WATER USE EFFICIENCY OF INDIGENOUS FRUIT TREES IN SOUTH AFRICA

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ABSTRACT. South Africa is endowed with many indigenous fruit tree species (IFTs). Besides Marula (*Sclerocaryea birrea* subsp. Caffra), use of indigenous fruit products in the country is generally low compared with other countries on the African continent. Indigenous fruit can play an essential role in alleviating poverty through income generation and improving food security especially in poor rural households. The main objective of this study was to measure the water use of indigenous fruit trees with domestication & commercialisation potential, monitor the fruit yield and eventually calculate the Water Use Efficiency (WUE). Tree transpiration was measured using the Heat Pulse Velocity method of the sap flow technique while fruit yield was obtained by manually counting the number of fruits. The WUE of indigenous trees was low compared to that of exotic species found in literature. Use of indigenous fruit products should be invigorated as these fruits thrive with minimal water demand while having potential to alleviate poverty.

Keywords: *Transpiration; soil water content; water productivity; microclimate*

Introduction

Most IFT's growing in the wild contain large amounts of vitamins, minerals, starch, vegetable oils, and protein [3]. Thereby contributing towards the United Nations' Millennium Development Goals through ensuring food and nutritional security especially for poor rural households [8]. water use efficiency is defined in this study as the ratio of the fruit yield/net photosynthetic assimilation to the transpiration/water use. This definition is widely used in Eco-physiological studies that seek to relate the amount of carbon dioxide (CO_2) assimilated during photosynthesis to the water transpired [11]. WUE defined in this way depicts leaf level gas exchange representing the amount of water lost in exchange for a single molecule of CO_2. The main aim of this study was to measure the water use of indigenous fruit trees with domestication and commercialisation potential and monitor the fruit yield to eventually calculate the water use efficiency. It is important to understand the water use of indigenous fruit trees, especially those that have a potential of domestication and commercialization [4,8], as the sustainable use of water shall always be made priority especially in semi-arid regions.

Materials and methods

A workshop that comprised of specialists in the field and people from rural communities where IFT's are used as sources of food and for medicinal purposes, was held at the end of October 2017. The main purpose of this gathering was to identify indigenous fruit trees that have domestication and commercialization potential. In their selection, the participants considered attributes such as: 1) range of uses, 2) abundance, 3) commercial value of the products, 4) ease of propagation, 5) drought and disease tolerance, 6) ease of harvesting, transportation, and storage. A list of ten species were first identified and further trimmed, resulting in the top four species listed in order of priority: 1) *Sclerocaryea birrea* (Marula) 2) *Strychnos spinosa* (Strychnos), 3) *Dovyalis caffra* (Kei apple) and 4) *Vangueria infausta* (Vangueria). The common names for these species are used throughout this document as they are the widely used names and are the most familiar even in literature search.

After the selection of these species, the next step was to identify suitable study sites and instrument the trees with water use monitoring equipment. Sap flow was measured using the heat ratio method (HRM) of the heat pulse velocity sap flow technique [2]. Leaf gas exchange measurements were taken using an Infrared Gas Analyzer while Root- and branch-level sap flow was quantified using the HRM. The water use efficiency of the species was calculated as the *kilograms or grams of fruit produced, per-litres of water consumed; WUE = Fruit yield / Water consumption.* To sample fruit from the indigenous trees, when the fruit had reached a ripening stage, they fell randomly under the tree, they were then picked up as they were counted as shown in Fig.1. To determine fruit mass, the fruit were measured in the lab using vernier calipers. Further analysis included plotting correlations between the water use and climate.

Fig.1 An indigenous fruit tree showing (a) fruit collected into plastic bags and (b) tree with fallen fruit

Results and Discussion

Microclimate

Typical microclimate over a full year at the study site is summarized in Table 1. The daily average solar radiation was lowest in winder (June) recording values of less than 10 MJ/m^2 while reaching their peak at ~22 MJ/m^2/d in summer (December). The highest temperature recorded during this period was ~40.2 °C reached mid-summer (December). The vapor pressure deficit (VPD) peaked at ~1.6 kPa (Table 1), such low values could be associated with proximity of the study site to the Indian Ocean that is located ~10 km to the east of the study site.

Table 1: summary of the study site microclimate

Month	R_s	T_{max}	T_{min}	RH_{max}	RH_{min}	VPD	U_{avg}	ET_o	Rainfall
	(MJ/m^2/d	(°C)	(°C)	(%)	(%)	kPa	(m/s)	(mm/d)	(mm)
Jan 18	18.9	38.2	19.6	94	39	1.3	0.6	84.2	62
Feb 18	16.8	36.6	17	95	38	1.2	0.4	76.8	105
Mar 18	15.1	36.1	16	95	41	1.1	0.5	67.3	68
Apr 18	13.4	29.8	15.1	69	56	1.0	1.6	59.8	19
May 18	12.7	30.1	14.1	96	45	0.8	1.1	56.8	82
Jun 18	9.9	32	5.9	97	20	0.9	0.4	49.2	21
Jul 18	11.4	29.3	4.4	96	33	0.7	0.7	41.6	18
Aug 18	11.4	37.1	7.4	96	17	1.2	0.8	52.7	34
Sep 18	12.5	39.6	7.8	95	20	1.2	0.8	62.5	38
Oct 18	15.1	35.4	7.2	96	30	0.9	0.9	73.2	46
Nov 18	20.4	38.9	9.9	94	32	1.1	1.2	102	42
Dec 18	21.9	40.2	13	95	30	1.3	0.9	105	92
Total								**831.1**	**627**

The coldest month in the country is July, at the study site, temperatures were as low as 4.4°C (Table 1). Rain fell throughout the year in the form of mainly subtropical thunderstorms in the summer months (October to March) and frontal precipitation in the winter months (May to August). The annual rainfall total was ~627 mm while to the reference evapotranspiration was ~831 mm.

Plant water use

The first four indigenous species with domestication and commercialization potential showed a variable overall water consumption when the total was summed up for the year (Fig.2). Water use mainly depends on the density of the monitored species as well as the plant leaf area index (LAI). The leaf area index for the marula trees was ~1.2, while strychnos had a LAI of ~1.4, Kei apple had an LAI of ~1.3 and Vangueria had an LAI of ~1.5. Plant density also varied, with Marula having the most plant density of 48 trees per hectare, strychnos having 37, kei apple 27 and Vangueria with 33 trees per hectare. The seasonal water use amounted to 6061 L/Tree/year for Strychnos, while this was ~2160 for Marula and Kei apple 3478 while Vangueria water use amounted to 5960 L/tree/year. The Strychnos, Kei apple and Vangueria trees had a very short dormant period in winter lasting just under one month between June and July when they shed their leaves, while dormancy period for Marula lasted from July to early October [4,1]. This extended dormancy period is likely a contributing factor to the observed low water use rates of Marula.

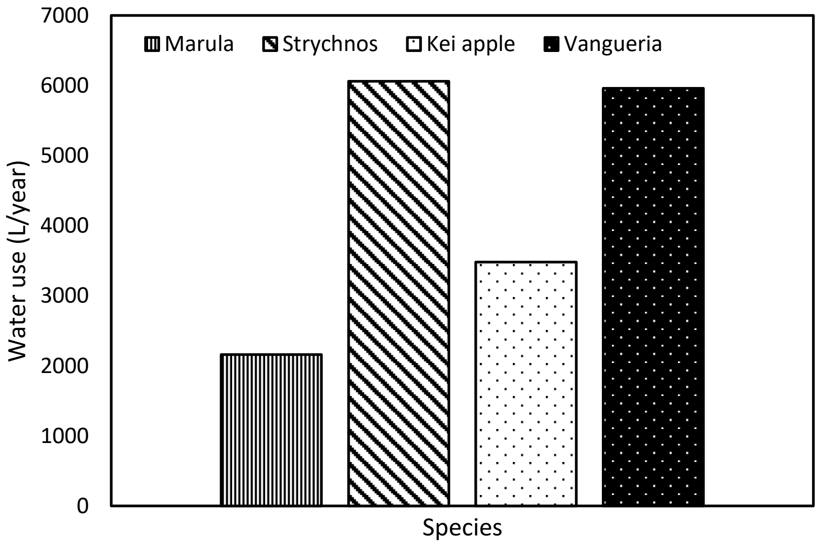

Fig. 2 Water use of four indigenous fruit tree species with domestication and commercialization potential

Water use drivers

Despite all these species growing in sandy soils under the same microclimate, and therefore experiencing the same resource constraints, their water use patterns responded differently to environmental factors as illustrated in Fig. 3. Strychnos, Kei apple and Vangueria transpiration was better correlated ($R^2 = 0.37$) to the atmospheric evaporative demand (Fig. 3d), as compared to soil water deficit $R^2 = 0.04$ (Fig. 3b). Marula water use was strongly correlated to the soil water deficit, where more than 65% of variation ($R^2 = 0.66$) could be explained by the soil water deficit (Fig.3a). Less than 20% of the variation could be explained by the atmospheric evaporative demand (Fig. 3c). Other studies [9,10] have correlated the water use of plants with weather variables and recorded some strong correlations with vapor pressure deficit and solar irradiance. When [10] correlated water use of indigenous grasses with weather variables, they found a hysteresis effect between water use and solar irradiance, with correlation coefficients of >0.9.

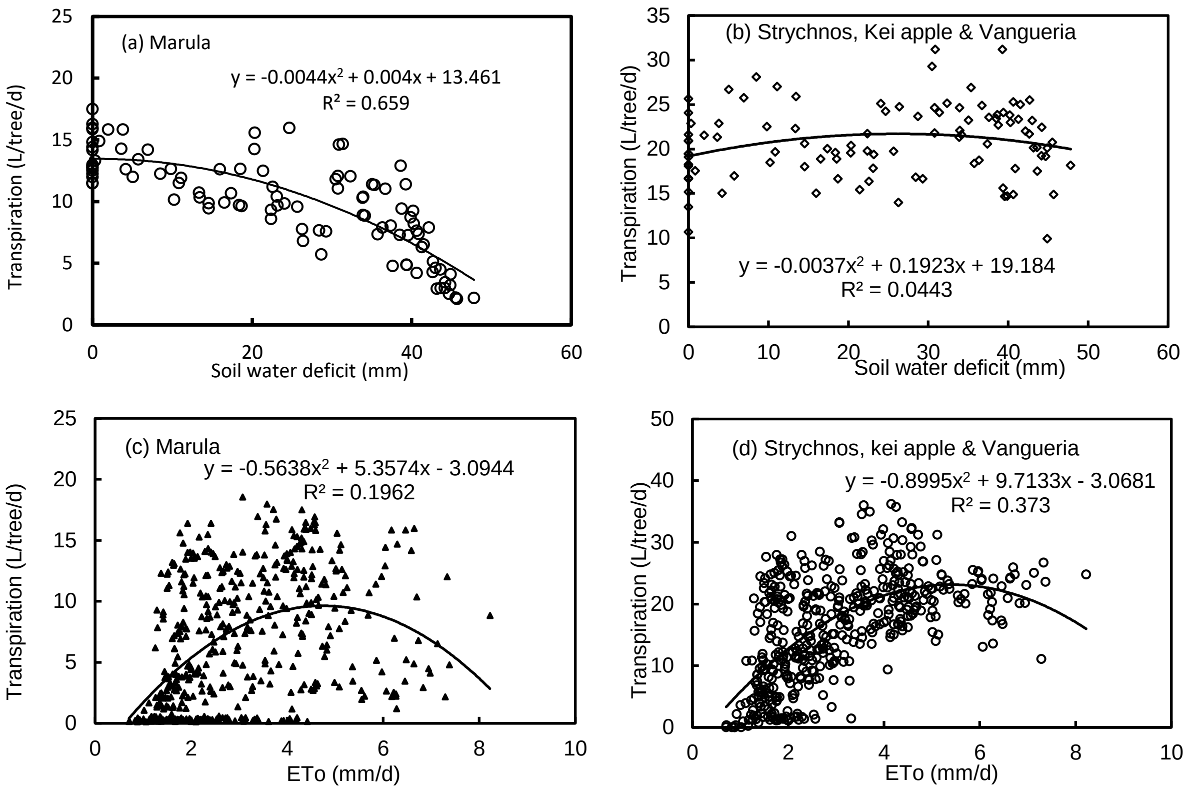

Fig.3 Influence of soil water content on (a) Marula water use, (b) Strychnos, Kei apple and Vangueria water use, (c) & (d) show the effects of reference evapotranspiration on transpiration for Marula and the other three species, respectively.

Water Use Efficiency

The marula trees studied here were relatively small in size, growing in harsh conditions resulted in low average yields ~4.3 kg/tree (Table 2). Though fully grown Marula trees in the same country but different provinces produce higher yields [1,4]. Strychnos yielded ~15.2 kg, while Kei apple yielded ~8.9 kg and Vangueria 14.6 kg. The latter three species fruit were calculated as an average from 10 trees. More trees were used in the yield study to ensure representative yield estimates. The WUE of these indigenous fruit trees has differed slightly across the different species studied, however it remains lower when compared to exotic species that have been measured in previous studies [5,6,7,12]. [7] measured the WUE of citrus and recorded values in the range 4.4 – 6.1 Kg/m^3. Water productivity (WP) of apple trees was found in the ranges of 4 Kg/m^3 and 18Kg/m^3 [7,6]. WP of plums (5.97Kg/m^3) and peaches (3.5 Kg/m^3) were recorded by [5].

Table 2 Summary of the water use, yield and water use efficiency of indigenous fruit with domestication and commercialisation potential

Variable	Marula	Strychnos	Kei apple	Vangueria
Average annual total transpiration (L/tree/year)	2160	6061	3478	5960
Average yield per tree (Kg)	4.3	15.2	8.9	14.6
Water Use Efficiency/ Water Productivity (Kg/m3)	2.0	2.5	2.6	2.4

Conclusions

This study has reported on the water use efficiency of selected indigenous fruit tree species growing in their natural habitats. This information provides insights on the performance of these species both in terms of their physiological responses to the environment in the short term and how this translates to yield in the long term. The WUE of the monitored indigenous fruit tree species was recorded to be lower than that of exotic species reported in literature. Therefore, the use of indigenous fruit products should be invigorated as these fruits thrive with minimal water demand while having potential for domestication and commercialisation.

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