Original Research Article

Hydric-stress tolerance in cocona (*Solanum sessiliflorum* Dunal)

ABSTRACT

Aims: The present work aims to assess hydric stress tolerance in cocona (*Solanum sessiliflorum*).

Study design: Four cocona genotypes were planted in completely randomized blocks design with three replicates. Each replicate was irrigated with different water volumes, tantamount to 50, 100 and 150% of evapotranspiration (ET) respectively.

Place and Duration of Study: The present study was developed in National Institute of Amazonian Research at the agricultural experimental station, which is located on Km 14 AM-10 roadway, from January 2014 to August 2016

Methodology: The fruits were harvested each 15 days by three months. The assessed characters were plant stand, stem diameter, plant height, fruit yield, number of fruits per plant; fruit mass, length, diameter and length/diameter ratio.

Results: Irrigation treatments, both 50 and 150% ET, reduced height plant, fruit mass and length. Other characters were no affected by the hydric stress.

Conclusion: Cocona is tolerant to both hydric stress, being the major hydric stress effect fruit size and mass decreasing. Other studies must to be performed to determinate the hydric stress threshold which lead to decrease fruit yield and dead plant.

Keywords: abiotic stress; Amazon crop; cubiu; drip irrigation; water management

1. INTRODUCTION

Cocona (*Solanum sessiliflorum* Dunal) belongs to Solanaceae family and Lasiocarpa section. This section holds 13 cultivate species distributed from northern Andes region to Amazon. Cocona is distributed in the Amazon region, which includes Peru, Ecuador, Brazil, Colombia and Venezuela [1, 2]. This region presents heavy high rainfall (>2500mm). But recently an interest has recently been demonstrated on having this species grown under subtropical conditions with lighter rainfall. In the future, perhaps it will be adapted in a greenhouse system. Thus, hydric tolerance studies in cocona are need to face future cocona cultivation challenges.

Cocona is also well adapted to an acid, low nutrient soil and high temperatures [3]. Its fruits look resemble tomato and its plant architecture is like that a large-leafed eggplant. Its fruit tastes like a citric fruit combination. It is used for making ice cream, juice [2], meat dishes, sauce, jelly and desserts [3].

Cocona researches have focused on assessing genotypes [3, 4], outcrossing rate studies [3, 5, 6], chemical characterization for food processing industry [7, 8]. However, there is paucity of regarding its physiology; especially on what concern hydric tolerance. In spite of this fact, there are some studies on eggplant hydric tolerance. These studies can be help to understand hydric tolerance in cocona, on account of, both species being phylogenetically related [9].

In eggplant, irrigation with 85% of evapotranspiration (ET) had no effect on fruit yield, but 65% and 40% one reduced it by 35 and 46% respectively [10]. Water management can be raise fruit yield and quality of several species [11-14]. Therefore, cocona hydric stress studies can help to manage irrigation of this species, specially, during dry season in the Amazon (June to October).

The present paper aim to assess the hydric stress effect on fruit yield by over and under irrigating cocona, 150 and 50% ET respectively.

2. MATERIAL AND METHODS

The experiment was conducted in greenhouse at INPA experimental field "Dr. Alejo von der Pahlen" (02º 59'48.2'' S and 60º 01' 22.4'' W), during January to August, 2014. The mean annual rainfall was 2450 mm (mainly from November to June) [15] and mean temperature 27^{o}C. The soil was non-flooded land, red-yellow argisoil, sandy texture and pH=6.0. This is a typical Amazon soil, which is poor in organic material; therefore, it was fertilized using 2kg of compost per plant.

Cocona genotypes were CUB-10, CUB-11, CUB-12 and CUB-13. These genotypes were originating from Santa Isabel do Rio Negro municipality, Amazonas State (00^{o} 24'50'' S; 65^{o} 01' 08'' W), from Acariquara, Abianai, Matozinho and Nararé do Enuixi cities, respectively.

The genotypes were planted in a completely randomized block design with three replications. Each replication was irrigated with one type of irrigation regime, which were 50, 100 (control) and 150% of evapotranspiration (ET). The fruits were harvested during three months and assessed characters were stand of plant, stem diameter (cm), plant height (cm), fruit yield (t.ha^{-1}), number of fruits per plant, fruit mass (g), length (cm), diameter (cm) and length/diameter ratio.

The drip irrigation system combining with evaporation data were used to adjust water quantity in each block. We used three type of drip irrigation lines, which had emitters spaced in 10, 20 and 40 cm. The climatic data and evapotranspiration are presented in Table 1. The climatic data were obtained using digital termohygrometer Incoterm®. The evapotranspiration (ET) was estimated via Ivanov equation:

$$ET=0.006 \times (25+T)2 \times (1-RH/100) \times Kc$$

ET= Evapotranspiration (mm.day^{-1}), T=Mean temperature (^{o}C), RH=Relative humid, Kc= Crop coefficient, which has four values, depending of growing stage. This coefficient (Kc) was adapted from eggplant [16].

Table 1. Temperature, relative humid, and evapotranspiration per month. Manaus 2013-2014

Month	Temperature (°C)	Relative humid (%)	Evapotranspiration (mm/day)	Rainfall (mm/day)
2013				
Set	35.8	77	4.04	0.89
Oct	32.8	52	7.66	4.51
Nov	31.3	51	5.75	12.00
Dec	31.9	46	6.48	4.22
2014				
Jan	31.4	46	5.99	7.60
Feb*	30.2	51	4.86	9.10
Mar*	29.9	57	4.59	13.95
Apr*	31.4	51	5.60	10.86

*The fruit harvests were performed during these months.

Data were submitted to analysis of variance, and Duncan test ($P<0.05$) using SAS Software, and procedure PROC GLM. In addition, it was made quadratic equations to predict characters behavior. The equation vertex was estimated by $-b/(2a)$, which indicates the equivalent irrigation that maximize fruit mass, number per plant and yield.

To show the relationship among characters and irrigation treatments was make a biplot graphic using GGEBiplotGUI package in R software (R Core Team). For this purpose, the data were scaled by standard deviation of each character.

3. RESULTS AND DISCUSSION

We had found no previous studies on cocona hydric stress, but there are in other Solanaceae such as tomato [17], hot pepper [18] and eggplant [19]. In them, the evapotranspiration (ET) method seems appropriate to measure the effect of hydric stress.

Equivalent irrigation to 100% ET indicates that irrigation restores evaporated water. Thus, water quantity above or below 100% ET would be lead to hydric stress. The irrigation accuracy based on ET was observed through Biplot analysis ["which won where what" method] (Fig. 1), where 50, 100 and 150% ET were far apart from each other with all high-valued characters associated with 100% ET. In other words, it would indicate 100% ET to be optimal to maximize every character expression. Far apart points indicated the contrasting effect of irrigation treatments on characters. Therefore, this irrigation management showed to be optimal to assess hydric stress. In addition, these results suggest that eggplant crop coefficient may be used in Ivanov equation. Probably eggplant and cocona have similar physiology, on account of both are similar phylogenetically [9].

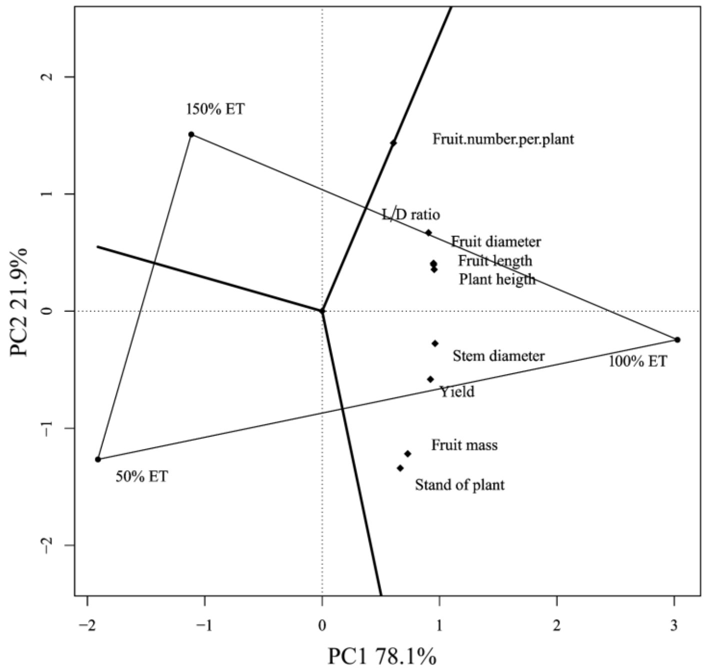

Fig. 1. Biplot graphic shows a relationship among irrigation volume and morphological characters by "which won where what" method.

Eleven t.ha^{-1} was the maximum fruit yield, which is very low comparing with other studies. Silva Filho and Yuyama [4] reported fruit yield from 40 to 100 t.ha^{-1} in Manaus. Low fruit yield may be accounted for by the fruits having to be harvested for three months, due *Sclerotium rolfsii* infestation. Normally, the harvesting is performed following four to five months. Nevertheless, the results were sufficient to show the effect of hydric stress on early yield.

The findings showed significant effect of both hydric stresses (50% and 150% ET) mainly on plant height, fruit mass and length (Table 2). However, it was found no significance difference to stand of plants, stem diameter, fruit yield, fruit number per plant, fruit diameter and length/diameter ratio (Table 2). Therefore irrigation of 50% and 150% ET would be utilized without decrease the potential fruit yield.

Table 2. Duncan test for irrigation regime of 50, 100 and 150% of evapotranspiration (ET) considering various fruit characters. Manaus 2014.

Irrigation based on ET (%)	**Plant stand**	**Stem diameter (cm)**	**Plant height (cm)**	**Fruit yield (t.ha^{-1})**	**Fruits Number per plant**	**Fruit mass (g)**	**Fruit length [L] (mm)**	**Fruit diameter [D] (mm)**	**L/D ratio**
50	4.5 a	3.9 a	128.5 b	7.9 a	7.1 a	132.4 ab	62.5 b	59.0 a	1.04 a
100	4.8 a	4.2 a	140.3 a	10.6 a	8.6 a	153.4 a	68.6 a	61.7 a	1.19 a
150	4.0 a	3.9 a	132.8 ab	7.3 a	8.6 a	107.4 b	64.6 ab	60.0 a	1.07 a

Generally, hydric stress led to the decrease of cocona growing and developing. Over and under irrigation, 150 and 50% ET, decreased fruit mass by 30 and 13% respectively. Plant height decreased by 5 and 8% respectively. Fruit length decreased 8 and 6% respectively. Despite irrigation treatments having presented no significant differences on the fruit yield, they presented a tendency to lower it by 31 and 25% respectively. These facts would support the former observation of Silva Filho [20], which over irrigation would decrease fruit yield. Comparatively, these yield decreases are minor than in eggplant [10], which were 35% for 60% ET. It suggests cocona has more tolerance to hydric stress that it.

On the other hand, cocona genotypes showed difference in fruit mass, length and L/D ratio (Table 3). Indicating there to be genotypic diversity. Therefore, these results concerning hydric stress may be valid to cocona species.

Table 3. Duncan test for cocona genotypes considering various fruit characters. Manaus 2014

Genotype	Plant number per plot	Stem diameter (cm)	Plant height (cm)	Fruit yield ($t.ha^{-1}$)	Fruits number per plant	Fruit mass (g)	Fruit length [L] (mm)	Fruit diameter [D] (mm)	L/D ratio
CUB-10	4.3 a	4.2 a	130.3 a	8.1 a	7.7 a	157.7 ab	71.3 ab	67.9 a	1.04 ab
CUB-11	4.3 a	3.9 a	137.6 a	10.4 a	10.5 a	164.8 ab	79.5 a	64.3 a	1.23 a
CUB-12	5.0 a	3.8 a	134.4 a	11.0 a	9.2 a	182.4 a	83.1 a	67.3 a	1.23 a
CUB-13	4.0 a	4.0 a	133.1 a	5.4 a	5.1 a	140.6 b	62.0 b	69.2 a	0.90 b

Usually, quadratic equations are used to find maximum yield points [21]. Fruit mass and number of fruits per plant had quadratic behavior (Figure 2).

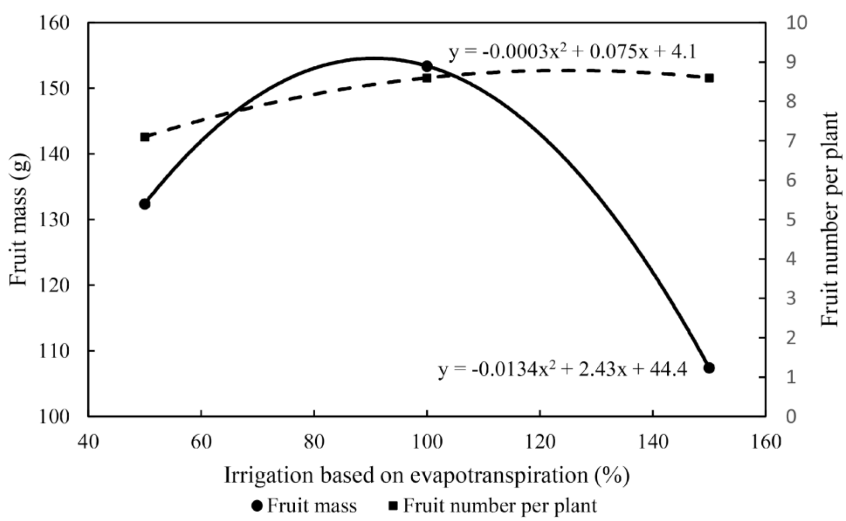

Fig. 2. Quadratic behavior of fruit mass and fruit number per plant for different irrigation volumes in cocona.

In the same figure is showed fruit mass is more sensible to hydric stress while fruit numbers per plant is more stable. The vertex equation shows the high fruit mass and fruit number per plant would be found at 91 and 125% ET respectively. In other words, irrigations from 50 up to 91% ET tend to increase both fruit mass and fruit number. Irrigations from 91 up to 125% ET tend to reduce the fruit mass, but to increase fruit number per plant. Irrigations from 125 up to 150% ET decrease both characters. This quadratic behavior was observed in “gigante cocona” [22].

On the other hand, when fruit mass was compared with fruit yield (Figure 3) was observed fruit mass is more sensitive to the hydric stress than fruit yield. Vertex equation showed that around 98% ET led to high fruit yield.

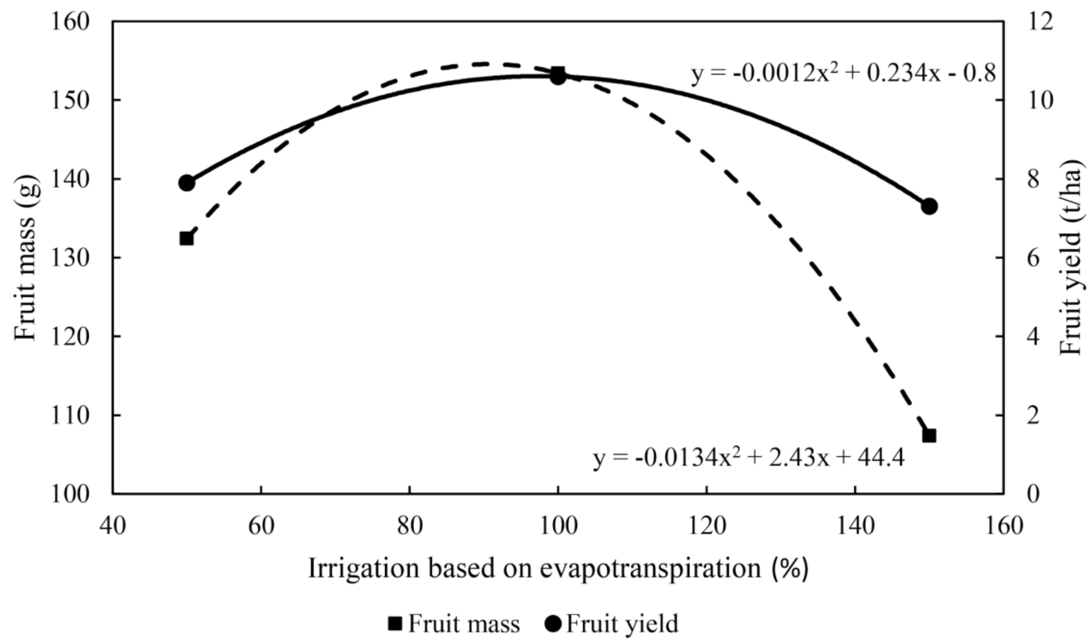

Fig. 3. Quadratic behavior of fruit mass and yield for different irrigation volume in cocona.

Since genotypic point view there was genetic variability for fruit mass (140.6 – 182.4 g), fruit length (62.0 – 83.1 mm) and length diameter (L/D) ratio (0.9 – 1.2). CUB-12 showed the highest fruit mass (182.4 g) with elongated fruits and yield of 11 t ha^{-1} (Table 3). In contrast, CUB-13 showed the lowest values to fruit mass (140.6 g) with flat-round fruits and yield of 5.4 t ha^{-1}.

Biplot analysis (Figure 4) accounted for the 99% of variation. It indicates the interpretations are highly reliable. The vectors represent each character and their direction the behavior. Thus, the biplot analysis is doing by vectorial comparisons. All vector directions were predominantly towards 100% ET. It shows a positive association between 100% ET with all high values of characters, in other words, this irrigation level increased all character values. In contrast, 50 and 150% ET negatively affected the character expression.

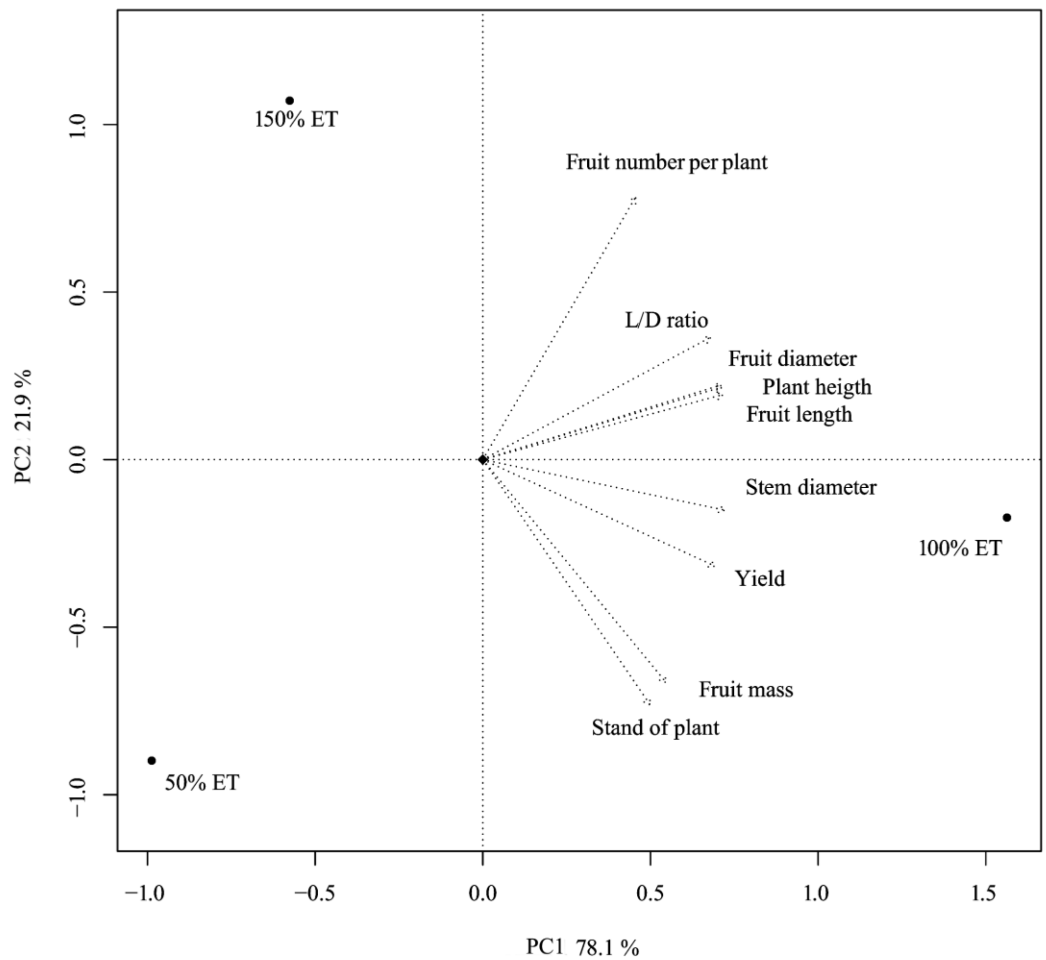

Fig 4. Biplot graphic shows a relationship among irrigation volume and morphological characters (50, 100 and 150% ET represent water volumes used in cocona irrigation based on evapotranspiration)

However, 50% ET would be slightly associated with high plant stand and fruit mass. At the same time, 150% ET would be associated with high fruit number per plant, which is agreeing with maximum quadratic curve point estimated by vertex formula (125% ET).

4. CONCLUSION

Cocona is tolerant to hydric stress both excessive irrigation and its shortage. Its characters more sensible to this stress were plant height, fruit mass and length.

Further studies will have to be conducted in order to test more extreme hydric stress, such as 25 and 175% of evapotranspiration, considering different phases of growing: seedling, vegetative and reproductive phase.

COMPETING INTERESTS

Authors have declared there not to be any competing interests.

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