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MEILING LI

RESPONSE OF TARO [*Colocasia esculenta* (L.) Schott] GROWTH, YIELD, AND CORM QUALITY TO VARYING WATER REGIMES AND SOIL TEXTURES

Botucatu

2019

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Thesis presented to the Agronomical Sciences College - campus of Botucatu, São Paulo State University, to obtain the title of PhD in Horticulture.

Advisor: Prof. Dr. Lin Chau Ming

Coorientator: Prof. Dr. Angélica Cristina Fernandes Deus

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Título: RESPONSE OF TARO [*Colocasia esculenta* (L.) Schott] GROWTH, YIELD, AND CORM QUALITY TO VARYNG WATER REGIMES AND SOIL TEXTURES

AUTORA: MEILING LI

ORIENTADOR: LIN CHAU MING

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Prof.ª Dr.ª LAÍS LORENA QUEIROZ MOREIRA
Fertilidade do Solo / Instituto Federal do Norte de Minas Gerais

Botucatu, 21 de fevereiro de 2019.

To my beloved grandmother,

Li Fan Shi,

I dedicate.

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ABSTRACT

Irrigation is an important agricultural practice for the cultivation of taro, however, there are few experimental results focus on this practice in Brazil, and there is no information on water requirement for this crop under different soil textures in São Paulo State. Therefore, the objective of this work was to evaluate the development, biomass and corm quality of taro under varying water regimes and soil textures. The experiment was conducted from 2016 to 2017 with two harvests, in a greenhouse of Agronomical Sciences College, São Paulo State University (UNESP), Botucatu, São Paulo, Brazil. The five irrigation levels were 20%, 60%, 100%, 140%, and 180% of crop water requirement (ET_c), with 100% ET_c as the control. And three soil textures: clay soil (CS), sandy clay loam soil (SCL) and sandy soil (SS) were used. Results showed that plant height, petiole diameter, leaf number and area, above-ground, root, and corm fresh/dry weight, corm number and diameter of taro were lower at 20% and 60% ET_c, and higher at 140% ET_c and 180% ET_c when compared with 100% ET_c. SS exhibited higher leaf number at all water regimes, whereas leaf area for SS was higher than SCL and CS at 20% ET_c. For the first harvest, SCL showed higher root fresh/dry weight, and SS exhibited higher corm dry weight than the other two soils. The highest water-use efficiency (WUE) and index (HI) were detected at 20% ET_c. For the second harvest, SS showed higher root and corm fresh weight, corm number and diameter. The 20% ET_c had the highest WUE, whereas the lowest HI was observed at the same water regime; The highest WUE and lowest HI were observed in SS. Generally, reducing sugars and starch content increased with the increase in water regime, while a different trend was observed in total soluble solids, total total titratable acidity, and protein content in taro corm. SS was had higher total sugars, reducing sugars, and starch content than the other two soils. Briefly, irrigation management plays an important role in improving the growth of taro. The application of sandy soil should be one good way for taro to adapt limited water availability conditions.

Keywords: Irrigation. Soil type. Water-use Efficiency. Canopy Size. Chemical Composition. Water-stress.

RESUMO

A irrigação é uma prática agrícola importante para o cultivo do inhame, entretanto, há poucos resultados experimentais focados no Brasil, e não há informações sobre a necessidade de água para essa cultura sob diferentes texturas de solo no estado de São Paulo. Objetivou-se com o presente trabalho avaliar o desenvolvimento, biomassa e qualidade dos tubérculos do inhame sob diferentes lâminas de irrigação e texturas de solo. O experimento foi conduzido de 2016 a 2017 com duas colheitas em casa de vegetação na Universidade Estadual Paulista (FCA/UNESP), Botucatu. Estudou-se cinco lâminas de irrigação: 20%, 60%, 100% (controle), 140% e 180% da necessidade de água da cultura (ET_c), e três texturas de solo: solo de textura argilosa (CS), solo de textura média (SCL) e solo de textura arenosa (SS). Os resultados mostraram que a altura da planta, diâmetro do pecíolo, número de folhas, área foliar, peso fresco/seco da parte aérea, da raiz e do tubérculo, número e diamêtro de tubérculo do inhame foram menores em 20% e 60% ET_c e maiores em 140% and 180% ET_c quando comparado com 100% ET_c. SS apresentou maior número de folhas em todas as lâminas de irrigação, enquanto a área foliar para SS foi maior que SCL e CS em 20% ET_c. Para a primeira colheita, SCL apresentou maior peso fresco/seco da raiz, e SS apresentou maior peso seco do tubérculo do que os outros dois solos. A maior eficiência no uso da água (WUE) e índice de colheita (HI) foram detectados em 20% ET_c. Para a segunda safra, SS apresentou maior peso fresco e de tubérculo, número e diâmetro de tubérculo, comparados com os outros dois solos. A 20%ET_c apresentou a maior WUE, enquanto a HI menor foi observado nessa mesma lâmina; A maior WUE e a menor HI foram observadas no SS. Geralmente, açúcares redutores e teor de amido aumentaram com o aumento na lâmina de irrigação, enquanto uma tendência diferente foi observada em sólidos solúveis totais, acidez total titulável e teor de proteína no tubérculo de inhame. O SS apresentou maiores açúcares totais, açúcares redutores e teor de amido do que os outros dois solos. A irrigação desempenha um papel importante na melhoria do crescmento do inhame. O solo arenoso pode ser uma boa maneira para cultivar o inhame nas condições limitadas de disponibilidade de água.

Palavras-chave: Irrigação. Tipo de Solo. Eficiência no Uso da Água. Tamanho da Copa. Composição Química. Estresse Hídrico.

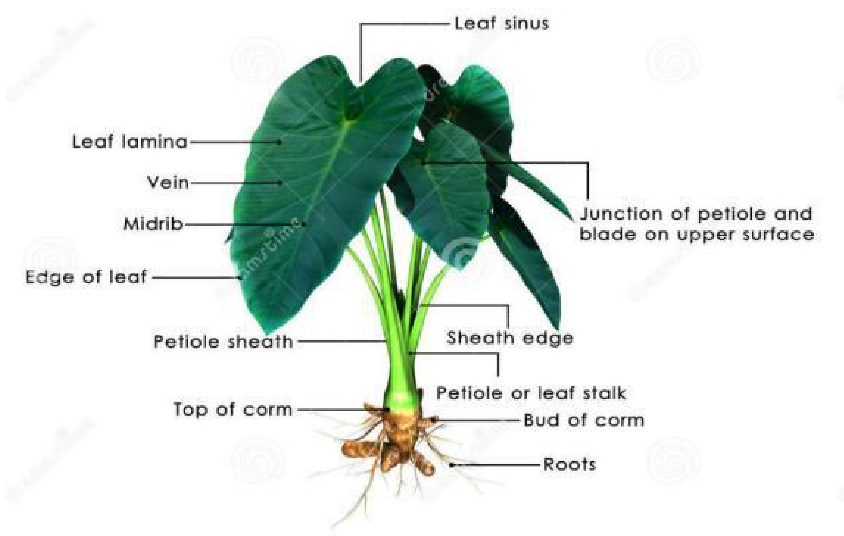
SUMMARY

GENERAL INTRODUCTION

Taro (*Colocasia esculenta* L. Schott) is known by various names, including dasheen, eddoe, cocoyam, or tania (ONWUEME, 1999; PRAGATI; KAUSHAL, 2015; CABI, 2017). It is a tuber crop from the family of Araceae monocot, was spreaded from Asia to eastern of Southeast Asia and then to China, Japan, and Pacific Islands (SINGH et al., 2007; MODI, 2007; MARE, 2009). Belonging to the subfamily of Aroideae (LEBOT, 2009), which includes about 100 genera and 1500 widely distributed species (MERLIN, 1982).

The above-ground (Figure 1) of taro is composed with large leaves and long petioles (ONWUEME, 1978; PURSEGLOVE, 1972). The leaf blade ranges from 25 to 85 cm in length and 20 to 60 cm in width (PURSEGLOVE, 1972), the petioles measured between 1 and 2 m in length (ONWUEME, 1978; PURSEGLOVE, 1972). Taro has starchy underground stems, widely dilated, which are designated as corms (BROUK, 1975; COURSEY, 1968; PLUCKNETT, 1970).

Figure 1 Taro leaves, petioles, roots, and corms.



Source: SCIENCE PICS, 2017

Taro corm is composed, externally, of concentric rings of scars and leaf scales (WINTON; WINTON, 1935). It has one or more minor secondary corms that arise from lateral sprouts present under each scale or leaf base (ONWUEME, 1978; WINTON; WINTON, 1935). There are highly variable to humidity, size, color and chemical composition for taro corm (PLUCKNETT, 1970; STRAUSS et al., 1980). The shape of corm varies from elongated to spherical with an average diameter of 15 to 18 cm (BROUK, 1975; ONWUEME, 1978; WINTON; WINTON, 1935). Generally, the taro root system is adventitious and fibrous (ONWUEME, 1978; PURSEGLOVE, 1972).

Taro flowers are not common in all cultivars. One author recorded that "The taros have been cultivated for so long while many of them never flowered and it is likely that no civilized man has seen a viable seed of taro" (BARRETT, 1928). This led to the supposition that taro seeds were indeed quite rare (KIKUTA, WHITNEY; PARRIS, 1938; MACCAUGHEY; EMERSON, 1913; WHITNEY, 1937; WILIMOT, 1936).

Taro growth, maturity, and harvest period depend on the cultivar. In the initial of planting the growth rate is slow but will increase rapidly after one to two months (ONWUEME, 1999). Taro has four physiological stages: dormancy, vegetative stage, reproductive stage, and maturity (MARE, 2009). The dormancy and vegetative stage is the period of root and leaf establishment (SIVAN, 1982). This stage is characterized by sprouting and root growth. The vegetative growth is marked by an increase in plant height, number of leaves and leaf area, and slow corm growth (TUMUHIMBISE et al., 2009), at this stage, the leaf and petioles are the dominant collectors for photo-assimilates (SINGH et al., 1998). The reproductive stage is the period of rapid corm development after five months planting age (SIVAN, 1982).

At the maturity stage, the growth of corm is at the peak, with a rapid increase in the formation of corms. This stage is a period of senescence of canopy size, associated with decreased plant height, leaf area, and leaf number, whereas with the continuous increase of corm size (SIVAN, 1982). At this stage there is a rapid decline in sprout growth, and reduction in the number of active leaves, decrease in average petiole length, total leaf area per plant, and decrease in plant height (ONWUEME, 1999; SILVA et al., 2008). According to Goenega (1995), a increase in biomass occurred after obtaining maximum leaf area, and dry matter partition for the corms remained constant from 150 days after planting. Tumuhimbise et al. (2009) also reported that the maturity stage is a growth period in which the diameter and length of the corm increased rapidly over the 150 days.

Taro is produced and consumed mainly in subsistence, and the surpluses are sold as production crops, which plays an important role in Fighting against hunger (ONWUEME, 1999). The production characteristics include total weight of corms, number of corms, and individual weight per corm and so on (MARE, 2009). In 2017, the world production of taro reached 10.222 million tonnes in 1.724 million hectares (ha) of land, with Nigeria accounting for about 3.901 million tonnes, followed by China with 1.656 million tonnes, and Ghana with 1.512 million tonnes (FAO, 2019). In addition, taro corm has a broader complement of nutrients than other tuber crops (KAUSHAL et al., 2015; FILHO et al., 1997), it is superior to potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*), cassava (*Manihot esculenta*) and yam (*Dioscorea* L.).

In Brazil, its importance is mainly linked to the center-south region of the country, specifically in the states of Minas Gerais, Rio de Janeiro and Espírito Santo, where most of the national taro production concentrated. Taro is associated with family farming in producing regions, since its technological input needing is low (GONDIM et al., 2007). For example, in the state of Rio de Janeiro, such as Cachoeiras de Macacu and Magé, they produce more than 8,000 t/year in total, which represents approximately 40% of the crop's production of the state (CIDE, 2007).

Compare with taro leaf and petiole, taro corms are the primary use of its consumption, since they are sources of carotene, potassium, calcium, phosphorus and iron (DEO et al., 2012). As good resources for infant feeding because its starch is easily digestive, which is helpful for people with problems digestive (JOUBERT and ALLEMANN, 1998; ONWUEME, 1999; SHANGE, 2004). They also contain higher starch content than potatoes and sweet potatoes (TUMUHIMBISE et al., 2009), which is suitable for gastric patients.

In addition, taro has a number of medicinal uses (PAUL; BARI, 2011). Taro corms can be used as an abortifacient, as for treating tuberculous ulcers, pulmonary congestion, fungal abscesses in animals, and as anthelmintic. Foliage is used as a hemostasis and poultice, and the petiole is used as a treatment for wasp stings (WILBERT, 1986) which is also a good source of dietary fiber. Additionally, high levels of dietary fiber in foods are also advantageous for their active role in regulating intestinal transit (WILBERT, 1986).

As an important tuber crop taro can grow in many tropical and subtropical countries (SLOAN et al., 2016). The optimum temperature for taro growth ranges from 21°C to 27°C, and well distributed summer rains of 1000mm or more additional irrigation is preferred (WILSON et al., 2013). However, under tropical conditions, the crop is often subjected to unfavorable growth conditions, due to stress of water deficit, low humidity and high temperature which may limit productivity due to their harmful effects on taro growth (PARDALES, 1985).

Taro yield and quality fluctuate due to the differences in cultivar, irrigation management, soil textures, planting density, levels of fertilizer application, among other environmental factors (MANNER; TAYLOR, 2010; CHUN-FENG; KUN, 2004). Compared to other tuber crops, the plant is characterized by the ability to grow under adverse conditions, such as excess water, high temperature, shaded habitat, and tropical forests (SMITH, 2006). This plasticity in adaptation has made it possible to use taro in agroforestry systems, including intercropping, between shrub, and tree species (ANUEBUNWA, 1992; OLIVEIRA et al., 2006), or in lines (OLIVEIRA et al., 2007). In addition, chemical composition of tuber crops differs with different cultivars (MARE, 2009), it is also influenced by climatic conditions, which are dependent upon the site and planting date. Another important factor for the success of irrigated agriculture is irrigation water management, since it is one of the major concerns related to the agricultural system (BRITO, 2015).

The amount of water available with its distribution pattern results in increased production and longer growing period. According to Daff (2011), it is important to ensure a constant availability of water during the growing season of taro, since water scarcity can cause water stress, which results in reduced yield, malformed and poor-quality corms. In order to provide such water supply, irrigation should be used, especially where there is irregular precipitation (JOUBERT; ALLEMANN, 1998). The main methods of irrigation are by flood, furrows, sprinkler, pivots and localized (micro sprinkler and drip irrigation). The choice of the appropriate irrigation method depends on several factors, such as topography, soil physical properties, culture, available water quality, among others. As one of the most efficient method used in irrigated agriculture, drip irrigation system is able to promote higher yields with greater efficiency in water use.

On the other hand, taro can grow in a wide variety of soil textures, from clay soils to sandy soils (ONWUEME, 1999). However, the taro produce better when planted in fertile soil, rich in organic matter with high capacity water retention. A slightly acid soil with pH of 5,5 to 6,5 with moderate clay content is considered ideal (ONWUEME, 1999; SAFO-KANTAKA, 2004). Soil texture refers to the proportion of the sand, silt and clay particles of soil, which varies according to the type and mineral composition of the source material and the chemical weathering processes involved in soil formation. It is an very important physical property of soil, as it influences the soil physical and chemical behavior (BOWMAN; HUTKA, 2002), with influence on water retention capacity and its availability, nutrient leaching and aeration (HUNT and GILKES, 1992), thus, soil texture is also used to estimate the other soil properties, particularly water properties related with soil. Soil texture also influences root growth indirectly, whereas root response directly to soil textures in water, oxygen and nutrient availability in soil, soil aeration and nutrient content (GLINSKI; LIPIEC, 1990). In addition, the physical and chemical properties of the soil affect the quantity and the movement of these substances essential for the growth of the plants. The first concern in the relationship between soil texture and plant growth will be the behavior of root in different soil textures (GLINSKI; LIPIEC, 1990; HILLEL, 1982).

Furthermore, as one of the most limited factor for plant growth (FISCHER; TURNER, 1978), water availability for plants depends heavily on soil texture, which controls hydraulic conductivity and field capacity (WALTER; STADELMAN, 1974). As the infiltration of rainwater into coarse-textured soils is much deeper than in fine textured soils, the evaporation of coarse-textured soils is much smaller than that of fine-textured soils after precipitation (WALTER; STADELMAN, 1974). Thus, knowing the textural classes of soils is an important step in using management practices that maximize productivity and minimize environmental damage (HILLIARD; REEDYK, 2014).

However, little information is found on the water stress tolerance of taro under different soil textures. Sivan (1995) and Sahoo et al. (2006) observed that canopy size of taro decreased in response to water stress. Uyeda et al. (2011) evaluated the response of taro to five irrigation levels (50%, 100%, 150%, 200%, and 250% ET_0 - reference evapotranspiration) and found maximum taro yield at 150% ET_0. A study by Buragohain et al. (2013) focus on taro quality response to 20 cultivars in Nagaland reported that the corm length and diameter reflected wide variation among the cultivars, as well as the starch content, corm humidity, and corm number. Kaensombath et al. (2012) reported that the yield of taro leaves and petioles were larger with more frequent harvesting, while corm yield was not affected by harvest interval. Also, based on crop water requirement (ET_c), Mabhaudhi et al. (2013) investigated the effect of three water regimes on growth of taro. They found that leaf number and leaf area decreased at 60% and 30% ET_c. In addition, taro yield was higher at optimum irrigation (100% ET_c) when compared with 60% and 30% ET_c, whereas water-use efficiency (WUE) was relatively stable among water regimes.

Research on taro is still suffering from the lack of scientific information in relation with soil texture. Filipović et al. (2016) reported that the soil with a high content of clay significantly improved the corm number per plant of Jerusalem artichoke (*Helianthus Tuberosus* L.). Martin and Miller (1983) studied the response of potato to deficit irrigation under different soil textures (sandy and loam soil), they found that in sandy soil its yield greatly increased with increase in irrigation level. Furthermore, Katerji and Mastrorilli (2009) observed a significant reduction (22%-25%) in WUE in clay soil for potatoes, corn (*Zea mays* L.), sunflowers (*Helianthus annuus*), and sugar beets (*Beta vulgaris*), comparing with that detected in loam soil.

Chemical composition of taro corm has been well documented by previous researches (ONWUEME, 1978; KAUSHAL et al., 2015). The proximal composition of taro corm varies depending on variety, growing condition, soil type, moisture and fertilizer application, maturity at harvest, post-harvest management, and storage (ONWUEME, 1978; BRADBURY et al., 1985; BRADBURY; HOLLOWAY, 1988). Its nutritional composition is low in protein and fat like other root crops, but high in carbohydrate. The moisture content of taro is also very high, which generally ranges from 60-83% (HUANG, et al., 2007). Taro starch is the most important component (JANE, et al., 1992) of taro corm (70-80% dry weight basis). It contains about 11% crude protein on a dry weight basis. However, the chemical composition research of taro is still suffering from the lack of scientific information in relation with water regime and soil texture.

It is evident from the literatures reported above that the majority of agronomical knowledge about the crop was derived from environments outside Brazil, basic agronomic studies on taro occurring in Brazil are still lacking. Thus, the focus of the current study was to study the response of taro development, biomass, and corm quality to varying water regimes and soil textures.

improve harvest index, while there is a limit of duration of water stress, when the irrigation treatment last more than this limit could negatively affect on taro harvest index and ultimately on its growth and biomass accumulation. In the second harvest, sandy soil was shown to have significantly higher root fresh weight, corm number, and corm diameter, while a lower harvest index, compared with clay and sandy clay loam soil. It is suggesting that under limited available water conditions, taro may be better adapt in sandy soils, as in which it shown to have higher biomass accumulation, and stronger root system to avoid or reduce water stress damage.

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sandy clay loam soil than sandy soil, especially at lower water regimes for leaf area. Furthermore, canopy size and corm yield increased by increasing water regimes in all the soil textures. The highest water-use efficiency was observed at 20% ET_c, whereas no statistically significant differences were detected between 60%, 100%, 140%, and 180% ET_c in both harvests. Sandy soil showed to have significantly higher water-use efficiency and corm yield in the second harvest, suggesting that, under conditions of limited water availability, taro may be better adapted to sandy soils.

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between 63 and 85% (Kaushal et al., 2015). Results reported above demonstrated that limited water availability resulted in reduced CH. CS had higher CH compared with SCL and SS, which was also proved indirectly by the fact that SS obtained higher SC and PC.

3.5 CONCLUSION

Results described here confirmed that irrigation treatment and soil texture affected significantly on chemical composition behavior of taro corm. Higher water regime had a positive effect on taro corm humidity, reducing sugars, starch content, root dry weight, and corm dry weight, whereas had a negative effect on total soluble solids, total titratable acidity, and protein content. In addition, sandy soil may be more suitable to cultivate taro, as total soluble solids, total sugars, protein, starch content, and corm dry weight were observed higher in this soil in comparison with the other soil textures. Though the sandy soil also showed higher total titratable acidity content, which is inadequate to the flavor of taro corms, that we can try to increase the water regime to control the total titratable acidity content. Additionally, results of dry biomass of taro proved again that higher water regime and sandy soil were more beneficial to the growth of taro. Briefly, adequate control of water regime may improve the quality of taro corm, and the application of sandy soil to cultivate taro may be a good way to improve its quality under water limited conditions.

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FINAL CONSIDERATIONS

Taro growth, its corm production and corm quality response to irrigation level and soil texture were discussed in the present study. Based on issues related to botany, environmental requirement, and the importance of taro cultivation presented throughout the general review, the canopy size (leaf number and leaf area), water-use efficiency, and corm yield of taro were discussed in the first chapter; the plant height, petiole diameter, fresh biomass, corm diameter, corm number, and harvest index of taro were analyzed in the second chapter; and the analysis of chemical composition and dry biomass of taro response to water regime and soil texture was done in the last chapter.

With the results reported above, it is possible to conclude that, reasonably controlling the amount of irrigation applied and correctly selecting the soil texture should be key objectives for taro production. Doing so would be helpful to improve its water-use efficiency, corm quality, and possibly corm yield. The taro physiological parameters, yield parameters, and chemical composition parameters responded differently to water regime and soil texture. It is evident that higher water regime played a positive effect on growth and yield of taro, despite that water-use efficiency was higher at 20% $ET_{c,}$ compared with the other irrigation treatments. It is not necessary to applied irrigation level with 180% ET_c, as higher water regime could decrease water-use efficiency and protein content. In addition, 140% ET_c was observed to have the highest corm yield rather than 180% ET_c as reported above. It is considered to select soil texture correctly to guarantee taro yield and its corm quality with less water applied. The response of taro chemical composition parameters to the treatment in the present study was relatively irregular, it was not simply increased or decreased with the increase or decrease in water regime. Additionally, there was no one soil texture was more beneficial to all the chemical compositions parameters of taro corm, whereas the sandy soil was observed to have higher total sugars, starch content, and total soluble solids than the other two soils. Briefly, adequate control of water regime may improve growth, corm yield, water-use efficiency, and corm quality of taro. The application of sandy soil to cultivate taro may be a good way to improve its quality under limited water availability conditions.

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