Scientia Horticulturae 168 (2014) 258–266

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Mango trees have no distinct phenology: The case of mangoes in the tropics

Fernando Ramírez [a,*], Thomas Lee Davenport [b], Gerhard Fischer [c], Julio Cesar Augusto Pinzón [d], Christian Ulrichs [e]

[a] Facultad de Ciencias, Universidad Colegio Mayor de Cundinamarca, Calle 28 No 5B-02, Bogotá, Colombia
[b] Director of Research and Development, Vivafresh Technologies, 18421 SW 224 St., Miami, FL 33170, USA
[c] Facultad de Ciencias Agrarias, Universidad Nacional de Colombia, Carrera 30 No. 45-03, Bogotá, Colombia
[d] Facultad de Humanidades, Departamento de Filosofía, Universidad Pedagógica Nacional, Calle 72 No. 11-86, Bogotá, Colombia
[e] Faculty for Agriculture and Horticulture, Division Urban Plant Ecophysiology, Humboldt-Universität zu Berlin, Lentzeallee 55-57, 14195 Berlin, Germany

ARTICLE INFO

Article history:
Received 26 November 2013
Received in revised form 13 January 2014
Accepted 17 January 2014

Keywords:
Anacardiaceae
Flowering
Fruit
Landmark stages
Vegetative
Colombia

ABSTRACT

We propose a convenient, easily observable set of landmark developmental stages during vegetative and flowering flushes and fruiting events to characterize the changes through which individual growing mango shoots pass in the tropics and subtropics. Individual non-growing stems are in the Resting stage (R), when the apical bud (following a previous vegetative growth event) or lateral buds (following a previous flowering event) are dormant. A flush event is one in which the resting buds on many stems in a section of tree canopy initiate growth (asynchronous flush) or when the entire canopy initiates bud growth at once (synchronous flush). The stages describing vegetative shoot growth are: Vegetative Bud Emergence and Development stage, Elongating Green Leaf stage, Limp Red Leaf stage (LRL), Immature Green Leaf stage, and Mature Green Leaf stage. Reproductive growth stages in purely flowering, or generative, shoots are: Floral Bud Initiation, Emergence and Development stage, Early Panicle Elongation stage, Mid-size Panicle Early Anthesis stage, and Full-size Panicle Maximum Anthesis stage. Fruiting stages are: Emergent Fruit stage, Small-size Green Fruit stage, Mid-size Green Fruit stage, Near Full-size Immature Fruit stage, and the Full-size Mature Fruit stage. Mixed shoots, bearing both leaves and lateral inflorescences at each node, exhibit characteristics of both vegetative and flowering shoots. Landmark stages for Tommy Atkins and Keitt, two cultivars commercially growing in the Americas, were observed in tropical orchards near the village of La Mesa, Colombia. Tommy Atkins leaves had a more intense red coloration during the LRL than did 'Keitt'. More pedicels were found in 'Tommy Atkins' than in 'Keitt' during panicle development. Young fruits of 'Tommy Atkins' developed their distinctive, dark red coloration, whereas 'Keitt' fruit developed less intense reddish coloration once they were mature. Aside from these minor phenotypic differences in distinctive shoot and stem developmental stages, attempts to ascribe a distinct phenological pattern of mango tree growth and development are impractical. Each stem terminal or groups of stem terminals borne on scaffolding branches act as independent structures influenced by environmental conditions, such as temperature, water relations, and nutrition coupled with their physiological age resulting in widely variable tree responses even in similar environments.

1. Introduction

Phenology is "the science dealing with the influence of climate on the recurrence of such annual phenomena of animal and plant life as bird migrations and budding" (Anonymous, 1989). Particular interest has become attached to the development of phenological stages in woody angiosperms. Phenological scales such as the BBCH scale (Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie) and the extended BBCH scale have been developed for angiosperms (Hack et al., 1992; Hernández Delgado et al., 2011; Rajan et al., 2011). The BBCH scale has been used to characterize the phenological stages in several trees such as guava (*Psidium guajava* L.) (Salazar et al., 2006), cherimoya (*Annona cherimola* Mill.) (Cautín and Agustí, 2005), olive (*Olea europaea*) (Sanz-Cortés et al., 2002), and mango (*Mangifera indica* L.) (Hernández Delgado et al., 2011; Rajan et al., 2011) among other horticultural crops such as herbaceous plants (Ramírez et al., 2013). A number of phenological stages have been proposed for mango. The first mango

* Corresponding author. Tel.: +57 13109409.
E-mail addresses: fermp44@yahoo.com, framirezl@unicolmayor.edu.co, fernando.ramirez@javeriana.edu.co (F. Ramírez), tldav@ufl.edu (T.L. Davenport), gfischer@unal.edu.co (G. Fischer).

0304-4238/$ – see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scienta.2014.01.040

phenological cycle model for subtropical conditions was proposed by Cull (1987, 1991). This model was a holistic approach for tree crop research and management to maximize sustainable fruit production. It was based on the axiom of genotype/environment adaptability expressed through the annual phenological cycle and offered an alternative to the traditional reductive-based approach to crop research and development (Cull, 1987, 1991). This model proposed a "normal" phenological pattern that is followed from year to year and is driven by the genetic expression of productive cultivars in relation to specific environments. The fundamental principle expressed is that yield is a product of photoassimilate (carbohydrate) accumulation and redistribution during the annual growth cycle, thus a carbohydrate-based flowering model. Departure from the "normal" pattern results in reduced or total crop failure.

Other investigations have described a distinct phenological cycle of mango flowering. Aubert and Lossois (1972) developed a mango phenological scale that described five stages for shoot and nine stages for inflorescence development. Oosthuyse (1991) described 18 stages from buds to mature fruits. Schnell and Knight Jr. (1998) studied the phenology of mango flowering among 212 different accessions from India, Southeast Asia, and Florida. They reported significant differences in flowering responses in years and cultivars. A number of investigators have developed phenological cycles dealing with mangoes in the subtropics (Whiley, 1993; Robert and Wolstenholme, 1992; Crane, 1998; Strassen and Janse Van Vuuren, 1997).

Most studies have based their results on broad generalizations that could apply to most cultivars. All of the above-mentioned studies have a set of distinctive phenological stages, as though mango trees grow synchronously throughout the canopy and pass through distinctive stages in subtropical environments. Moreover, most of these studies describe the phenology of mangoes as a continuous set of events driven by the "usual" climatic changes. This is not entirely the case; for example, trees in subtropical climates may not always behave as expected when exposed to tropical warm climatic conditions (Fischer, 2012). Though resting buds usually break to form vegetative shoots during warm temperatures, a coincidental period of water stress can delay bud break in spite of the warm temperatures until the summer rains arrive. Therefore, the course of plant development may be dependent on multiple coincidental environmental and internal factors. This is the case of the observed plant architecture, which results from both endogenous structural and temporal components, and their interplays (Dambreville et al., 2013). Studies dealing with phenology often disregard the combined impacts of annually variable factors, such as precipitation and temperature or the age of resting stems since their last flush of growth. As a result, it is often difficult to forecast the phenological impact of weather variation precisely and to monitor the age of stems in the tree canopy.

In contrast to the phenological cycle described for subtropical conditions, mango trees in the tropics and those in the subtropics that have experienced a mild winter have been described as having an asynchronous growth pattern (Davenport, 2003, 2006, 2007, 2009; Ramírez and Davenport, 2010, 2012a,b). Individual stems go through distinctive developmental stages, but the canopy does not follow a defined phenology, as would be the case for trees under cool subtropical conditions. This is the case of 'Tommy Atkins' and 'Keitt' mangoes that were selected in subtropical Florida where they have a synchronous flushing habit driven by cool winter temperatures but grown in the low-latitude tropics where flushes are normally asynchronous and trees can remain in rest until the onset of the rainy seasons (Ramírez et al., 2010a).

'Keitt' trees are medium size, moderately vigorous, and upright with open canopy (Knight et al., 2009). The fruit is greenish yellow, with a pink or red blush, numerous small white or yellow lenticels, oval with rounded base, 13–15 cm long, 9–11 cm broad, 8.5–10 cm thick, and weighing 510–2000 g. The skin is thick, tough, and adherent. The flesh is firm and juicy with little fiber, lemon yellow, sweet, and mild with a pleasant aroma, with good to excellent quality. The seed is monoembryonic in a thick and woody stone (Knight et al., 2009).

Tommy Atkins is considered the most commercially important mango cultivar in the western hemisphere (Knight et al., 2009). The tree is vigorous, with a dense, rounded canopy. The fruit is orange-yellow, with a crimson or dark-red blush and numerous small, white lenticels, oval to oblong, with a broadly rounded base, 12–14.5 cm long, 10–13 cm broad, 8.5–10 cm thick, and weighing 450–700 g. The skin is thick, tough, and adherent. The flesh is firm and medium juicy; with a medium amount of fiber, lemon to deep yellow color, mild and sweet with a strong pleasant aroma and fair to good eating quality. It bears a monoembryonic seed in a thick, woody stone (Knight et al., 2009).

'Tommy Atkins' and 'Keitt' growing under tropical conditions with two distinct rainy seasons, have a growth cycle that is repeated twice on different branches during the year (Ramírez and Davenport, 2010; Ramírez et al., 2010a; Ramírez and Davenport, 2012a,b; Fischer et al., 2012). They can produce vegetative or reproductive shoots and fruit on different branches of canopy throughout the year depending on individual stem age and the influence of overcast and rainy conditions. These findings demonstrate the importance of describing landmark stages of these cultivars when introduced into Colombia where little research has been conducted on mango phenology. The aim of the current study is to conveniently identify easily recognizable landmark developmental stages and to explain how individual stems have a defined phenology that can differ greatly from those of other stems within the canopies of 'Tommy Atkins' and 'Keitt' mangoes.

2. Materials and methods

Observations were made in orchards on four farms, La Tebaida, El Consuelo, Monterrey, and Santa Rosa, located near La Mesa (Lat: 4:31:02 N, Long: 74:33:37 W), Cundinamarca State, Colombia (Ramírez et al., 2010a,b; Ramírez and Davenport, 2010). The cultivar observed at La Tebaida and Santa Rosa was Tommy Atkins, and Keitt was observed at Monterrey, whereas cultivars observed at El Consuelo were both Tommy Atkins and Keitt. Trees at all locations were 15 years old and were grafted onto 'Criollo' rootstocks. Mean tree height at El Consuelo and Santa Rosa was 4 m; however, the trees at la Tebaida ranged from 6–7 m in height (Ramírez et al., 2010a). 'Keitt' mango trees at Monterrey were 3–4 m in height (Ramírez et al., 2010b). Daily temperatures are nearly constant with the annual mean for the La Mesa area being 22 °C. Yearly precipitation averages 1300 mm (57 in.), most of it falling in two distinct rainy seasons extending from February to May and September to December that result in two annual flowering seasons that occur after the onset of each rainy season (Ramírez et al., 2010b).

Detailed observations of individual scaffold stems on representative 'Tommy Atkins' and 'Keitt' mango trees were recorded every 15 days from January 2006 to September 2008. Terminals of both vegetative and generative shoots were photographed to identify key individual landmark features that occur as they mature into stems.

We used landmark stages of vegetative growth and development proposed by Davenport et al. (2001) to describe vegetative shoot changes as they develop into stems with resting apical bud (RAB), such as Vegetative Bud Break (VBB) that occurs when the resting apical buds are initiated to grow under vegetatively inductive conditions. Subsequent stages after Vegetative Bud Break are Vegetative Bud Elongation stage (VBE), which occurs as vegetative