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# Avocado fertilization: Matching the periodic demand for nutrients

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ABSTRACT

The main objective of this study was to assess the seasonal nutrients requirement of 'Hass' avocado trees grown in lysimeters, especially during flowering and the early period of fruit development that may affect later on the fruitlet abscission and determine crop yield. The experimental design included three fertigation treatments applying a fixed nutrient solution at three different starting dates of fertigation: (a) T1 – continuous fertigation, including macro nutrients (N-P -K) and micronutrients application, all over the year; (b) T2 – no fertilization (only irrigation) until 15 March, and fertigation as T1 since then; (c) T3 - no fertilization (only irrigation) until 15 May, and fertigation as T1 since then. Absence of fertilization during the winter period induced leaf-chlorosis while healthy, dense and plenteously green leaves characterized the fertilized trees (T1). The beneficial effect of early fertigation on fruit yield was statistically significant, mostly because of higher fruit number. Leaf analyses are commonly used in the avocado industry as a guide for fertilization yet; fruits rather than leaves are the main products of avocado orchards. Consequently, fruit rather than leaf analyses should determine fertilization management. Based on fruit growth data and nutrient concentration in the fruit, the N, P and K quantities removed by 'Hass' avocado fruit yield of 30 t $ha^{-1}$ were 120, 25 and 240 kg $ha^{-1}$. Taking into account common efficiency consideration (nutrient quantities removed by fruit yield divided by quantities added), the annual quantities of N, P and K required for attaining high quality avocado yield are 250–300, 80–120 and 500–600 kg $ha^{-1}$, respectively. Thus, fertilization rate together with nutrient combination should be modified in order to insure optimal fruit development.

## 1. Introduction

'Hass' avocado (*Persea Americana* Mill.) trees are vigorous and the potential photosynthetic capacity of mature trees can support commercial crop yields higher than 30 t $ha^{-1}$ (Wolstenholme, 1986). However, alternate bearing and fruit abscission generally limits the long-term average crop yield to less than 10 t $ha^{-1}$ (Garner and Lovatt, 2008). High 'Hass' avocado yield equivalent to approximately 40 t $ha^{-1}$ was obtained in a lysimeter irrigation experiment few years ago (Silber et al., 2012). The experimental irrigation treatments in that study have practically not affected the vegetative growth, flowering or fruit-set processes, but have induced significant differences on fruitlet abscissions and accordingly, on fruit yield. Fruitlet abscission was the outcome of a multifaceted process starting few months before it occurred, rather than a sudden and abrupt event as one could imagine from the visible aspects of this phenomenon. The causes for fruitlet abscission were attributed to malfunction of embryo or seed induced by water and \or nutrient deficiency during the early period of fruit development (Silber et al., 2012).

The major and most important role of plant leaves is to convert light energy into chemical energy throughout the photosynthesis process by transforming carbon dioxide and water into carbohydrates, the driving forces for all plant-growing. Reproductive organs in avocado are strong sinks for carbohydrates (Whiley and Wolstenholme, 1990; Wolstenholme, 1986), and nutrients (Silber et al., 2013) from early stages of bloom throughout embryo seed formation and fruit ripening. In case of nutrient deficiency in the reproductive organs, nutrients are mobilized from the leaves towards the new developing reproductive organs in order to ensure satisfactory development. In cases of severe nutrient deficiency, the leaves become chlorotic and may abscise by a mechanism of programmed cell death. Thus, beyond their major role in carbohydrate production, leaves may also serve as an "operational

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reservoir” for nutrients to meet the peak demand in essential plant processes.

Healthy and dense foliage is certainly required to achieve high yields, and leaf nutritional status is commonly used for fertilization management decisions in the avocado industry (Lahav and Aycicegi-Lowengart, 2003). The leaf nutrients thresholds were developed empirically in various studies that demonstrated the relationships between leaf mineral concentration and fertilization (mainly N) regime (Koen and du Plessis, 1992; Lovatt, 1995, 2001; Salvo and Lovatt, 2016). Yet, the nutrients fertilization thresholds may vary with many factors such as: (i) leaf age (Castillo-Gonzalez et al., 2000; Lahav, 1995; Lahav and Kadman, 1980; Lahav et al., 1990; Salazar-Garćıa et al., 2015); (ii) rootstock (Young and Koo, 1977); and (iii) physiological and phenological status (Koo and Young, 1977; Salazar-Garćıa et al., 2015). Salazar-Garćıa et al (2015) proposed a mathematical model to determine the correct time for leaf sampling recently. So far, no relationships were found between yield and fruit size of ‘Hass’ avocado and Leaf-N concentration (Lovatt, 2001; Lovatt and Witney, 2001). Lahav (1995) concluded that the nutrient demand of avocado trees is low and crop yield did not respond to N-P -K fertilization. It is important to note that all the above studies were based on field experiments focusing mainly on N fertilization, without P addition to the fertilization system (except in Koen and du Plessis, 1992). Furthermore, solid fertilizers rather than fertigation (simultaneous addition of water and soluble fertilizers through the irrigation system) were applied, which introduces variations in nutrient availability throughout the season. An alternative approach of monitoring fruit peduncle (Razeto and Salgado, 2004) and fruit pulp was reported (Razeto and Palacios, 2007; Razeto and Castro, 2007) to represent nutrient status compared with leaf analysis. Recently, Campisi-Pinto et al (2017) reported that analyses of nutrient concentration in the cauliflower stage inflorescence may serve as a good predictor for yield. In summary, previous studies indicated that leaf analysis is certainly useful; however, it is insufficient for optimal management of avocado orchards. Avocado trees may survive 30–50 years and therefore, such long-term tree fertility imposes that the effective annual quantities of nutrients added should correspond to the annual quantities removed by the fruits. Otherwise, nutrient deficiency may be the limiting factor for achieving high yields. Lahav and Kadman (1980) and Lahav (1995) reported that 10 t of ‘Hass’ avocado fruits removes 11, 2 and 20 kg of N, P and K, respectively, and that fertilization with 55 kg of $(NH4)_2SO_4$ and 33 kg of KCl are sufficient to compensate for the removed N and K, respectively. Higher values of N, P and K quantities removed by ‘Hass’ avocado fruit of, 22–26, 4–5 and 30–40 kg $ha^{-1}$, respectively (based on 10 t $ha^{-1}$ yield) have been reported by Salazar-Garćıa and Lazcano-Ferrat (2001) and Rosecrance et al. (2012).

The current fertilization recommendation for avocado orchard in Israel include application of 50 kg $ha^{-1}$ of N at the beginning of March and later on 200–250 kg $ha^{-1}$ of N and K from April to October (Noy, 2006). Commonly, P is not applied during the growing season and only added in October–November in form of phosphoric acid (20–30 kg P $ha^{-1)}$ as a practical tool for cleaning the irrigation system and preventing emitter clogging.

Developing a proper seasonal fertigation protocol accounting for the actual demand for nutrients is therefore a major challenge. To address this challenge, we have investigated the response of ‘Hass’ avocado trees grown in lysimeters to different fertigation regimes. Although the root volume and water stress sensitivity of a lysimeter-grown tree differ from those of a field-grown tree (Goldhamer et al., 1999) this setup provides a major advantage as it enables direct measurement of plant water and nutrients uptake at high temporal resolution during successive growth stages.

The main objective of this research was to assess the seasonal nutrients ‘Hass’ avocado, especially, during flowering and the early stage of fruit development which may affect later on the fruitlet abscission and determine crop yield.

## 2. Materials and methods

### 2.1. General information and site characteristics

The study was conducted between 2014 and 2016 at the Acre Experimental Station, located in the Western Galilee, in Israel (32°57′ N; 35°05′ E; 10 m ASL). The climate is Mediterranean, with mild, wet winters followed by dry hot summers. The rainfall season in the region is between October and May, and annual precipitation at Acre totaled 317, 687 and 280 mm in 2013–4, 2014–5 and 2015-6, respectively. The response of ‘Hass’ avocado trees grafted on ‘Degania 117’, a West–Indian avocado rootstock, to different fertigation treatments was studied. The trees were planted in 2006 and grown in 1000-L plastic containers. The containers were covered by a plastic sheet to prevent evaporation. A volume of 50-L of coarse tuff (volcanic material) was placed at the bottom of the container to insure proper drainage and the rest of the volume was filled with perlite of 2-mm grain size. Perlite was chosen as the growth medium because of its high drainage qualities, especially, low air–entry suction. The density and pot capacity of the perlite were 72 g $l^{-1}$ and 0.55 $l^3\ l^{-3}$, respectively. The drainage from the containers was collected through PVC pipes and conducted outside the experimental site. Trees spacing during 2014 and 2015 was 4 × 5 m (500 trees $ha^{-1}$) while in 2016 it was changed to 4 × 6 m (417 trees $ha^{-1}$).

### 2.2. Experimental design

The experimental design comprised three fertigation treatments with three dates of starting fertigation application at fixed water-nutrient concentration allocated to eight randomized trees. The treatments in 2014 and 2015 were:

(a) $T_1$ – continuous fertigation, including macro nutrient N-P-K and micronutrients application, all over the year
(b) T2 – no fertilization (only irrigation) until 15 March, and fertigation as T1 since then
(c) T3 - no fertilization (only irrigation) until 15 May, and fertigation as $T_1$ since then.

The different treatments started on November 2013, after harvesting the 2013 yield. In 2016, the treatments changed and aimed to examine the commercial assumption that application of P during the growing season is not necessary. As a result, the treatments were:

(a) $T_1$ – continuous fertigation, including macro nutrient N-P -K and micronutrients application, all over the year
(b) T2 – continuous fertigation, including macro nutrient N-K and micronutrients application until 15 March, and fertigation as T1 since then
(c) T3 – continuous fertigation, including macro nutrient N-K and micronutrients application until 15 May, and fertigation as T1 since then.

The irrigation system consisted of a loop of 13 2.3 L $h^{-1}$ pressure-compensated drippers (Netafim Inc., Israel) installed around the trunk in each lysimeter. A pulsed irrigation (10–20 min every 30 min) was applied using an irrigation controller. All the treatments received the same daily amount of water. The irrigation amount exceeded the tree evapotranspiration to allow a leaching fraction (ratio of drainage and irrigation amounts) above 0.4, so that the EC of the draining solution could be kept below 1.5 dS $m^{-1}$ to prevent salt stress. All the horticultural practices were performed uniformly according to the recommendations of the Israeli Extension Service.

The harvest of 2014 yield was on 20 August 2014. The early harvest was chosen for insuring almost similar growth conditions between 2014 and 2015 seasons and to minimize possible effects of fruit load on the