2001; Sdoodee and Chiarawipa, 2005).

Recently, numerous available data from studies of plant phenology (Myneni *et al.*, 1997; Menzel and Fabian, 1999; Menzel and Estrella, 2001) have indicated that phenological changes are mostly due to an increase in the number of days in the dry period. Thus, phenology is an important indicator of climate change that impacts on ecosystems (Schleip *et al.*, 2006; Cosmulescu *et al.*, 2010). It is a dominant (and often overlooked) aspect of mangosteen ecology. The usual in-season flowering of mangosteen in southern Thailand starts approximately at the end of March to early April, and harvesting occurs in August, while off-season flowering starts during August–September with harvesting from November to January if there is long enough drying period to induce flowering. The flowering may be explained as the result of mangosteen needing to be induced by drought to accumulate nutrients. During the three years of the experiment, the flowering of mangosteen was induced by a drought period of approximately 21 d, followed by irrigation or rainfall. Yaacob and Tindall (1995) also reported that mangosteen under natural conditions needs a short dry season (15–30 d) to stimulate flowering followed by irrigation or rainfall. In Phatthalung province during the period 2008–2010, there were two annual harvesting periods; however, there was no off-season flowering in 2010 because of climatic variability. The results from this study showed climatic variability and a trend of ongoing change in the future. This supports other claims that climatic variability is one of the main sources of uncertainty and risk in agricultural production (Oram, 1989).

It was notable that the mangosteen yield increased under suitable weather conditions. In 2009, the highest yield occurred during the in-season, due to the optimum drying period to induce flowering, followed by rainfall for fruit setting and development. In contrast, a low yield was recorded in the 2008 and 2010 seasons because of low rainfall and high evaporation during fruit development. In the period 2008–2010, the phenological pattern changed in the mangosteen trees studied because of irregular rainfall distribution that also affected yield and fruit quality. In 2009, heavy rainfall occurred during November and December leading to the highest percentage of fruit disorders. Sdoodee and Limpun-Udom (2002) indicated that excessive water caused the incidence of TFD and GD in mangosteen. However, in 2009, the fruit weight of mangosteen was higher for the in-season than the off-season; this might have been due to food accumulation that was retained from 2008. In 2010, the high yield in the previous year may have resulted in low photosynthesis by the mangosteen leading to low assimilation (Wiebel, 1993), which might in turn affect the imbalance of the source–sink relationship. Consequently, this led to high shedding of flowers and young fruit. With regard to small fruit size, Sdoodee *et al.* (2008) explained that an excessive crop load caused an adverse effect on the fruit size of mangosteen, leading to a decrease in the yield of large fruit. The results of the current study also indicated that fluctuations in rainfall and climatic variability cause uncertain flowering of mangosteen.

CONCLUSION

There was evidence of climatic variability during the period 1981–2010 in Phatthalung province, when a marked change in the rainfall distribution affected phenological changes, the yield and the fruit quality of mangosteen.

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