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Review

Mango (*Mangifera indica* L.) pollination: A review

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ABSTRACT

Flowering and pollination are key reproductive events leading to mango fruit development. The mango inflorescence is a branched terminal panicle or determinate thyrse. Mango flowers are either male (staminate) or hermaphroditic, containing both stamens and carpels (perfect). Sex ratio (the proportion of perfect to staminate flowers) is a variable component within panicles, trees and among cultivars. Endogenous, genetically regulated events and environmental factors influence sex ratio. Pollen grains are 20–45 μm long. Mango pollination commences with deposition of pollen on the stigmatic surface of the style. Pollen germination is different among cultivars. Mango pollen viability is highest soon after anther dehiscence and rapidly degrades. Mango viability is an important feature for breeding programs. Floral anthesis occurs in the morning or at night depending on cultivar. Mango has self- cross- pollination, self-incompatibility and self-sterility systems; however, some cultivars are semi- compatible or fully compatible. Wind is important in mango pollination. Outcrossing rates using molecular markers have been poorly studied around the world, and more studies need to be conducted in this particular field of research. *In vitro* mango pollen germination has been used widely. This review provides the current state of knowledge of pollination from a diverse array of environments and climatic conditions ranging from subtropical to tropical environments were mango is grown.

Contents

1. Introduction

Pollination in woody angiosperms has been studied in several tropical, temperate and subtropical fruit tree species. This is the case of citrus, (Davenport, 1990), avocado (Davenport, 1986), lichee (Stern and Gazit, 1996) and apple (Ramírez and Davenport, 2013) among other tree species. Mango (*Mangifera indica* L.) pollination has attracted much interest, and to date, studies have dealt with cross-pollination mediated mainly by insects, self- pollination, pollen morphology, physiology, *in vitro* germination, outcrossing and the effects of environmental factors on pollination.

Flowering and pollination are key events for mango fruit development to occur (Ramírez and Davenport, 2010; Ramírez et al.,

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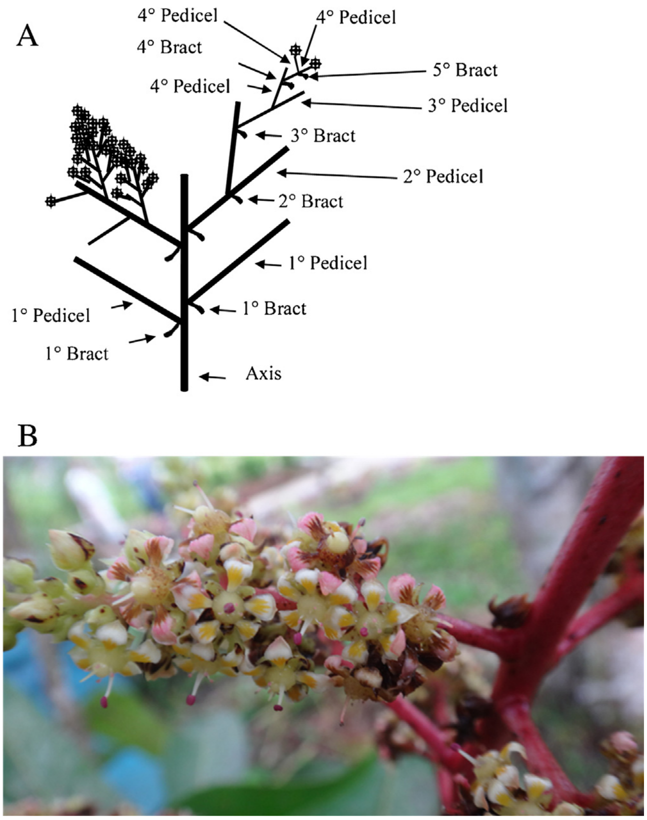

Fig. 1. Panicle with branching (pedicels) (A) and panicle detail (B). Note that each individual flower forms a cluster. Drawing and Photo by Fernando Ramírez.

2010a). Pollination has been known to have a controlling effect on mango fruit set (Jutamanee et al., 2002). Mango pollination is a complex physiological process wherein pollen contacts the stigmatic surface, migrates down the style (Ramírez and Davenport, 2012a), and a series of steps lead to the fusion of the generative cell with the ovule within the ovary. Pollen is viable during warm temperatures, but cool weather can negatively impact pollen development and tube growth to the ovule (Davenport, 2009). Self and cross–pollination have been documented in mango; but unreliable results have been reported on cross-pollination mechanisms in most parts of the world (Ramírez and Davenport, 2012a,b). Some studies favor cross-pollination as the most reliable mechanism (Dag, 2009) and yet, other studies claim that self-pollination is the most successful mechanism (Sousa et al., 2010). Cross pollination is mediated by insects, wind and perhaps, vertebrate species. The aim of this review is to discuss mango pollination mechanisms, such as pollen morphology, anthesis in subtropical environments and with special reference to tropical environmental factors affecting pollination, self-pollination, and cross pollination.

2. Floral morphology

The mango inflorescence is a branched terminal panicle, 4–24 in. long, bearing what has been variously estimated to range from 500 to 10,000 (McGregor, 1976), 200 to 6000 (Free, 1993), and 1000 to 6000 (Mukherjee, 1953) individual flowers per panicle. The number of panicles range from 200 to 3000 per tree depending on tree size and extent of branching (McGregor, 1976). Individual flowers are borne collectively on panicles or thyrses (Weberling, 1989) that consist of a central axis with lateral peduncles that further divide from primary, secondary or further peduncle architecture, each terminating in a cymose triad of flowers (Fig. 1). Coetzer et al. (1995) considered the mango inflorescence a determinate thyrse and not a panicle. Vestigial leaf primordia (floral bracts) are depicted at the base of each level of pedicel architecture (Fig. 1) (Davenport, 2009). The panicle bears both perfect, or hermaphroditic, flowers having both pistil and staminate structures and purely male, or staminate, flowers (Ramírez and Davenport, 2012a). Mango panicle architecture varies among cultivars. For example, 'Tommy Atkins' inflorescences have more ramifications (peduncles) bearing more individual flowers per panicle when compared to 'Keitt' (Ramírez et al., 2014) (Fig. 2).

Individual mango flowers are small, ranging in size from five to ten mm in diameter. The perianth usually consists of five petals and sepals that are ovate–ovoid to lanceolate, thinly pubescent, and variable in color (Fig. 3) (McGregor, 1976; Scholefield, 1982; Galán-Saúco, 1999; Mukherjee and Litz, 2009; Ding and Darduri, 2013). The three to nine (usually five) cream-colored petals typically change color before falling (Naik and Rao, 1943). Petals can be white, red, pink, (Free, 1993; Sousa et al., 2010) or even yellow depending on time since anthesis (Fig. 3). Greenish-yellow sepals can range in number from four to seven (Kosterman and Bompard, 1993). Pedicels are short (Kosterman and Bompard, 1993). Perfect and staminate flowers bear stamens and four sterile staminoids that are surrounded by a gland or nectary (Galán-Saúco, 1999; Mukherjee and Litz, 2009). The nectary is a fleshy disk surrounding the ovary (McGregor, 1976). Nectar production is continuous and in small amounts, on an average of 0.045 μL/flower (Siqueira et al., 2008). Anthers are four-lobed, and dehiscence occurs longitudinally to reveal pollen (Scholefield, 1982). The ovary has one chamber that contains one ovule (Free, 1993). The ovule is anatropous and pendulous (Mukherjee and Litz, 2009). The ovary is superior, sessile, free, gibbose, yellow- colored (depending on cultivar), and laterally inserted style with a point like stigma (Kosterman and Bompard, 1993; Galán-Saúco, 1999).

According to Singh et al. (2005) staminate flowers lack a gynoecium and are, therefore, soon committed to separation from panicles. Unsuccessful union of the egg and sperm in hermaphroditic flowers results in no formation of an embryo. It is plausible that, in the absence of embryo formation in both flower types, there lacks the ability of those organs to produce the hormone(s), such as auxin and possibly other classes of hormones that are necessary for maintenance of the abscission zone and prevention of elevated ethylene formation. Each flower can, thus, be viewed as programmed to abscise unless saved by fertilization giving rise to production of protective factors before the onset of increased ethylene subsequent separation layer formation (Singh et al., 2005).

3. Sex ratio

Sex ratio (i.e. the proportion of perfect to staminate flowers) is a variable component within panicles, trees and among cultivars (Singh, 1954; Coetzer et al., 1995; Davenport, 2009). This ratio varies with cultivar, but is usually < 50% (Davenport and Núñez-Elisea, 1997). Most perfect and staminate flowers are borne in the proximal portion of panicles due to their architecture (Musahib-ud-din and Dinsa, 1946; Cobin, 1950; Pimentel et al., 1984; Davenport, 2009); however, this condition can be reversed in some cultivars (Hussein et al., 1989). Sex ratio varies among cultivars, between same cultivars grown in different regions, in relation to tree age, and varies between inflorescences on the same tree (Coetzer et al., 1995). Environmental and internal physiological factors have been claimed to influence sex ratio in mango (Asif et al., 2002; Davenport, 2009).

Environmental factors include: rainfall, relative humidity and temperature (Pandey, 1988). High temperature has been associated with an increased number of perfect flowers and low tempera-