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A Study of the Effect of Replacing Drip Irrigation System by Micro-Sprinklers in Avocado (Persea americana Mill) in Morocco

Hassan Ben Taleb [1]; Najiba Brhadda [1]; Rabea Ziri [1]

[1]laboratory of Plant animal and agro-industry production, Faculty of Sciences, University Ibn Tofail, Kenitra, BP. 133, Kenitra, Morocco

Corresponding author: Ben Taleb Hassan

E-mail address: hassanb16@hotmail.com

ABSTRACT

In this work, we implemented a new irrigation system based on micro-sprinklers specially adapted for sandy soils instead of the drip system usually used in the avocado irrigation. This process has resulted in a very pronounced improvement of the tree's condition in general and that of the leaves and fruits in particular. This can be related to the increase of the irrigated surface as well as the wetted volume, without disregarding the stimulation of the physiological and metabolic activity of the tree as a result of the increase of the quantity of usable water absorbed and improving water productivity as well as the surface exploited by the radical system of the tree. This technique usually unusable for fruit trees in Morocco, allowed us to reduce the expenses of the farm in which we carried out our tests, in terms of water consumption by 16% and electricity by a quantity proportional to that of the water used. We have also managed to significantly increase the yield by 35% without altering or disturbing the natural balance of the environment and by rationalizing water consumption, we have also reduced the amount of pollutant-rich water that can eventually seep into the ground and thus contaminate the water table.

Keywords
Avocado, drip irrigation, micro-sprinklers, agricultural yield, natural balance.

Introduction

The avocado tree (Persea americana Mill) is a plant species that is mainly found in tropical regions and is known for its adaptability to subtropical and mild winter climates. Its study and cultivation have received increased attention in recent years because of its crucial economic, nutritional and pharmacological value and that is why the emergence of this culture is absolutely necessary. This fruit contains some active substances with nutritional and medicinal purposes such as guacamole and flavonoids known for their anti-tumour and anti-radical effects, vitamins E and A, known for their role in the prevention of cardiovascular diseases, which are abundantly present in its oil, used in the cosmetic and paramedical industry. This explains this intense growth in its market (Gupta et al. 2018).

And from this, the avocado has become one of the most important tropical fruits financially on the world market, this is due to the considerable increase in its production and consumption over the last 150 years.

This can be explained by two main factors; the increase in consumption and the growing expansion of demand from more and more markets around the world (Sommaruga et Eldridge 2020).

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Extreme climatic conditions can be fatal for the tree, which can lead to the stopping of fruit ripening due to the inhibition of growth and development mechanisms, early fruit drop and catastrophic impact on foliage and wood as evidenced by abrupt wilting and well below average inflorescence, these unfavourable climatic conditions are often encountered in the Mediterranean area and therefore require adequate technical interventions (Hammoud and al. 2021). The optimal climates for the growth and development of the avocado tree are humid climates with moderate and well-distributed rainfall (1000 to 1600 mm), a long dry season leads to defoliation of the trees. Concerning the hygrometry, it must be high during the fruit setting (70 to 80%) and more moderate during the fruit enlargement, thus, humidity is the second constraint that arises during the cultivation of the avocado tree, the development of appropriate irrigation technique is necessarily important for the avocado tree to adapt well to a relatively dry season in summer or relatively cold season in winter (Jiang et He 2021). The optimal Physico-chemical and edaphic conditions that play a crucial role in the adequate development of the avocado tree are, the chemical nature and physical texture of the soil, i.e. porosity, permeability, water retention capacity, and pH, which must be between 5.5 and 6.5, alkaline environments prevent the absorption of some vital cations for the tree such as Fe2+, Mg2+, and Zn2+. The avocado tree has a particular preference for sandy soils because of the pH and the presence of nutrients necessary to the plant, however, the sandy soil is known for two major drawbacks, its low retention capacity, and high permeability. To cope with this problem, farmers often resort to intense and extensive irrigation which leads to soil leaching and indirectly to soil depletion as well as the infiltration of some pollutants to the water table (Du et al 2021). These are the reasons that pushed us to propose a new irrigation technique which is micro-sprinkling instead of the usual drip technique, this new irrigation method recently adopted for fruit trees has allowed us to minimize the problems of water wastage (Yuan and al 2022), and energy. It also significantly improves the plant's absorbance of water by increasing the wetted surface area (Waseem et al 2018), while ensuring optimal protection of the environment, which led us to a very pronounced qualitative and quantitative improvement of the yield.

Materials and methods

Plant material choice criteria

The cultivation of the avocado tree keeps for some decades an increased and accelerated increase at the level of the cultivated surface, at the level of the price as well as the profitability and commercial exchanges, Its turnover has exceeded that of oil in countries such as Venezuela as well as certain crops are known for their economic profitability such as cannabis and coca. The emergence of this crop has made it of major economic importance because of its nutritional and medicinal virtues. But a problem has recently cast its shadow on this tree, which is the early fall of its fruits due to the interference between climate change and technical conduct. These are the reasons that led us to choose the avocado tree as a subject of study and mainly the two races with worldwide vocation "Hass" and "Fuerte". We opted for an avocado orchard containing these two races.

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Criteria for site choice

We chose an orchard located in the rural area of Souk lhad center of the agricultural direction of Bouknadel, province of Salé Morocco. It is an orchard where we find four varieties of avocado: Hass, Fuerte, Bacon, and Zutano with a density of 7m / 3.5m, the windbreaker used is the cypress. It is a very favorable site for this crop, due to its climatic and edaphic characteristics, it is located in a coastal area with a medium-altitude compared to the neighboring sites with sandy soil. The irrigation systems used for this crop and that are widespread in the region are drip systems that have many disadvantages and defects in terms of flow rate, surface and volume wetted as well as the cost in energy and economic terms.

Experimental protocol

We conducted this study for 3 successive years (2016-2017, 2017-2018, and 2018-2019) in an orchard consisting of 45% each of Hass and Fuerte and 5% each of the remaining two varieties. As the avocado trees have a planting age of 16 years, we also focused our attention on the choice of large and small fruits as well as the influence of a 38*C heat wave. For the yield estimation, we asked an expert in this field.

We have chosen an orchard, which presents a drip irrigation system and considering the importance of irrigation in the life and for the yield of the plant. In this context, we carried out a study to evaluate the influence of the change of the irrigation system on the productivity of the avocado tree. For this reason, we set up a micro-sprinkler irrigation system instead of the drip system usually used for this crop, the irrigation depth was determined by a probe. The determination of the water gain following the installation of the micro-sprinkler system we proceeded as follows:

We multiplied the flow rate of the irrigation pump which is 3200l/h by the daily irrigation time which is 2 hours and then we multiplied the result by the percentage of water gain, and finally, we managed to calculate the annual gain at a rate of 300 days of irrigation per year at the farm level and at the level of Morocco

A comparative study of these two irrigation systems was conducted in this sense. The results are discussed in the following paragraphs.

Parameters involved

We tried to highlight the influence of the irrigation system on the yield and productivity by resorting to a comparative study of the different hydrological, pedological, climatological, economic and agronomical parameters related to the two irrigation systems as well as the different varieties of avocado trees present in the studied orchard.

Results

During our study, we achieved a very pronounced improvement in the various parameters by opting for the micro-sprinkler irrigation system. These parameters are shown in Tables 1 and 2 below:

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Table 1: Hydro- climatic and economic parameters for the two irrigation systems

Parameters		**Drip irrigation**	**Micro-sprinklers**
1Hydrological	Wetted area	1.5m2	9m2
	Volume of wetted soil	3m3	7.2m3
	Irrigation time	1hour	50min
	The annual water gain in L		307200
	Irrigation depth	+ de 2m	0 m
2-Pedological	Presence of terrestrial fauna / m2	15	30
	Percentage of deciduous leaf degradation	6.53 %	71 %
3-Climatological	The temperature difference in °C in summer	0	-2
	The temperature difference in °C in winter	0	+2
5-Economical	Irrigation energy		-16%
	Annual maintenance costs /ha	5 days	3 days
	Irrigation costs per plant		-16 %

Table 2: Agronomic parameters for the four avocado varieties

Variety	**Variety Number of fallen fruits/tree after a heat wave**		**The average weight of large fruits/tree (g)**		**The average weight of small fruits per tree (g)**		**Estimated yield per hectare(T)**	
	Drip	Micro-sprinkler	Drip	Micro-sprinkler	Drip	Micro-sprinkler	Drip	Micro-sprinkler
Hass	200	30	260	286	120	156	9	13.00
Fuerte	100	60	260	286	130	169	10	12.50
Zutano	50	20	280	308	140	182	12	15
Bacon	50	20	280	290	140	182	12	15
Estimated orchard yield							9.75	13.20
Estimated increase in orchard production								**+33.02%**

Discussions

Hydrological parameters

Following the replacement of the drip irrigation system by the micro-sprinkler system, the wetted surface was remarkably increased by 500% and the volume of wetted soil by 140%. We also found a pronounced decrease in irrigation duration and depth (Jabeen et al 2021) as well as an annual gain in water at the farm level of 307,200 L/ha, i.e. 1,843,200,000 L at the level of Morocco, based on 6,000 ha. The considerable improvement in hydrological parameters positively influenced the physiology and growth of the avocado tree, subsequently

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increasing the amount of water absorbed (Da Silva et al 2013), due of course to the great availability of capillary water exploitable by the tree, the same result was found for rice (Luo et al 2022).

Climatological parameters

We found a temperature difference of -2°C in summer and +2°C in winter and this is due to humidification of the air by water vapor sprayed and dispersed by micro-sprinkler (Zhang et al 2020), this promotes the tree's resistance to cold and heat and thus the fight against the scourge of premature fruit drop as a result of extreme summer temperatures, the same problem has been encountered in mango (Hahn-Schlam 2021). In winter, the water vapor present in the air due to the effect of micro-sprinkling prevents the damage of the buds and young leaves due to the cold, so the water condensed on the leaves constitutes a protective film against the harmful effect of the frost on the plant tissues of the tree.

Pedological parameters

The micro-sprinkler irrigation system has favoured the proliferation of superficial root systems and edaphic fauna (100% increase in density) and the construction of active and transgressed ecosystems, the same improvement was noted in mango (Hahn 2021), and the consequent stimulation of the flow of matter and energy, this leads to the very marked promotion of humification and mineralization transformations (an increase of the biodegradability rate of the leaves from 6.53 to 71%), which are vital for the fertilization of the soil and its enrichment by micro-elements, including nitrogen as a macro-element that promotes tree resistance to frost and increased yield (Li et al 2021). Micro-sprinklers also contributed to the improvement of the physicochemical properties of the soil (permeability, water retention capacity, and pH).

Economical parameters

The micro-sprinkler irrigation system has allowed us to make significant savings in terms of energy and irrigation costs, which have decreased by 16.66%. Water productivity has been increased and the same result was reported in the grapefruit (Morianou et al 2021). The annual maintenance expense per hectare has also decreased by 20%. The installation of this irrigation system also resulted in water-saving by decreasing the amount of water lost, which was also observed for potatoes (Wang et al 2019), and consequently that of the chemical fertilizers lost by the soil, which can infiltrate in the water table, which thus allows an effective greening.

Agronomical parameters

Hass variety

As a result of the change in the irrigation system, the number of fallen fruits per tree after a heat wave decreased in a very pronounced way almost the same behaviour was observed for the mango (Hahn et Antonio García 2022), and this is due to an improvement in the water

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and physiological state of the tree due to the amount of water available to the tree which has also been observed for tomatoes (Hu et al 2021). For the same reasons, the average weights of large and small fruits also increased and this largely promoted the improvement of the yield and productivity of the whole orchard, the same results were noted in the apple (Chen et al 2018).

Fuerte variety

The Fuerte variety is relatively more resistant to fruit drop after a heat wave, and this can be explained by its Mexican origin as opposed to Hass which is of West Indian origin. Li and these collaborators (2019) observed root proliferation from the surface area, number, and size of superficial roots. Also, the micro-sprinkler irrigation system reduced fruit drop by 40% and generally improved average fruit weight without affecting calibre, which was also encountered in the Ettinger avocado in Egypt with the combination of micro-sprinkler and drip irrigation (Darwish et Elmetwalli 2019). The estimated yield per hectare as well as that of the entire orchard was improved for the same reasons mentioned above, the same was observed for the melon (Hong et al 2021).

Zutano and Bacon varieties

These two varieties are used in the farm as windbreaks as well as for pollination, they are known by their partial phenological identity as well as a similarity in their behaviour towards the climatic conditions. They are very resistant to fruit drop compared to other varieties and similar results have been observed in some apple varieties (Küçükyumuk et al 2020), the latter was also improved by the use of micro-sprinkler systems, which also increased the average weight of small and large fruits per tree, and of course, The estimated yield per hectare was increased by 25% for both varieties, the same behaviour was found in the olive tree (Conde-Innamorato et al 2022).

Conclusion

In our study we found that the replacement of the drip irrigation system by the micro-sprinkler system has largely improved the physicochemical characteristics of the soil, water, and all abiotic constituents of the avocado ecosystem, especially for the Moroccan west coastal region known for its sandy soil. This has led to the improvement of the physiological state of the tree, especially its resistance to heat and cold, the number and the calibre of the fruit, the decrease of the fruit falls at the relatively early stage of development. This system has also contributed to an important improvement of the vegetative system of the tree and more precisely of the root, circulatory, and leaf systems. This has led to a considerable increase in the fruit load with a rate of 35% in the conditions of the farm in question.

Micro-sprinkling has also ensured the reduction of fertilizer losses by leaching and consequently the protection of the water table as well as the increase of the quantity of water available for the tree and also the water productivity. This had a very beneficial effect on the cost of production as well as on the yield and productivity of the tree (for the four varieties studied) and of the whole farm.

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