Agriculture and Natural Resources 51 (2017) 243–246

Contents lists available at ScienceDirect

Agriculture and Natural Resources

journal homepage: http://www.journals.elsevier.com/agriculture-and-natural-resources/

Original Article

Effect of environmental conditions on flower induction of marian plum (*Bouea burmanica* Griff)

Vusie L. Mavuso,[a] Chinawat Yapwattanaphun[b,*]

[a] Graduate School, Kasetsart University, Bangkhen, Chatuchak, Bangkok 10900, Thailand
[b] Department of Horticulture, Faculty of Agriculture, Kasetsart University, Bangkhen, Chatuchak, Bangkok 10900, Thailand

A R T I C L E I N F O

Article history:
Received 15 September 2016
Accepted 1 January 2017
Available online 14 October 2017

Keywords:
Air temperature
Flower induction
Marian plum
Water stress
Weather station

A B S T R A C T

Marian plum flowering naturally occurs during the cool, dry season so Thailand farmers usually withdraw irrigation a month before flowering. However, irregular flowering continues to be a serious problem. This study investigated the effects of environmental conditions (air temperature, soil moisture and relative humidity) on flower induction of marian plum. Daily weather data were collected using weather stations in three orchards where flowering was also recorded. Thirty representative trees per orchard were randomly selected for data collection. The results showed that trees from all orchards flowered in response to low temperature (below 18 °C) despite different levels of water stress and relative humidity. These results indicated that soil moisture content and relative humidity had no influence on marian plum flower induction but enhanced flower bud development. Night temperatures of 18 °C or lower are essential for marian plum flower induction.

Introduction

Marian plum (*Bouea burmanica* Griff), is an evergreen, tropical, fruit tree belonging to the Anacardiaceae family and is native to Southeast Asia and commercially grown in the ASEAN region in Malaysia, Thailand and Indonesia (Subhadrabandhu, 2001). In 2013, Thailand's area under production and yield was recorded as 2787.36 ha and 14,162 t, respectively (Office of Agricultural Economics, 2013). This high-value fruit was identified as one of the under-utilized tropical fruit crops which have potential for commercialization and export (Subhadrabandhu, 2001). In Thailand, marian plum flowering occurs during the cool, dry season (November–December) and fruits matures February–March (Subhadrabandhu, 2001).

According to Department of Agricultural Extension (2013) irregular flowering continues to be a serious limitation in marian plum production in Thailand and climate variation and extreme events are among the contributing factors. Irrigation control by withholding of water for 1–2 mth before flowering is a common practice in marian plum farming, but poor flowering still persists. The use of paclobutrazol and foliar spraying with nutrients to induce off season flowering of marian has not been successful (Chairuangyod, 1996). Studies in Thailand have shown the positive effects of a cool, dry period on longan flowering (Subhadrabandhu, 2001; Sritontip et al., 2012). In the subtropics, low temperatures (≤15 °C) induced flowering in mango (Shu and Sheen, 1987), while in the tropics, soil moisture stress for 5 wk resulted in early flowering and a high flowering intensity of mango (Lu and Chacko, 1999). Soil moisture stress is also responsible for flower induction in lime (Southwick and Davenport, 1986) and mangosteen (Apiratikorn et al., 2012) under tropical conditions.

Anecdotally, low temperature and soil moisture stress are believed to induce flowering in marian plum as it naturally flowers during the dry, cool season but there is no published scientific evidence to support this. Consequently, the current study investigated the effects of environmental conditions (in particular, temperature, soil moisture stress and relative humidity) on flower induction in marian plum. Knowledge of the effect of environmental effects on the flowering of this species will be essential for the development of new orchards and proper timing of cultural management practices such as pruning, irrigation and fertilizer application.

Materials and methods

Study site

This study was carried out during the reproductive season of marian plum in 2014/15 and 2015/16 (November–February) at farmer's orchards in Nakhon Nayok province, eastern Thailand.

* Corresponding author.
E-mail address: agrcwy@ku.ac.th (C. Yapwattanaphun).

https://doi.org/10.1016/j.anres.2017.01.004

Three orchards were used for the study: orchard A (14°9′N, 101°10′E, altitude 24.8 m above sea level, m asl); orchard B (14°15′8.2″ N, 101°10′46.9″ E and altitude 11.4 m asl); and orchard C (14°17′14.1″ N, 101°16′34″ E and altitude 28.6 m asl). The study areas had a monsoon climate with a dry season (November–May) and a cool season (November–February). The average annual rainfall and temperature during the study was 1500 mm and 28.8 °C, respectively. This study used three orchards managed according to standard horticultural practices comprising annual pruning, fertilizer application and crop protection.

Weather data

Daily weather data were recorded every 30 min using Watchdog weather stations (Spectrum Technologies Inc.; Aurora, IL, USA) installed in each orchard. Recorded weather parameters consisted of air temperature, soil moisture (at 15 cm and 30 cm depth), relative humidity, rainfall, photosynthetic active radiation (PAR) and wind speed. Weather data were collected during the dry season (November) until the last day of flowering in both seasons. Due to budget constraints, only one weather station was available in orchard A, but it was possible to include weather station measurements at the other two orchards (B and C) in the second season.

Flowering data

Representatives samples of 30 trees with diameter at 1.3 m above ground level ≥25 cm were randomly selected in each orchard and 30 shoots per tree were randomly selected on each hedgerow for data collection. The trees were aged 8–12 yr and the tree spacing was 8 m between rows and 6 m within rows. The production of flower buds and open flowers (flowering) was observed in each orchard. Flowering ability was considered as two categorical variables with two possible values. Each sampled individual was attributed the value 1 if flowering, otherwise it was 0. The peak flowering date was recorded as the date when most of the flowers were open. The total inflorescence with either flower buds or open flowers was estimated by direct counting on marked shoots in the crowns of selected trees.

Statistical analysis

Data were analyzed using the SPSS software (SPSS Inc.; Chicago, IL, USA) to determine statistical relationships among environmental factors with regard to flowering. Daily average weather data from a month before anticipated flowering time were plotted using the Excel software (Microsoft, Redmond, WA, USA) for each season from the three orchards.

Results

Weather

The weather differed between seasons and among the orchards used in the study. The average daily temperature from December to February was 0.6 °C higher in season two than in season one in orchard A. During the 2014/15 season flowering months, the daily average minimum temperature, relative humidity, PAR and soil moisture was 21.1 °C, 68.2%, 89 μmol/s/m^2, and 144.8 kPa, respectively, in December and 19.3 °C, 62.8%, 100 μmol/s/m^2 and 200 kPa, respectively, in January. In season 2, the average daily minimum temperatures from December to February were 21.4 °C, 20.5 °C, and 20.1 °C in orchards A, B, and C, respectively. The average daily relative humidity was 67.0%, 72.0% and 65.3% in orchards A, B and C, respectively. The relative humidity dropped to less than 50.0% from the first to the second week in February during the second season which was followed by a high flower drop in most trees in all orchards (Fig. 1 A–D). The average soil moisture at 30 cm depth was

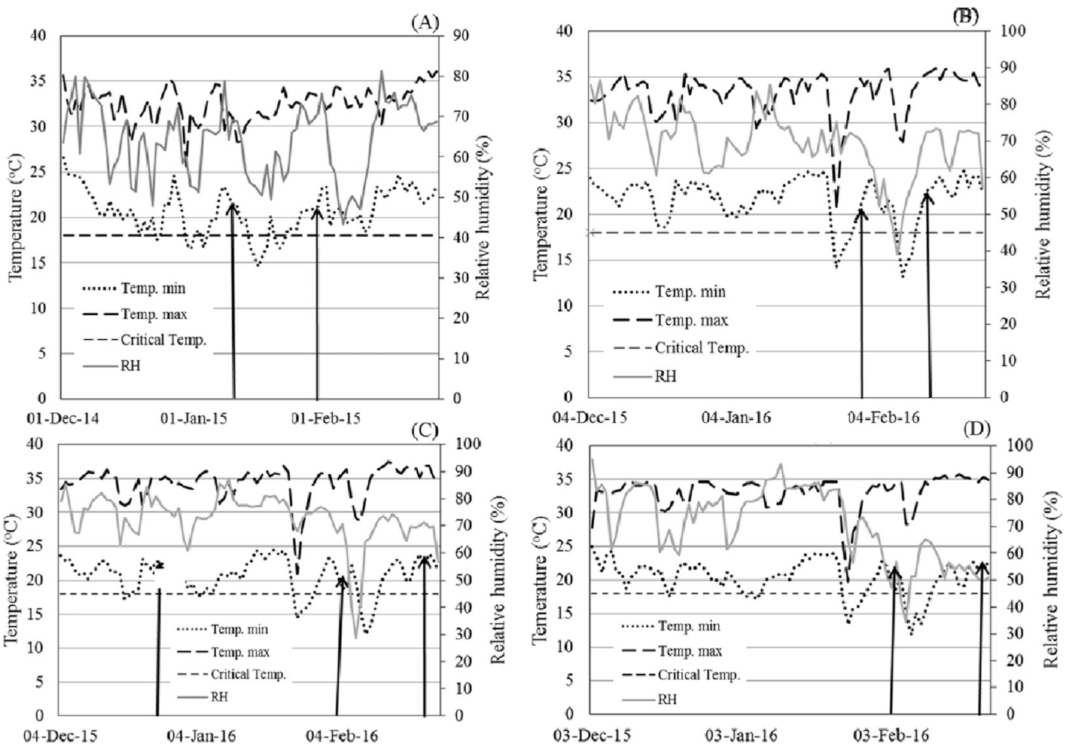

Fig. 1. Daily minimum (min) and maximum (max) air temperature (Temp.) and daily average humidity (RH) along with the flowering time (shown by arrows) of marian plum in: (A) orchard A in 2014/15; (B) orchard A in 2015/16; (C) orchard B in 2015/16; and (D) orchard C in 2015/16.

200, 132 and 21 kPa in orchards A, B and C, respectively. During the second season, the total amount of rainfall received in January was 10.2 mm, 8.0 mm and 79.6 mm in orchards A, B and C, respectively. The PAR was 93 μmol/s/m^2, 290 μmol/s/m^2 and 30 μmol/s/m^2 in orchards A, B and C, respectively. The correlation coefficients between marian plum flowering and weather parameters (Table 1) showed that only the minimum temperature was strongly correlated with marian plum flower induction.

Flowering

Asynchronous flowering of marian plum was observed in both seasons in all orchards, with orchard A flowering twice in both seasons, and in the second season, orchard B flowered three times and orchard C flowered twice (Fig. 1 A–D). First flowering in both seasons resulted in a high flower drop which resulted in little or no fruit. The flowering trends in all seasons coincided with the transition from a low night temperature (≤18 °C) to warmer days in all orchards. The cumulative number of hours below 18 °C was in the range 13–52 h and this induced flowering during the study. Flowering initiation, which was observed by bud swelling, started at 5–7 d after induction and the flowers were in full bloom 5–8 d later (Fig. 1 A–D). During December in the second season, the temperature dropped to less than 18° C only in orchard B (Fig. 1C) which resulted in early flowering. The average date of peak flowering was 28 January in season one and 18 February in the second season. The flowering percentage was high (54% at the tree level) and 80% of sampled tress flowered in orchard C while lower (23% and 60%) levels of sampled trees flowered in orchard A in both seasons.

Discussion

Observations from this study showed that marian plum flowering was induced by low temperatures (13–17 °C) for at least 2 d followed by warm temperatures (>20 °C) to enhance flower development. Low temperatures promoted flowering by checking vegetative growth, while high temperature promoted vegetative growth and suppressed flowering. Similar results were reported for litchi and longan where cool winter temperatures of 13.0–15.5 °C and 15.0–20.0 °C, respectively, induced flowering (Menzel and Simpson, 1988; Davenport and Stern, 2005; Sritontip et al., 2012). These observations were also consistent with Parmar et al. (2012) who reported that temperatures below 17 °C were responsible for the flowering of mango in south Gujarat, India. The reliability of induction and flowering intensity in marian plum increased with increased exposure to inductive low temperatures.

The relative humidity had no influence on marian plum flower induction. This related directly to the findings of a previous study where high relative humidity promoted flower development and retention in *Tamarindus indica* (Fandohan et al., 2015). Trees in all orchards flowered at the same time irrespective of the different soil moisture contents. A period of water stress (200 kPa) could not induce flowering in marian plum when temperatures were above 18 °C. However, adequate soil moisture in orchard C resulted in a large amount of inflorescence per tree through there was reduced vegetative flushing during the flowering period compared to water stressed plants (orchard A). These results differed from observations made on litchi where soil moisture stress a month before flowering checked vegetative flush and increased the amount of inflorescence per tree (Stern et al., 1998). These results implied that marian plum does not require shoot dormancy before flower induction. Rainfall received during the critical time of flower-bud-initiation stimulated vegetative growth at the expense of flowering on the water stressed trees (orchard A). Vegetative flushing during mango flowering was reported to inhibit flowering (Kulkarni, 1991) and most perennial fruit trees do not flower when they are in vegetative growth (Wilkie et al., 2008).

Delay in marian plum flowering time was observed in this study as it was formerly reported to flower in November–December (Subhadrabandhu and Yapwattanaphun, 2001). According to Khan (1999), wood trees flowering and fruiting activities are naturally timed to coincide with favorable weather conditions for optimizing performance; under favorable growth conditions, the timing and intensity of flowering greatly determines fruit yield for a given season. Nevertheless, the higher flower production in orchard C did not result in greater fruiting ability, so future studies should work on the impact of weather on yield parameters such as fruit set and fruit development.

Table 1
Correlation coefficients between marian plum flower induction and weather parameters.

Season/Orchard	1A	2A	2B	2C	Correlation
Minimum temperature (°C)	20.7	21.6	20.6	20.3	−0.63†
Maximum temperature (°C)	32.5	33.2	34.4	33.1	0.24
Relative humidity (%)	65	69.2	72.2	68.7	−0.14
Photosynthetic active radiation	115	93	290	30	0.34
Soil moisture (30 cm depth)	139.8	200	132.6	26	0.14

†Significant at $p \leq 0.05$.

Conflict of interest

None declared.

Acknowledgement

The first author was supported by a scholarship from H.R.H. Princess Maha Chakri Sirindhorn, as well as receiving financial support from the Thailand International Development Cooperation Agency (TICA).

References

Apiratikorn, S., Sdoodee, S., Lerslerwong, L., Rongsawat, S., 2012. The impact of climatic variability on phenological change, yield and fruit quality of mangosteen in Phatthalung province, Southern Thailand. Kasetsart J. (Nat. Sci.) 46, 1–9.
Chairuangyod, N., 1996. Maprang-mayongchid. Matichon Publ., Bangkok, Thailand, p. 54 (in Thai).
Davenport, T.L., Stern, R.A., 2005. Flowering. In: Menzel, C.M., Waite, G.K. (Eds.), Litchi and Longan: Botany, Productionand Uses. CABI Publishing, Wallingford, UK, pp. 87–113.
Department of Agricultural Extension, 2013. Annual Report 2013. Challenges of Marian Plum Production in Nakhon Nayok, Thailand.
Fandohan, A.B., Salako, V.K., Assogbadjo, A.E., Diallo, B.O., Van Damme, P., Sinsin, B., 2015. Effect of climatic conditions on flowering and fruiting of *Tamarindus indica* (Fabaceae). J. Hortic. For. 7, 186–192.
Khan, J.A., 1999. Periodicity of major phenophases in woody species in dry deciduous forest of Gir. India. Trop. Ecol. 40, 299–303.
Kulkarni, V.J., 1991. Physiology of flowering in mango studied by grafting. Acta Hortic. 291, 95–104.
Lu, P., Chacko, E.K., 1999. Effect of water stress on mango flowering in low latitude tropics of Northern Australia. In: VI International Symposium on Mango. Pattaya City, Thailand, pp. 283–290.
Menzel, C.M., Simpson, D.R., 1988. Effect of temperature on growth and flowering of litchi (*Litchi chinensis* Sonn.) cultivars. J. Hortic. Sci. 63, 349–360.
Office of Agricultural Economics, 2013. Planting Area and Harvest Data of Major Economic Fruit Crops, 5 January 2016. (in Thai). http//www.oae.go.th/.
Parmar, V.R., Shrivastava, P.K., Patel, B.N., 2012. Study on weather parameters affecting the mango flowering in south Gujarat. J. Agrometeorol. 14, 351–353.
Shu, Z.H., Sheen, T.F., 1987. Floral induction in axillary buds of mango (*Mangifera indica* L.) as affected by temperature. Sci. Hortic. 31, 81–87.
Southwick, S.M., Davenport, T.L., 1986. Characterization of water stress and low temperature effects on flower induction in citrus. Plant Physiol. 81, 26–29.
Sritontip, C., Jaroenkit, T., Manochai, P., Sangchyoswat, C., 2012. The impact of climate changes on yield of longan production in Northern Thailand. In: IV International Symposium on Litchi, Longan and Other Sapindaceae Fruits. White River, South Africa, pp. 155–162.

Stern, R., Meron, M., Naor, A., Wallach, R., Bravdo, B., Gazit, S., 1998. Effect of fall in irrigation level in ‘Mauritius’ and ‘Floridian’ litchi on soil and plant water status, flowering intensity and yield. J. Am. Soc. Hortic. Sci. 123, 150–155.
Subhadrabandhu, S., 2001. Under-utilized tropical fruits of Thailand. RAP Publication, FAO, Rome, Italy.
Subhadrabandhu, S., Yapwattanaphun, C., 2001. Regulation off-season flowering of longan in Thailand. Acta Hortic. 558, 193–198.
Wilkie, J.D., Sedgley, M., Olesen, T., 2008. Regulation of floral initiation in horticultural trees. J. Exp. Bot. 59, 3215–3228.