EFFECT OF DIFFERENT LOCALIZED IRRIGATION SYSTEMS ON GROWTH AND PRODUCTION OF SUGAR APPLE (ANNONA SQUAMOSA L.)

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ABSTRACT

The problem of water scarcity is currently one of the inhibitory factors affecting crop production and adaptation. In Lebanon, the adoption of a suitable irrigation system for annona cultivation is still unpracticed. Therefore, this study aims to compare drip and mini sprinkler irrigation systems in order to recommend the optimal one. The experiment was done during two consecutive years 2017-2018 on sugar apple (Annona squamosa L.) scion cleft grafted on cherimoya (Annona cherimola Mill.) rootstock. Water requirement of annona was calculated and applied through mini-sprinkler and drip irrigation. The vegetative and reproductive growth of irrigated trees were compared to those of non-irrigated trees (control). As a result, in the second experimental year, plant height, leaf number, leaf area and internodal length were significantly higher in the trees irrigated by drip compared to the control respectively by 40cm, 20leaves, 8cm² and 1.7cm. In addition, a significant improvement in flower number and diameter of primary roots and number of secondary roots was observed following mini-sprinkler irrigation compared to control. Fruit weight and number were most significantly improved by drip irrigation system by 10 fruits and 77g compared to control. However, in both experimental years sugar apple trees irrigated by drip system yielded the most (31kg in the second year) compared to the remaining treatments (29kg for trees irrigated by mini-sprinkler and 22kg for the control in the second year). The choice of both systems improved all growth traits of sugar apple and ameliorated the adaptation of this culture to Lebanese conditions.

KEYWORDS:
Sugar apple, irrigation, water scarcity, growth, production

INTRODUCTION

The cultivation of tropical and subtropical crops in the Mediterranean region is witnessing high interest by farmers. Annona species is one of these crops belonging to the family Annonaceae. This family which includes more than 2000 species is originated from tropical lowland of Central and South America [1]. The most commercial species are *A. squamosa* (sugar apple), *A. cherimola* (cherimoya), *A. atemoya* (atemoya: a hybrid between *A. cherimola* and *A. squamosa*), *A. muricata* (sursop) and *A. reticulata* (custard apple) [2]. In Lebanon, in the last decades, areas cultivated with annona trees are constantly increasing. These commodities are gaining high prices in the local market facing high demand from consumers. The adaptation of such commodity to local climatic and soil conditions is lately a subject of interest for researchers and farmers. Previous works were done aiming to improve the adaptation and the performance of annona tree. Cleft grafting on *A. cherimola* rootstock was reported [3, 4] to improve vegetative and reproductive growth of *A. squamosa*. In addition, iron fertilization has been also effective on enhancing the adaptation of annona cultivars obtained by self and cross grafting of both *A. squamosa* and *A. cherimoya* [5] which was reflected by a better height, trunk diameter, leaf biomass, and root growth compared to non-fertilized plants.

In fact, many environmental factors affect also annona adaptation and performance to orchard conditions such as temperature [6] and soil humidity which includes drought, flooding and salinity [7]. Global warming and climate change will occur more frequently causing a shortage in water resources and leading to an increase in the incidence of drought stress [8]. Normally, stomatal conductance and CO₂ assimilation decreases under drought stress in annona trees [9]. However, the endogenous accumulation of abscisic acid (ABA) and ascorbic acid under water deficient conditions was previously demonstrated to confer tolerance. ABA reduces water loss by triggering stomatal closure [10] and ascorbic acid reduces the reactive oxygen species caused by stress.
[11]. In Lebanon, nowadays, the problem of water scarcity is causing a drastic reduction in crop productivity mainly in the coastal and internal regions. Annona orchards that are concentrated in the coastal zone are subjected to such conditions. The majority of farmers either do not adopt a scheduled irrigation regime or do not use irrigation at all. Therefore, the aim of the current study is to evaluate the effect of different irrigation methods (mini-sprinkler and drip) on the vegetative and reproductive growth of *A. squamosa* and to compare it to water deficit conditions (no irrigation).

**MATERIALS AND METHODS**

**Treatments.** Sugar apple (*A. squamosa*) plants were selected from an orchard (calcareous clay soil) located in Beblyeh-South of Lebanon. This region is situated at 150 m above sea level, characterized by a temperate climate characterized by: a temperature of 25 ±5°C in summer and 10 ±5°C in winter, rainfall of 900 mm (between October and April) and relative humidity of 70%. Sugar apple plants were obtained through cleft grafting on cherimoya rootstock in 2013 (spacing 5x5m). The experiment was conducted during 2 consecutive years 2017 and 2018. Prior to the experiment, the orchard was irrigated regularly. Three treatments were applied in the orchard: drip irrigation, irrigation with mini-sprinklers, and no irrigation (control). Calculations were done using CROPWAT computer program, which models crop-specific water requirement based on the Penman–Monteith equation [12]. Crop coefficients (Kc) were adjusted based on Rodriguez Pleguezuelo et al. [13] findings on *A. cherimola* and were respectively of 0.63, 0.65 and 0.5 at flowering (February till April), fruit set (May) and fruit growth (July till October). Irrigation started from February till October. During calculation, an irrigation efficiency of 95% was assumed for the drip irrigation system and of 85% for mini-sprinkler system. Three treatments were applied in the orchard: drip irrigation, irrigation with mini-sprinklers, and no irrigation (control). For the drip system, irrigation was done with four emitters per plant (2 emitters per line, and 2 lines on each plant) with a flux of 41l per hour per each emitter. For the mini-sprinklers, irrigation was done using two emitters (1 emitter per line, and 2 lines on each plant) with a flux of 40l per hour per each emitter. Irrigation in both systems started from February till October. For control (non-irrigated) plants, water was only applied during iron fertigation. This latter practice was done on all plants, once per month, starting from May to September, using 25g/plant (including control plants).

**Vegetative and reproductive parameters.** Plant height was measured on field during the flowering period. At this stage, all vegetative indicators were measured: Trunk diameter (using a measuring tape), number of lateral shoots, and internodal length (on each lateral shoot). During the growth, a continuous monitoring was done for determining flower number and yielding capacity (fruit number, individual fruit weight and yield/plant). Leaf number (through visual counting) and area (length x width) were measured after the removal of the plants at the end of the harvest season (each experimental year, 9 plants were removed from each treatment using a bulldozer). At this period, the fresh and dry weights of plant parts (shoots, leaves and roots) were measured after oven-drying at 100°C until obtaining of a constant weight. Finally, parameters regarding primary (number, length and diameter) and secondary (number) roots were measured.

**Statistical analysis.** Trees were organized in a randomized block design consisting of three treatments and three repetitions per treatment. Each repetition consisted of 30 trees (10 plants/line x 3 lines). Data analysis was done using STATISTICA10 program and consisted on means ± SE compared by Fisher's least-significant differences test (LSD) with a *P* <0.05.

**RESULTS AND DISCUSSION**

**Vegetative growth.** The effect of irrigation on plant height was only significant in Year 5 experiment; this indicator was improved by 20 cm and 40 cm by the use of mini-sprinkler and drip irrigation respectively compared to control. Both irrigation systems improved internodal length significantly starting from Year 4 to Year 5 with the best effect obtained always with drip irrigation (Fig. 1). However, the effect of irrigation despite the system was not significant on the average of lateral shoots (*P*<0.099) while it was significantly ameliorative only in Year 4 on trunk diameter (*P*<0.000021) (Results not shown).

Leaf number and leaf area were mainly enhanced by drip irrigation system (Fig. 2). Mini-sprinkler system only significantly improved the leaf area rather than leaf number compared to control.

Sugar apple trees irrigated by drip system had significantly higher leaf number and area compared to the control in Year 4 (respectively 360 leaves and 129.5 cm² compared to 315 leaves and 120 cm²) and Year 5 (respectively 390 leaves and 130 cm² compared to 370 leaves and 122 cm²).

**Reproductive growth.** The response of flowers and fruit number to the irrigation systems differs between Year 4 and Year 5 (Fig. 3); in specific, under irrigation (mini-sprinkler or drip) flower number was inhibited in Year 4 while it was improved in Year 5 compared to the control. However, the fruit number of irrigated trees which was equal between
the two systems was higher compared to non-irrigated trees (control) in both years (respectively in Year 4 and 5, 70 fruits and 73 fruits in irrigated trees compared to 62 fruits and 63 fruits in control).
In general, the irrigation of sugar apple using mini-sprinkler or drip has led to the production of heavier fruits (Fig. 4) and consequently better yield compared to the control. In fact, this ameliorative effect was higher in Year 5 than Year 4. Under drip irrigation system, the weight of the individual fruit and the yield of sugar apple trees were improved respectively by 77 g and 9 kg compared to control, and by 20 g and 2 kg compared to trees irrigated by mini-sprinkler.

**Weight of plant parts.** Fresh and dry weights of shoots (Fig. 5) were also affected by irrigation with an optimal result obtained with drip irrigation. Between year 4 and 5, the fresh and dry weights of shoots increased respectively by 263 g and 190 g under mini-sprinkler system while between the same years, both indicators increased respectively by 295 g and 250 g under drip irrigation. This reflects the better annual growth of sugar apple under drip irrigation. In fact, a similar trend was observed for fresh and dry weights of leaves and roots (Results not shown).

**Rooting indicators.** The number and length of primary roots were boosted under irrigation systems (mini-sprinkler or drip) starting from year 4 (Fig. 6). The optimal ameliorative effect was observed in Year 5 for plants irrigated by drip system where the number and length of primary roots (respectively 124 roots and 143 cm) were significantly higher than the ones of trees irrigated by mini-sprinkler (respectively 98 roots and 121 cm) and the ones of the control (respectively 82 roots and 88 cm).

In Year 4, the adoption of mini-sprinkler did not enhance significantly the diameter of the primary roots or the number of secondary roots (Fig. 7). The significant effect was observed in Year 5 only. On the contrary, the drip irrigation system significantly improved both indicators in both years. Particularly, in Year 5, the diameter of primary roots...
and the number of secondary roots were significantly higher in trees irrigated by drip (respectively 5 cm and 557) compared to control trees (4.2 cm and 501). However, when comparing between both systems, the number of secondary roots was only significantly higher in drip treatment compared to the mini-sprinkler one, while the diameter of primary roots was not.

Non-irrigated plants of sugar apple had the lowest growth and yielding capacity among all treatments. However, *A. squamosa* is considered as a drought tolerant plant [14]. This tolerance was represented by the production of approximately 22 kg of fruits per tree under water deficit conditions. It seemed that control plants took benefits from the very low amount of water that was added during iron fertigation in drought season. According to Rodrigues et al. [9], drought stress caused a reduction in stomatal conductance and CO$_2$ assimilation. In addition, the stress condition induced an increase in endogenous ABA which can stimulate H$_2$O$_2$ production (stress signaling). This latter promotes the maintenance or secretion of ascorbic acid which confer the antioxidant system in the plant [15, 16].

Compared to irrigated plants (mini-sprinkler or drip), non-irrigated plants had the lowest number of leaves, flowers, fruits and consequently yield. In addition, stressed-plants produced less vigorous shoots. In fact, previous studies reported a correlation between the vigor of anona plants and the capacity of fruit bearing. According to Gonzàlez and Cuevas [17] the vigor of bearing shoots and the position of flowers on the shoots aects fruit size, as vigorous shoots and basal flowers potentially produce heavier fruits.

This fact was also validated by George and Nissen [18] and George and Campbell [19] on custard apple. Furthermore, weak shoots set two fruits while high vigor shoots could set four to five fruits [20]. This growth pattern is similar in stone fruits and pomes [21, 22]. Under water deficit conditions, the low relative humidity inside the canopy will affects
the floral cycle and anthesis [23] leading to a reduction in fruit set which is dependent on the receptivity of the stigmas [19].

On the contrary, despite the system, irrigation induced an improvement in all indicators; this ameliorative effect started by the root zone of the plants which was reflected by a high number of primary and secondary roots in the two irrigated treatments [17]. Consequently, there was a better absorption of vital elements mainly in that of the chelated iron that was applied. Irrigation systems also enhanced shoot elongation and leaf formation in sugar apple which improved the capability to bear fruits. Actually, irrigation enhances fertilization and fruit set in annona trees. It leads to a higher relative humidity favoring anthesis and petal abscission [2]. This latter phenomenon is related to an increase in ethylene concentrations in the anthers accelerating pollen discharge and advancing male stage [24]. Irrigation increased both fruit number and weight contradicting previous findings claiming that an increase in production causes a diminution in fruit size [25]. This ameliorative effect was attributed to cell enlargement and division during fruit growth [26]. Reproductive organs such as flowers and fruits are more sensitive to drought stress than vegetative organs (shoots and leaves). In a comparison between both irrigation systems, it was obvious that the efficiency was higher in drip system compared to mini-sprinkler [27, 28]. Sugar apple plants irrigated by the drip system had the optimal vegetative growth, yielding a better capacity and root distribution. As a matter of fact, many factors affect root distribution; these include primarily irrigation systems and the availability of water [29, 30].

Several authors reported earlier the ameliorative effect of water and irrigation of annona under drought conditions [31, 32]. However, the difference between irrigation systems was less investigated on sugar apple or other annona species. But, differences in efficiency level were studied on other crops. Irrigation with a drip system uses less water than sprinkler irrigation [33, 34]. Fallahi [35] showed that with less water amount per season (less by 40%), apple trees irrigated by drip gave similar yield and fruit weight compared to trees irrigated by sprinkler. This reflects a better efficiency of the drip system. Moreover, on grapevines, the adoption of drip irrigation has led to an increase in root length and root area compared to sprinkler system. This was attributed to the smaller wetted soil volume in the closer soil proportions (vertical and horizontal directions to trunk) [36]. Similar findings were observed in the current study concerning rooting indicators.

The adoption of drip irrigation reduces the amount of required water, and also increases and expands the wetted area resulting in higher income per water unit [37, 38]. In fact, with drip irrigation, low soil moisture can be kept in the root zone due to the precisely controlled system. This system seems to be advantageous, especially in case of fertigation with dissolved salts which is unsuitable with other methods. Thus, it seemed to be the best method used, first to reduce water volume applied during drought season (facing the limited water resources) and second to enhance the most yielding capacity of sugar apple.

**CONCLUSION**

In the current work, it was justified that the use of localized drip irrigation system is a good method to reduce water loss and increase the efficiency of a certain amount of water compared to mini-sprinklers. The adoption of such methods could be improved further by determining the optimal rate and frequency of irrigation in order to combat the problem of scarcity of water resources worldwide.

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