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CORM QUALITY OF TARO UNDER IRRIGATION LEVELS AND DIFFERENT SOIL TYPES

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1 ABSTRACT

Irrigation amount is an important factor in the development of taro, however, there is little information focus on effects of water levels affect on its corm quality under different soil textures. Thus, this study aimed to evaluate the taro corm quality in response to five irrigation levels (20%, 60%, 100%, 140% and 180% ET_c - crop water requirement) under three soil textures. Results indicated that corm number total (CN_t) and diameter (CD) of taro decreased with reduced irrigation levels, higher values were detected at 140%ET_c and 180%ET_c. CD and CN_t performed better in sandy soil than in other two soils, especially in irrigation level lower than 100%ET_c. In general, total sugar (TS), reducing sugar (RS), and starch content (SC) of taro corm performed better in higher water regime, except that for protein content (PC). Taro corm had higher TS and SC in sandy soil, while lower PC was observed in the same soil treatment. Overall, higher water level was more beneficial to improve corm quality, and SS could be more suitable for taro cultivation under water stress.

Keywords: water stress, soil texture, colocasia esculenta l. schott.

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2 RESUMO

A irrigação é um fator importante no desenvolvimento de taro, no entanto, há poucas informações sobre os efeitos de lâminas de irrigação em diferentes texturas do solo. O

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objetivo do estudo foi avaliar a qualidade dos tubérculos de inhame em resposta a cinco níveis de irrigação (20%, 60%, 100%, 140% e 180% ET_c - necessidade hídrica da cultura) e três texturas de solo. O número de tubérculo (CNt) e o diâmetro (CD) diminuíram com os menores níveis de irrigação, os maiores valores foram detectados em 140%ET_c e 180%ET_c. CD e CNt tiveram melhor desempenho em solo arenoso do que nos outros dois solos, especialmente com lâmina de irrigação inferior a 100%ETc. Em geral, o teor de açúcar total (TS), açúcar redutor (RS) e teor de amido (SC) do tubérculo tiveram melhor resultado com maior lâmina de irrigação, exceto para o teor de proteína (PC). O tubérculo apresentou maior TS e SC em solo arenoso, enquanto menor PC foi observado no mesmo tratamento de solo. No geral, o nível de água mais alto foi mais benéfico para melhorar a qualidade do tubérculo, e o solo arenoso pode ser mais adequado para o cultivo de taro sob estresse hídrico.

Palavras-chave: estresse hídrico, textura do solo, colocasia esculenta l. schott.

3 INTRODUCTION

Originally from Asia, the taro is a monocotyledon plant of the Araceae family (CASTRO *et al.*, 2017) which is largely cultivated due to the consumption of its underground corm (MATTHEWS *et al.*, 2017), which is important to ensuring food security in many tropical and subtropical regions. Taro is a plant with low water-efficient (MARK *et al.*, 2013) and water stress is one of the key factors that seriously affect taro growth (SAHOO *et al.*, 2006). Some previous researches (DARYANTO *et al.*, 2016) studied effects of irrigation levels on the growth and yield components of taro, however, little information about irrigation levels in different soil textures focus on the quality of taro.

Sahoo *et al.* (2006) reported that water deficit significantly inhibited taro aboveground growth, while had little effect on corm yield components. Mabhaudhi *et al.* (2013) showed that in season 2010/11 the corm number per plant of taro (landrace from KwaNgwanase) was higher at 60%ET_c (6.20) compared with that of 100%ET_c (3.46) and 30% ET_c (3.88) in sandy clay loam soil. Some previous studies explored other tuber crops responded to water stress in varying soil textures. Filipović *et al.* (2016) reported that higher corm number of Jerusalem artichoke (*Helianthus tuberosus* L.) was observed in soil with a greater content of clay. Martin and Miller (1983) demonstrated that daily irrigation stimulated the increasing corm number in sandy soil, compared with the irrigation frequency applied every four days. The same authors reported in another study showed that irrigation frequency did not affect the corm number, and the yield reduction of potato was due largely to reduced corm size (MILLER; MARTIN, 1987).

Despite of some previous findings detected chemical compositions of taro corm in response to taro variety, harvest interval, and drying methods (ARICI *et al.*, 2016; CASTRO *et al.*, 2017; LEBOT; MALAPA; BOURRIEAU, 2011). There is still lacking information on how chemical compositions of taro corm respond to irrigation levels, in particular excessive irrigation in different soil textures. Based on this, the present study investigated how corm quality is influenced by levels of irrigation in different soil types.

4 MATERIAL AND METHODS

4.1 Site description

The experiment was carried out in a greenhouse in the experimental area of Botucatu, São Paulo State, Brazil, from July 18, 2016 to March 1, 2017. The dimensions of the greenhouse are 7 m wide by 30 m long, 6 m high at the highest point. Climate tropical, with hot, humid summer and cold, dry winter. The average air temperature during the experimental period was 21.0°C, the average ET_0 was 3.56 mm/day, and the average air humidity was 62.0 %.

4.2 Plant material

The taro (*C. esculenta*) cultivar selected for evaluation was 'Chinese', which was classified as an eddoe type landrace, it is characterized by a central corm and numerous side corms which are considered the edible part (LEBOT, 2009). Before sowing, the propagules initially selected were uniformed by size (weighing between 30 g and 50 g). They were sown in 400 mL plastic cups, which were filled with soil (sandy clay loam soil) and substrate (substrate commercial) with a ratio of 1:1 by volume. The substrate had a moisture content of 60%, a water-holding capacity of 130% (both by weight), a bulk density of 200 kg m^{-3}, a pH of 5.8, and an electrical conductivity of 2.0 mS cm^{-1}. At 48 days after sowing (May 31 to July 18, 2016), 180 seedlings (approximately three leaves per seedling) were selected and transplanted into the pots. Each pot had a capacity of 25 L, with a plant spacing of 0.6 m × 0.5 m.

4.3 Experiment design

A factorial experimental design was performed with five irrigation levels combined with three soil textures, in a randomized complete block, replicated four times with 3 useful plants each replication (one plant per pot). Five irrigation levels were 20%, 60%, 100%, 140%, and 180% ET_c (crop water requirement), and three soil types were clay soil (CS), sandy clay loam soil (SCL), and sandy soil (SS).

4.4 Irrigation

An automatic drip irrigation system was accomplished using an emitter with a flow rate of 2.0 L h^{-1}, which was connected by a 4 mm microtube on the 16 mm sideline which is the 25 mm shunt line. The system uniformity test carried out on a test bench for drip tubes and presented Christiansen Uniformity Coefficient -CUC of 98%. This test faithfully supports that the irrigation system assembled in the greenhouse was stable and accurate during the experiment period.

The irrigation time and the volume of water applied were based on the evaporation value of the Class A Evaporation Pan method (PEIXOTO *et al.*, 2010) installed inside of the greenhouse, pan coefficient (K_p) and crop factor (K_c) associated with phenological stages (ALLEN *et al.*, 1998). In the present study, the value of K_p was 1. The growth cycle of taro is of approximately seven months (LEBOT *et al.*, 2004). K_c values of taro were as described by Fares (2008), where K_c initial = 1.05 (two months), K_c med = 1.15 (four months), and K_c late = 1.1 (one to two month). Based on the values of K_c and ET_0, ET_c (Equation 1) was calculated using the single crop coefficient approach, as described by Allen *et al.* (1998):

$$ET_c = ETc \times K_c \quad (1)$$

Where: ET_c = crop water requirement, ET_0 = reference evapotranspiration, and K_c = crop factor; and

$$ET_0 = CAEP \times K_p \quad (2)$$

Where: CAEP = Evaporation value of Class A Evaporation Pan, and K_p = Pan coefficient.

All treatments were irrigated with 100% ET_0 from July 18, to August 17, 2016. And irrigation treatments were applied daily and were imposed on August 18, 2016 (30 days after transplanting). The last irrigation occurred on February 28, 2017. The total irrigation water applied (WU_t) taking into consideration the initial watering, ranging from 1580 mm (180% ET_c) to 1244 mm, 908 mm, 572 mm, and 236 mm for 140%, 100%, 60%, and 20% ET_c, respectively.

4.5 Agronomic practices

4.5.1 Soils

The soils used were classified as clay soil, sandy clay loam soil, and sandy soil that can be found frequently in Brazil. The three soils were collected in the field at the 0-20 depth layer in a place where there was no presence of crops or any agricultural practice in the last ten years. Before collection, each soil sample was air-dried and sieved through a 2 mm mesh for soil fertility and texture analyses. The physical characteristic of the soils was analyzed according to the methodology proposed by Claessen *et al.* (1997), and the chemical analysis was carried out according to Raij *et al.* (2001). Soil analysis results are shown in Table 1.

Table 1. Characteristics of soils, water, and organic compost used in the experiment.

SC	CS[a]-values	SCL-values	SS-values	WC	Values	OC	Values
pH	3.9	4.1	4.7	pH	7.3	pH	7.7
M.O (g/dm^3)	14	16	9	N (mg/L)	4	C/N	11/1
Presin (mg/dm^3)	5	4	5	P (mg/L)	1	O.M. (%)	34
H+Al (mmolc/dm^3)	87	77	17	K (mg/L)	22	P_2O_5 (%)	1.4
K (mmolc/dm^3)	0.5	0.7	1.1	Ca (mg/L)	18	K_2O (%)	0.6
Ca (mmolc/dm^3)	3	3	7	Mg (mg/L)	10	Ca (%)	1.8
Mg (mmolc/dm^3)	1	1	3	S (mg/L)	5	Mg (%)	0.4
SB (mmolc/dm^3)	5	4	10	N (mg/L)	3.8	S (%)	0.3
CEC (mmolc/dm^3)	92	81	28	B (mg/L)	0	Na (mg/Kg)	609
BS% (mmolc/dm^3)	5	5	38	Cu (mg/L)	0	Cu (mg/Kg)	63
Sandy (g/Kg)	436	652	957	Fe (mg/L)	0.16	Fe (g/Kg)	10
Silt (g/Kg)	456	291	34	Mn (mg/L)	0	Mn (mg/Kg)	348
Clay (g/Kg)	108	57	9	Zn (mg/L)	0	Zn (mg/Kg)	120

[a] CS: clay soil; SCL: sandy clay loam soil; SS: sandy soil. SC:Soil characteristics;WC:Water characteristics; OC:Organic compost characteristics.

After collection, the soils were dried in the air and passed through a sieve to remove leaves, stems, and roots. In order to guarantee the main nutrients, the soils need to be placed in each pot for correction of acidity and base fertilizer based on the chemical analysis. The acidity correction was calculated based on the need for liming to raise the base saturation of each soil to 60%, according to the recommendation of Bulletin 200 (2014). For fertilizer, 30 mg of N (urea - 45%), 200 mg of P (18% of P_2O_5, 16% of calcium -Ca), 40 mg of K (white potassium chloride) per 1L of soil were applied to each pot before transplanting.

4.5.2 Water

The irrigation water used was from Sabesp that is responsible for planning, executing, and operating basic sanitation services throughout the territory of the State of São Paulo of Brazil. It was classified as C1S1 according to the chemical characteristics (RICHARDS, 1954), and does not show restriction for irrigation. Water analysis results are shown in Table 1.

4.5.3 Earth-up

The earth-up was done twice (in September and December of 2016, respectively) with 250 mL of compound (the ratio of soil to organic compost was 2:1) each pot. The organic compost analysis results are shown in Table 1. The position of emitter was adjusted following earth-up to avoid uneven distribution of water in pot.

4.6 Data collection

In harvest, corm diameter and corm number total per plant were measured. The corms (central corm was separated) were classified as big corm [BC (>47 mm)], medium corm [MC (40-47 mm)], small corm [SC (33-40 mm)] and commercial part [CP (<33 mm)] based on diameter (transverse diameter) (PUIATTI, 2001). The corm number per plant of each class was counted, and the first three classes were considered as commercial part (CP).

Total sugar (TS) and reducing sugar (RS) obtained by alcohol extraction, according to the methodology recommended by Adolfo Lutz Institute, which was quantified by spectrophotometry with Somogyi-Nelson reagents, at 500 nm wavelength, in Spectrum 70 Bausch & Lomb apparatus, as described by Aued *et al.* (1989). And starch content (SC) was measured by the Lane-Eynon methodology, according to Instituto Adolfo Lutz (1985). For PC, the micro Kjeldahl method was used to estimate the total nitrogen, using the factor 6.25 to convert it into protein content, according to Association of Official Analytical Chemists (1984).

4.7 Statistical analysis

Analysis of variance (ANOVA) was used to statistically analyze data (corm number, corm diameter, total sugars, reducing sugars, starch content, and protein content) using Sigmaplot® version 11.0 (ISI, San Jose, California USA). The Tukey's Honest Significant Difference test (HSD) was used for multiple comparison tests, with a significance level of $\alpha = 0.05$.

5 RESULTS AND DISCUSSION

5.1 Yield components

Water scheme and soil texture influenced significantly on corm number total (CN_t) and corm diameter (CD), while no significant difference (Table 2) was observed between soil textures for number of big corm (NBC), number of medium corm (NMC), number of small corm (NSC), or number of commercial part (NCP). These results agree with Anita *et al.* (2022) who reported that water strategy significantly affected the tuber growth and nutrition composition of potato.The highest values for most of yield components were detected at 180%ETc in clay soil, while for NMC, the highest values were observed at 140%ET_c under sandy soil. And at water schemes lower than 100%ETc, taro exhibited better in sandy soil, rather than in clay soil. It indicates that choose soil type correctly could be a way to achieve better perform of taro, without costing too much water. Statistical results also showed that the CD and CN_t did not differ significantly between 140% ET_c and 180%ET_c.

Table 2 showing that the medium corms and small corms are the dominant components of NCP, as big corms only accounting for 0 to 6.4% of CN_t. No significant difference was observed between 100%, 140%, and 180%ET_c for NCP, while the values at higher water schemes are significantly greater than at 20% and 60%ET_c. It means that within a certain irrigation level, the number and size of taro corm increased greatly with increase in water scheme. Although 180% ETc has been over-irrigated, it did not negatively affect the number and size of corm due to the loss of nutrients in the soil and the permeability of the root system. However, when corm number and size increased slightly from 140%ETc to 180%ETc, water use efficiency decreased, through increase of irrigation amount to increase the number and size of corm does not pay off. These findings are consistent with Muhammad *et al.* (2021), who reported that the optimum water amount applied for potato tuber numbers and crop water productivity was not the highest one.

Table 2. Response of corm number total, corm diameter, and number of big corm, medium corm, small corm, and commercial production to irrigation level and soil texture

Soil texture	**Irrigation levels**				
	20%ET_c	**60%ET_c**	**100%ET_c**	**140%ET_c**	**180%ET_c**
			CN_t		
CS	5.8cdAB[a]	9.2cB	14.2bAB	17.5abA	24.2aA
SCL	4.0cB	9.5bcB	12.5bB	13.0abB	18.0aAB
SS	7.0cA	11.0bA	20.0aA	19.8aA	20.5aA
Soil texture			CD (mm)		
CS	54.8dB	183.9cB	327.5bA	493.2aA	541.7aA
SCL	59.9dB	194.2cAB	314.5bA	357.7abA	465.2aA
SS	93.4cA	238.4bA	363.2abA	445.2aA	491.9aA
Soil texture			NBC		
CS	0aA	0aA	0.9aA	0aA	1.9aA
SCL	0aA	0aA	0.6aA	0.8aA	0.7aA
SS	0.2abA	0bA	0.4abA	0.6abA	1.4aA
Soil texture			NMC		
CS	0bA	1.0bA	4.5aA	4.1aA	6.7aA
SCL	0bA	2.3bA	2.6abA	3.0abA	6.0aA
SS	0dA	2.3cdA	3.6bcA	7.3aA	7.0abA
Soil texture			NSC		
CS	1.0cA	4.3bcA	4.0bcA	6.3abA	9.2aA
SCL	0.8bA	2.9abA	5.5aA	6.8aA	4.6abA
SS	1.5bA	4.5abA	8.8aA	6.3aA	7.6aA
Soil texture			NCP		
CS	1.0dA	5.3cA	9.4bA	10.4bA	17.8aA
SCL	0.8cA	5.2bcA	8.6abA	10.5abA	11.3aA
SS	1.8cA	6.8bA	12.8aA	14.2aA	16.0aA

[a] Mean separation between irrigation levels within soil texture (capital letters) and between soil textures within

irrigation level (lower case letters) by t-test at α = 0.05.

Yield components responded slightly but differently to water scheme in different soil textures. In sandy soil, taro had more corms at 100%ET_c, the number of corms tend towards stability at irrigation level above this; while for sandy clay loam and clay soil, the highest values were detected at 180%ET_c, and there is still a tendency to continue to rise with increased irrigation level. It means that sandy soils probably be instrumental in taro growth, as more corms with higher diameter were observed in this soil. While this result contradicts the findings reported by Filipović *et al.* (2016), who reported that the soil with high clay content could stimulate corm number of Jerusalem artichoke. That maybe due to the application of organic matter in soils, in which lead to sandy soil well suited to taro (HIERNAUX *et al.*, 1999). Which was also confirmed indirectly by Adekija *et al.* (2020) who reported that soils with lower bulk density could enhance better root penetration for nutrient absorption, and taro corm does well in tuberization in the soil.

5.2 Corm physicochemical characteristic

Significant differences ($P < 0.05$) were observed between irrigation treatments as well as between soil textures for total sugars (TS) and reducing sugar (RS), the highest values were observed at 140%ET_c and 100%ET_c, respectively, in sandy soil (Table 3). The interaction between irrigation treatment and soil type was also significant ($P < 0.001$) for RS. In sandy clay loam soil (SCL), 180%ET_c showed higher RS in comparison with that of 100%ET_c (Table 3), whereas no significant difference was observed between 100%ET_c and 180%ET_c in clay soil (CS) and sandy soil (SS). These results agree with the founding of Anita *et al.* (2022) and Abbas & SRI RANJAN (2015), who reported that sugars content of potato decrease as water amount applied increased, while disagree with other authors (ELHANI *et al.*, 2019; WEGENER *et al.*, 2017). The contrary results reported by different authors showing that potato tuber sugar content is more sensible to irrigation treatment than we imagine, there could be other factors affect sugar accumulation, such as genotype. With respect to soil texture, at 20% and 100%ET_c, significantly lower RS was detected in SCL compared with CS and SS; At 60%ET_c, RS for SS was 16% and 17% lower, respectively, in comparison with that of CS and SCL. In addition, at 140%ET_c, taro planted in CS showed lower RS compared with in other two soil types; Whereas at 180%ET_c there was no significant difference for RS between soil textures. Overall, SC and TS were also highly affected by soil texture, soil with high content of sand may be more beneficial to the accumulation of sugar, as they are significantly higher in sandy soil than in other two soils.

Table 3. Effect of irrigation level and soil texture on chemical composition of taro corm

Irrigation levels	**Total sugar (%)**			**Reducing sugar (%)**		
	Soil texture			**Soil texture**		
	CS	**SCL**	**SS**	**CS**	**SCL**	**SS**
20% ET_c	2.0bB[a]	2.0bcB	2.5bA	0.39cA	0.30cB	0.44dA
60% ET_c	2.4aA	2.3abA	2.6bA	0.62aA	0.63aA	0.52cB
100% ET_c	2.3abA	1.7cB	2.4bA	0.62aA	0.49bB	0.69aA
140% ET_c	2.1abC	2.4aB	3.1bA	0.52bB	0.60aA	0.59bcA
180% ET_c	2.4aA	2.3abA	2.4bA	0.62aA	0.61aA	0.64abA
Irrigation levels	Starch content (%)			Protein content (%)		
	CS	SCL	SS	CS	SCL	SS
20% ET_c	17cB	17cB	21cA	2.8aAB	3.0aA	2.7aB
60% ET_c	20bB	19bB	26bA	1.8bC	2.0bB	2.3bA
100% ET_c	23aA	22aA	16dB	1.8bA	1.7cdA	1.9cA
140% ET_c	20bB	23aAB	25bA	1.7cA	1.5dA	1.7cdA
180% ET_c	19bcB	18bcB	29aA	1.8bcA	1.8cA	1.7dA

[a] Mean separation between irrigation levels within soil texture (capital letters) and between soil textures within irrigation level (lower case letters) by t-test at $\alpha = 0.05$.

Starch content (SC) of taro corm was significantly influenced by irrigation treatment as well as by soil texture (Table 3). There was also a significant difference ($P < 0.001$) of the interaction between irrigation treatment and soil texture (Table 3). In CS and SCL, 20% ET_c showed the lowest SC in comparison with the other four irrigation treatments, whereas in SS, 100% ET_c was observed to have the lowest SC, followed by 20% ET_c. These results were similar with the study by Anita *et al.* (2022), Alenazi *et al.* (2016) and Carli *et al.* (2014), who found that the potato SC increased with increasing amounts of water supply. In addition, at 100% ET_c, SC of SS was 30% and 13% lower than that of CS and SCL, respectively. While SC was 16% and 23% higher in SCL and SS, respectively, compared with that of CS at 140% ET_c. At 20%, 60%, and 180% ET_c, SS was observed to have the highest SC, compared with CS and SCL. Significant ($p < 0.001$) differences were observed between irrigation treatments (Table 3). Results of protein were contrary to TS, RS, and SC. The protein content (PC) was increased with decrease in water availability. Interestingly, 180% ET_c showed slightly higher PC compared with that of 140% ET_c, however, it was lower than that of the other three irrigation treatments. No significant differences were observed for PC between soil textures (Table 3). Some previous studies conducted to clarify the relationships between chemical composition and consumers' preferences, that taro corm with high starch content but low total sugars are preferred (LEBOT *et al.*, 2004; LEBOT; MALAPA; BOURRIEAU, 2011). In order to limit the corm sugar content we could choose clay soil or sandy clay loam soil, but then, it could influence negatively on SC content of corm. In brief, producers should reasonably choose soil types and corresponding irrigation levels based on local soil conditions, water conditions, and production goals.

6 CONCLUSIONS

Water scheme and soil condition influenced on behavior of taro corm number, corm size, and corm chemical compositions, which responded differently to irrigation level under different soil texture. Trough the results presented above, we conclude that: in well-watered areas, taro growth did not have strict requirements on soil type, however, we can not rely solely on irrigation amount to promote the growth of taro corm. Additionally, for sandy clay loam cultivation, the amount of irrigation should be appropriately increased, water scheme not lower than 100% ET_c is recommended; in areas dominated by sandy soil, the amount of irrigation can be appropriately reduced, which should not be higher than 100% ETc; in areas dominated by clay soil, the cultivation conditions requirements are relatively high; in areas where lacking of water, we can add organic compost to improve the physical and chemical properties of the soil in order to promote taro growth. This aimed to provide a reference for future research, and the deficiencies are left to be completed and supplemented by later studies.

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