WATER AND NUTRIENT REQUIREMENTS OF HASS AVOCADO: A GUIDE FOR PRACTITIONERS IN UGANDA, SUB-SAHARAN AFRICA AND BEYOND #9538

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ABSTRACT

Hass avocado production is increasing in Uganda and sub-Saharan Africa (SSA) to tap into the lucrative market especially in Western Europe, China, Japan, and Russia. However, there is limited information about its water and nutrient requirements in end-user-friendly formats especially in Uganda and SSA. We consolidated the scanty information about water and nutrient requirements of Hass avocado and made necessary recalculations and unit conversions to aid meaningful uptake of the information by practitioners without the necessary basic scientific background. This end-user-friendly format of reporting could increase uptake and correct use of information about climate smart water and nutrient requirements for increased Hass avocado yields, fruit quality and incomes.

Keywords: Climate smart water and nutrient conservation practices, Hass avocado, nutrient requirements, supplemental irrigation, water requirements

INTRODUCTION

Avocado *(Persea americana* Mill., family *Lauraceae*) is a tropical/subtropical fruit tree with the most nutritious benefits in the world (15-30% oil and 123-387 cal 100 g^{-1}). About 68 g Hass avocado fruit can supply 345 mg K, 114 kcal of energy, 43 lg vitamin A, 14 lg vitamin K, 185 lg lutein/zeaxanthin, and 57 mg phytosterols (Dreher and Davenport, 2013). Avocado oil consists of monounsaturated fatty acids (71%), polyunsaturated fatty acids (13%), and saturated fatty acids (16%) which help promote healthy blood lipid profiles (Selladurai & Awachare, 2020). Some phytochemicals in the oil have anti-cancer properties, anti-aging-related muscular degeneration, and can suppress cardiovascular diseases (Cervantes-Paz & Yahia, 2021). Avocado fruit is also widely used in the cosmetics industry because if its marked softening and soothing effect and the highest skin-penetration rate (Swisher, 1988).

Avocado is grown by more than 50 countries across the world with Mexico (31.5%), Dominican Republic (9.1%), Peru and Colombia (7.3% each), Indonesia (6.3%), Kenya (5%), and Brazil (3.3%) dominating total fruit production worldwide estimated at 7.31 million tons in 2019 (FAO, 2021). Sub-Saharan Africa (SSA)'s share of this production was very dismal, with Kenya and Ethiopia dominating the scene (FAO, 2021). Poor agronomic practices and in particular, limited use of fertilisers and supplemental irrigation to complement rainfall are among the major constraints to Hass avocado production in SSA. Even elsewhere where fertiliser application and irrigation are done the information is not readily available in end-user-friendly formats for use by avocado typical farmers in SSA. For example, evaporative demands of Hass avocado were reported in depth of water in millimetres Planningor inches per day (Carr et al. 2013; Lahav et al. 2013). Similarly for irrigation water requirements, units ranged from inches and gallons (Guides 2018) to m^3 $acre^{-1}$ or ha^{-1} (Hoffmann and Du Plessis 1999). This diversity in reporting was also observed for nutrient requirements (Lovatt et al. 2015; Selladurai and Awachare 2020). We, therefore, consolidated this information, made the necessary recalculations and unit conversions, and adopted a unified simplified reporting format for easier uptake by practitioners in Uganda, SSA and beyond.

MATERIALS AND METHODS

We accessed peer-reviewed journal articles from common search engines including Web of Science, Web of Knowledge, Research Gate, Google, Encyclopaedia, AGORA, and Google scholar using the keywords of the study. We also accessed textbooks, edited books, and book chapters of interest to the study from websites such as Google scholar, Be-ok Africa, College Library and Makerere University e-library. Technical reports were also accessed from authoritative repositories including the FAO and USDA databases.

The information collected was synthesized and where necessary, recalculations and unit conversions were made to generate a unified end-user-friendly package for Hass avocado practitioners. For example, for Hass avocado evapotranspiration requirements the millimetres (mm), inches and gallons (Guides 2018) were converted into litres or m^3 ha^{-1} day^{-1} or yr^{-1} as the standard unit of reporting. For irrigation water requirements reported in Western Australia (McCarthy 2001), we converted kilolitres (kL) into litres (L) and m^3 day^{-1} or yr^{-1}. The water requirements in mm ha^{-1} or $acre^{-1}$ day^{-1} reported for temperate, tropical, and Mediterranean climates (Lahave et al. 2013) were converted to SI units of m^3 ha^{-1} day^{-1}.

For nutrient requirements, much of the literature reported SI unit of kg but variation in unit area including acres, ha, with the exception of a few where weights were reported in pounds, ounces, etc., which we recalculated and reported as kg ha^{-1}. We also homogenised the grade analyses to aid computation of nutrient requirements from mineral fertilisers. What we found interesting and should be promoted is the reporting of nutrient requirements per unit diameter of each tree and nutrient replenishment based on quantity removed per ton of fruit yield (see Table 1 for the conversions made).

Table 1. Conversions made to standardise units of reporting water and nutrient requirements of Hass avocado.

Unit conversions for water requirements	Nutrient values in different fertilizers
1 ounce = 28.35g 1 pound (lb) = 1 inch = 2.5 cm 1MPa = 1000 kPa 1 gallon = 3.785 liters 1 Hectare = 2.45 acres 1 Hectare = 10,000 square meters 1mm depth of water ha^{-1} = 10 m^3 = 1000L	TSP = 40% P_2O_5 = 17% P (i.e., % P = % P_2O_5 / 2.29) CAN = 26.6% N MOP = 60% K_2O = 50% K (i.e., % K = %K_2O / 1.2) SSP = 20% P_2O_5 = 8.7 %P

RESULTS AND DISCUSSION

Average rainfall for leading Hass avocado-producing regions of the world ranges from 899 – 1312 mm yr^{-1}, implying that the crop can grow in much of Uganda and indeed, SSA. Daily irrigation requirements to meet the evapotranspiration needs of Hass avocado (Table 2) range from 1.5 mm (15 m^3 ha^{-1}) in winter (in South Africa) to 6 mm (60 m^3 ha^{-1}) during summer in California. Yields increase with supplemental irrigation (Erazo-mesa 2021) hence, a high potential to more than triple fruit yields under predominantly rain-fed Hass avocado producing areas (Fig. 1). Novel climate smart technologies for increased residence time of water within the plant root zones (Smucker et al. 2018; Olupot et al., 2021) can cut supplemental irrigation requirements by 40 to 60% (Smucker et al. 2018).

Table 2. Daily irrigation water requirements of Hass avocado (mm ha^{-1} day^{-1} vs m^3 ha^{-1} day^{-1}).

Country/Region	**Season**	Transpiration water requirements		**Author(s)**
		(mm ha^{-1} day^{-1})	(m^3 $ha^{-1}day^{-1}$)	
California (USA)	Summer	6	60	Lahav et al. (20130
Tropics	-	4	40	Lahav et al. (2013)
Mediterranean	-	3 – 5	30 – 50	Lahav et al. (2013)
South Africa	Summer	-	40	Hoffman & Duplessis (1999)
South Africa	Winter	1.5	15	Hoffman & Duplessis (1999)
Kenya	Dry season	3.57	35.7	Oxfarm (2022)

Note: We recalculated transpiration water requirements (m^3 ha^{-1} day^{-1}) from the mm ha^{-1} day^{-1} data published by the cited author(s).

Generally, nutrient requirements of Hass avocado increase with phenological growth stage and are critical at flowering and after a heavy fruit yield, implying that old trees need more fertilisation than young trees to sustain high yields especially after a 'heavy' season.

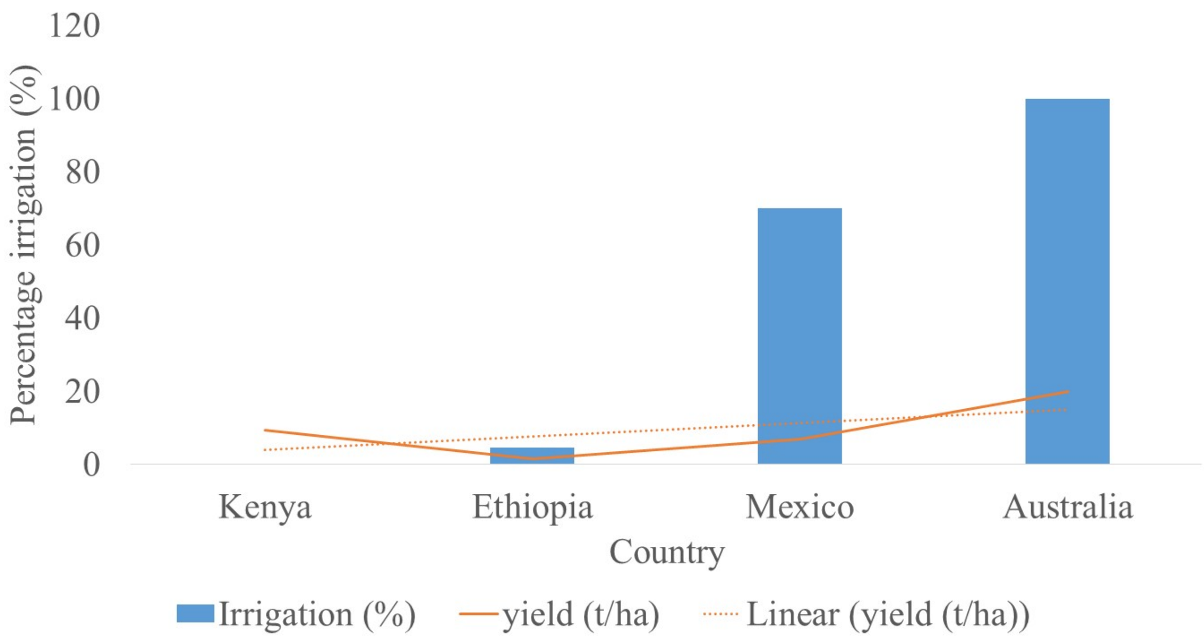

Fig. 1. Relationship between intensity of supplemental irrigation and average yields of Hass avocado orchards in selected countries.

For example, nutrient requirements increase from 5.2 kg N ha^{-1} (for one-year old trees) to 53.9 kg N ha^{-1} at ≥15 years; phosphorous increases from 6.0 kg P ha^{-1} to 31.8 kg P ha^{-1} and potassium from 17.6 kg K ha^{-1} in the 6th year to 50.7 kg K ha^{-1} at ≥15 years to supplement organic inputs such as farmyard manure (FYM) applied at 2,340 kg ha^{-1} (for one-year) or 4,680 kg ha^{-1} for seven-year old trees (Gentile et al. 2016). Best results are obtained when nutrients are applied per unit circumference of each tree (Table 3).

Table 3. Guidelines for Hass avocado nutrient requirements (g cm^{-1} tree trunk—Snijder & Stassen, 2000).

	Nutrient requirements of Hass avocado g cm^{-1} tree trunk circumference				
Soil type	N	P	K	Ca	Mg
Sandy soils (0 – 12% clay)	5.3	0.9	7.6	2.5	1.7
Medium potential soils (13 – 24% clay)	4.2	0.7	6.1	2.0	1.4
High potential soils (> 24% clay)	3.4	0.6	4.9	1.6	1.1

CONCLUSION

There is a potential to more than triple Hass avocado yields under predominantly rain-fed production systems in sub-Saharan Africa. This is possible with supplemental irrigation and novel climate smart technologies for coupling water and nutrient retention within plant root zones (Olupot et al. 2021). The simplified format of reporting information in this review should aid accurate targeting of water and nutrients as recommended to increase yields and production of high-quality Hass avocado fruit by practitioners.

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