Scientia Horticulturae 138 (2012) 108–119

Contents lists available at SciVerse ScienceDirect

Scientia Horticulturae

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

Photosynthesis and stomatal conductance of five mango cultivars in the seasonally wet–dry tropics of northern Australia

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ARTICLE INFO

Article history:
Received 12 October 2011
Received in revised form 13 February 2012
Accepted 15 February 2012

Keywords:
Leaf gas exchange
Poly-embryonic cultivars
Mono-embryonic cultivars
Soil water deficit
Seasonal changes
Mangifera indica L.

ABSTRACT

Field experiments were conducted over 3 years on 4–6 years old trees of cvs. Kensington Pride (KP), Strawberry (ST), Haden (HA), Irwin (IR) and Tommy Atkins (TA). They belong to two distinct groups, poly-embryonic cultivars (Australia originated KP and ST) and mono-embryonic cultivars (Florida originated HA, IR and TA). There was significant seasonal variation in net photosynthesis rate (A_{net}) and stomatal conductance (g_s) in all the five cultivars with the maximum values observed during the wet season (January–March) and the minimum at the end of June and beginning of July during the dry season. The dry season A_{net} values showed the largest variation between cultivars in photosynthetic capability. During this season the three monoembryonic cultivars had greater A_{net} accumulation than the polyembryonic cultivar, KP. Recovery of g_s and A_{net} was marginal and slow after the commencement of irrigation in most of the cultivars following preflowering imposed drought conditions for 2.5 months. The fruit setting and fruit development period was the time of maximum environmental stress, during which g_s and A_{net} remained very low especially for KP in spite of the irrigation and adequate soil water conditions. Significant recovery only occurred in the subsequent wet season when the atmospheric and soil moisture conditions were significantly improved. During the wet season variation between cultivars in A_{net} and g_s was smaller than during the dry season. g_s of KP and ST, both polyembryonic cultivars, was often significantly lower than that of monoembryonic cultivars. On both a seasonal and diurnal basis, A_{net} was highly positively correlated with g_s during both the wet and dry seasons. A_{net} and g_s were negatively correlated with leaf-to-air vapour pressure deficit (LAVPD). There was evidence for the poly-embryonic cultivars regulating A_{net} in response to conditions of high LAVPD to a greater extent than mono-embryonic cultivars in this study. It is concluded that in terms of A_{net}, cultivars IR and TA were the most suited to a hot tropical environment in contrast to the Australian dominant cultivar KP which did not maintain photosynthesis during periods of environmental stress. This information could be used for breeding programs to improve mango productivity in the Australian tropics.

1. Introduction

The photosynthetic performance among mango (*Mangifera indica* L.) cultivars is important to identifying suitable material for breeding cultivars with improved productivity, especially for the development of productive cultivars for specific environmental regions (Whiley et al., 1993). More recently good photosynthetic efficiency during flowering and fruit growth was identified as one of the important traits for improved mango variety productivity (Bally et al., 2009).

Comparisons of the photosynthetic performance of mango cultivars are useful to identify cultivars for breeding for productivity, but most studies have been of single mango cultivar. Important exceptions are multiple cultivar studies by Shivashankara and Mathai (1995, 2000) on monoembryonic cultivars, Elsheery and Cao (2008) and Elsheery et al. (2008) on polyembryonic cultivars and studies by Chacko et al. (1995), Searle et al. (1995), Schaffer et al. (1997),

Abbreviations: KP, Kensington Pride; ST, Strawberry; HA, Haden; IR, Irwin; TA, Tommy Atkins; A_{net}, net photosynthesis rate; g_s, stomatal conductance; a.s.l., above sea level; *E*, transpiration; PPFD, photosynthetic photon flux density; LAVPD, leaf-to-air vapour pressure deficit; Chl, chlorophyll content; CV, coefficient of variation; CSA, canopy surface area; cv., cultivar; LSD, least significant differences; SMC, soil moisture content.

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doi:10.1016/j.scienta.2012.02.019

Pandey and Tyagi (1999), and Elsheery et al. (2007) on both mono and polyembryonic cultivars.

Aspects of photosynthesis and associated assimilate production are affected by interactions between environmental factors and genotype (Whiley, 1993), making it important to understand the effects of environmental factors on photosynthesis in conjunction with in-field cultivar performance. In an opinion paper it was proposed that the notorious recalcitrance to consistent cropping of the mango tree is rooted in evolutionary adaptations to a predominantly hot, dry monsoonal environment (Wolstenholme and Whiley, 1995). Fruiting is only moderately energy and mineral expensive, but prolonged heat and moisture stress can escalate respiratory demand and compromise annual photoassimilate gain (Wolstenholme and Whiley, 1995). Environmental conditions in the tropics can limit photosynthesis. For example, a single cultivar study reported large seasonal declines between the wet monsoonal season and dry season on light saturating net photosynthesis rate for the polyembryonic Kensington Pride (KP) in the tropical environment of Northern Australia (Gonzalez and Blaikie, 2003). However, there have been few attempts to link environmental factors to the photosynthesis of differing cultivars and their fruit production using-field based studies. There are two exceptions (Chacko et al., 1995; Searle et al., 1995) of which only one was carried out in a tropical environment, and these studies only compared two cultivars.

Due to the current absence of information on the physiological performance of mango cultivars in conjunction with field based productivity in the wet–dry tropics, this study made use of trials carried out two decades ago. Comparisons of the genotypic and environmental effects on five cultivars for aspects of net photosynthesis and stomatal conductance in relation to fruit production in the seasonally wet–dry tropics of northern Australia are presented.

2. Materials and methods

2.1. Experimental trees and growing environment

Field experiments were conducted over 3 years from 1988 to 1990 on 4–6 year old trees of cvs. Kensington Pride (KP), Strawberry (ST), Haden (HA), Irwin (IR) and Tommy Atkins (TA). KP and ST are Australia originated poly-embryonic cultivars and HA, IR and TA are Florida originated mono-embryonic cultivars. All trees were growing in commercial orchards in the Darwin (12°S, 130°E, 13 m above sea level (a.s.l.)) or Katherine (14°S, 132°E, 108 m a.s.l.) regions, Northern Territory, Australia.

The weather data for Darwin and Katherine over the periods of this study are presented in Fig. 1 to show the inter-annual variation in weather conditions. During the wet season, the weather in Darwin is humid and hot, with an annual rainfall of 1500–1600 mm that is unevenly spread between October and April. Temperatures do not vary much with seasons because of the low latitude and proximity to the sea. The daily maxima are over 30 °C in the coolest months of June–July, which is little less than the 34 °C of the hottest month November. June to August is usually rainless and dry with lower relative humidity (<50% at midday). Night temperature during the dry season is lower (19 °C) than the wet season (24 °C) (20-year long term weather data, Australian Weather Bureau). In contrast, the climate of Katherine is more semi-arid with a distinct wet season from November to March. The wet season is characterised by irregular, heavy rainfall (867 mm), high relative humidity (>40–60% at midday) and maximum temperature ranging between 32 and 38 °C with a low diurnal variation (10–13 °C). These conditions are in marked contrast to the 'Dry' season from April to October, exhibiting only light and sporadic rainfall (85 mm), low relative humidity (10–40% at midday) and high temperatures (30–42 °C) with high diurnal variation (15–17 °C) (1941–2000 long-term weather data, Australian Bureau of Meteorology).

Except otherwise specified, trees in the three experiments were irrigated according to the normal orchard irrigation practice in these regions, which involved drought stressing the trees by withholding irrigation from the end of the wet season to improve flowering followed by under-tree sprinkler irrigation (600–800 L per tree at 3–4 days intervals, wetting an area up to the drip-line or more) at the onset of peak flowering in late June or early July. Irrigation was terminated at about the time of harvest in October.

Soils at the study orchards were a sandy loam textured Kandasol with a pH around 5–7 and variable content of gravel. These soils are extremely poor in all major and minor elements and organic matter. Mango trees grown in such soils are commonly fertilised with a complex fertiliser mix containing most major nutrients and several micronutrients. During the study period, the experimental trees received 2–3 kg of a complex fertiliser mix containing 11.8% (N), 6% (P), 15.6% (K), 0.05% (Cu), 0.05% (Zn), 0.13% (Ca), 1.0% (Mg) and 8.3% (S) in two split applications, first during the beginning of the wet season (November–December) and then at the time of fruit set (August, September). Supplementary foliar applications of Zn, Fe and other micronutrients were also provided 2–3 times using Foliar Nutrient at 2 mL concentrate per litre of Wuxal liquid (Schering Ltd., Australia) during the period of fruit set and development.

2.2. Experiment I: Seasonal variation in leaf gas exchange in five mango cultivars

Ten 5-year-old (in 1989) uniform trees each of the cvs. KP, ST, HA, IR and TA grafted onto KP seedlings growing in a commercial orchard near Darwin (Humpty Doo) were used for this experiment. The experimental trees were planted at 10 m × 10 m spacing with cultivars arranged in a randomised design. At the time of this study, the canopies were far from touching each other, therefore trees were in isolation. At the end of the study period (October 1990) height, stem diameter and canopy area/volume of the experimental trees were recorded. The number of fruit and yield of each tree was recorded over 3 years from 1988 to 1990. Flowering on 30 tagged shoots per tree was also recorded.

The moisture content in the soil to a depth of 2 m was monitored from January to December in 1989 using a Neutron Moisture Probe (Model 503 DR, CPN Corp., USA) at 0.5 m away from the trunk of the trees (one access tube per tree). The volumetric soil moisture content (SMC) at increments of 0.25 m depth was measured at monthly or bimonthly intervals.

In 1989, net photosynthesis (A_{net}), stomatal conductance (g_s) and transpiration (E) were measured on three leaves each of five replicate trees per cultivar at bimonthly (wet season) and monthly (dry season) intervals on clear days (at photosynthetic photon flux density (PPFD) > 1000 μmol m^{-2} s^{-1}) using a Li-Cor 6200 portable photosynthesis measuring system (Li-Cor Inc., Nebraska, USA). All measurements were carried out between 08:00 h and 11:00 h on two consecutive days. Recently matured (over 2 months old), healthy leaves on terminal vegetative flush (January–July and November–December) or on flowering/fruiting terminals (July–October) were used for gas exchange measurements. The mean specific leaf weight (g dry weight m^{-2}) was calculated from samples of 5 leaves per treed in June 1989. Leaf-to-air vapour pressure deficit (LAVPD) was calculated for each measuring period using leaf and air temperatures and ambient air relative humidity recorded by Li-Cor 6200. For the dry season and yearly integrated A_{net} values, the area below the curves shown in Fig. 3b was calculated using an area below curve function in SigmaPlot V10.

Total chlorophyll content (Chl) was estimated with a portable chlorophyll meter (SPAD-502; Minolta Camera Co, Osaka, Japan) on 10 leaves per tree from the same trees used for the leaf gas