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HARVESTING COMPOUNDS THE EFFECT OF WATER DEFICIT ON THE GROWTH AND YIELD OF WATER LEAF [*TALINUM TRIANGULARE* (JACQ.) WILLD.]

By

Dekoum VM Assaha*[1], Awasume Clovis Awasume[1], Pascal Tabi Tabot[1], Priscilla Mebong Mfombep[1]

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Abstract
Waterleaf is an important leafy vegetable in many parts of West and Central Africa, which can survive long periods of water deficit owing to its succulence and induced crassulacean acid metabolism. However it is not known whether harvesting during the offseason i.e. under water limited conditions can alter the resilience of the plant to adverse environmental conditions. To investigate this, a pot experiment was set up in the screen house in which, uniform-sized cuttings of waterleaf were planted in 10-L pots filled with field soil and irrigated as needed until the plants were established. Ten days from planting, irrigation was withheld in two groups of the plants, while one group (control plants) continued to receive water regularly as needed. In the water deficit groups, one group (T1) received water every two weeks coinciding with a period of harvest, while the other group received no water till the end. The shoot fresh and dry mass, height, leaf area, chlorophyll concentration, and leaf mass area ratio of the plants were recorded before and after harvesting. The results showed that at first harvest the fresh mass decreased by 33 % and 2.1 folds under T1 and T2 treatments, respectively, while at second harvest the decrease was 2.4 and 4.6 folds under T1 and T2 respectively. The dry mass remained unaltered in T1, but dropped by 34 % in T2 at first harvest, while at the second harvest the reduction was more pronounced (39 % and 3.1 fold for T1 and T2, respectively). In addition the leaf area did not change with increase leaf thickness for T1, but decreased with a drop in leaf thickness for T2; meanwhile Chl *a*, Chl *b* and Chl *a*+*b* increased in T1, but remained unaltered in T2. Taken together these results indicate that harvesting reduces the ability of waterleaf to adapt to water deficit, leading to a marked reduction in shoot production especially under severe stress (T2) due probably to downregulation of photosynthesis following source (leaf area) size reduction. Therefore minimal irrigation of water leaf after every harvest in the offseason could improve production.
Key words: Water leaf, water deficit, yield, leaf area, leaf thickness, biomass

1 Introduction

Water deficit is one of the most important abiotic stress factors affecting crop production globally. The situation of the stress is getting worse because of the constantly changing climatic conditions that are rendering the cultivation of crops very difficult especially in rain-fed production systems of many parts of Africa that are expected to be drier by 2050 and 2080 (Gizaw and Gan 2017). If no action is taken to remedy the stress condition, it will constitute a major challenge to food security, and undermine effort invested in breeding for high-yielding cultivars of crops, especially if they are not selected for stress resistance. Many crops are very susceptible to water deficit (Stagnari et al. 2016) and so cannot be cultivated out of the growing season (rainy season). It is during off season that the demand for many food stuffs is on the rise against declining crop production. Hence to meet up with this demand, cultivation of many crops during the off season will be required. However, this comes with a huge cost in acquiring and maintaining good irrigation systems throughout the dry period, as well as to ensure a constant availability of water. Water availability too during this season is a major challenge (Schneekloth et al. 2009) as many streams and rivers shrink in volume or dry off and human and animals scramble for the dwindling water resources. Some other crops however, are very tolerant to dry conditions and thus persist even during the off season although at much reduced

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growth rates. These water deficit resistant plants include the leafy vegetables *Talinum triangulare* (water leaf) (Oladoye and Liu 2022) and *Amaranthus hybridus* (green) (González-Rodríguez et al. 2019).

Water leaf (*Talinum triangulare* (Jacq.) Willd.) is a member of the family Portulacaceae, that is believed to have originated in Central Africa (Swarna et al. 2015). It is a perennial, succulent and shade-loving herbaceous plant that grows in humid tropical regions (Oluwole et al. 2018; Swarna et al. 2015) and is known to be of high nutritional and medicinal value. The plant is rich in anti-diabetic, hypoglycaemic, and hepatoprotective constituents as well alkaloids flavonoids, and saponins known for their antioxidant activities, hence making waterleaf an important nutritional and ethnomedicinal plant (Aja et al. 2010; Liang et al. 2011; Ikewuchi et al. 2017; Airaodion et al. 2019). Waterleaf is widely cultivated and marketed in Nigeria (Alozie and Ene-Obong 2018), and Cameroon as an accompanying vegetable in the preparation of eru (fufu and eru), a very popular dish in the Southwest region of Cameroon that has spread over the years to other regions and cherished by many. Because of this popularity, there is a need for supply to keep up with demand at all times by cultivating it during the dry season when it is very scarce and expensive. Although the plant is known to survive various environmental stress including water deficit (Herrera et al. 2015), the growth reduction is the cause of the shortage, in the off season, implying that minimal irrigation during this period can tremendously boost production during the off season. Therefore it is important to examine the growth and yield of the vegetable under conditions simulating the off season conditions. It will also be interesting to know how harvesting under conditions of water deficit will affect the growth and yield of the plant during subsequent harvest, as it is a perennial vegetable, which under normal conditions can be harvested multiple times before it ages outs such as in huckleberry which can be harvested about 9 times, with peak harvest yields around the 5^{th} and 6^{th} harvest (Berinyuy and Fontem 2011). There is little or no information to the best of our knowledge quantifying the effect of harvesting on the growth and yield of vegetables under water deficit conditions. Therefore the aim of the present research is to evaluate the effect of harvesting on growth and yield performance of waterleaf under normal and deficit irrigation conditions. The study will offer an answer to the following question: can harvesting alter the resilience ability of waterleaf to changing environmental conditions?

2 Materials and Methods

2.1 Plant material, growth conditions and treatments

The plant used was *Talinum triangulare* (water leaf) and propagation was by cuttings since seeds of members of the genus *Talinum* are known to have dormant seeds that are very difficult to germinate (Fawusi 1979). These cuttings were obtained from fresh harvested waterleaf shoots from a farmer's field In Kumba. The shoots were defoliated and cut into uniform-sized cutting (12 cm long), with one cutting per shoot axis and having the same number of nodes. The experiment was carried out in pots in the screen house at the experimental station of the Department of Agriculture, Higher Technical Teachers'

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Training College, University of Buea. The pots were 10 L in volume with the following dimensions: 27 cm diameter at the rim, 20 cm diameter at the bottom and 30 cm deep. Then field soil was collected and equal amounts used to fill the pots. A sample of this soil was analysed in the soil science Laboratory of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang and its characteristics are given in Table 1. Each pot had six cuttings and fertilized with 5 g NPK (20:10:10) at the beginning. The pots were irrigated as needed with fresh water until the plants grew and produced at least two branches with fully expanded leaves (two weeks after planting). Thereafter, the pots were arranged in the screen house in a completely randomized design with 1 factor (water deficit) and three factor levels: control (regularly irrigated as needed), T1 (irrigated fortnightly) and T2 (no irrigation to then end). The treatments were replicated 3 times and the treatments lasted for 4 weeks as shown in Figure 1. The irrigation volume was set at 500 mL of fresh water. This volume was calculated from the mean annual rainfall of 2200 mm for Kumba after standardizing to the area of the pot used (345 mL), according to Tabot et al. (2020). Then this volume was adjusted to 500 mL to reflect ~3200 mm rainfall. The plants were harvested twice and various measurements taken.

Table 1: Characteristics of the soil used in the present study

Soil parameter	**Value**	**Soil parameter**	**Value**
Sand	33	Organic matter (%)	9.75
Silt	24.5	Total Nitrogen. (%)	0.23
Clay	42.5	Carbon/Nitrogen	25
Textural class	clay	Calcium	4.80
Coarse element (%)	0	Magnesium	1.20
pH (H_2O)	5.4	Potassium	0.29
pH (KCl)	4.8	Sodium	0.5
Δ pH	- 0,6	Sum of base	6.79
CO (%)	5.65	CEC pH7	22

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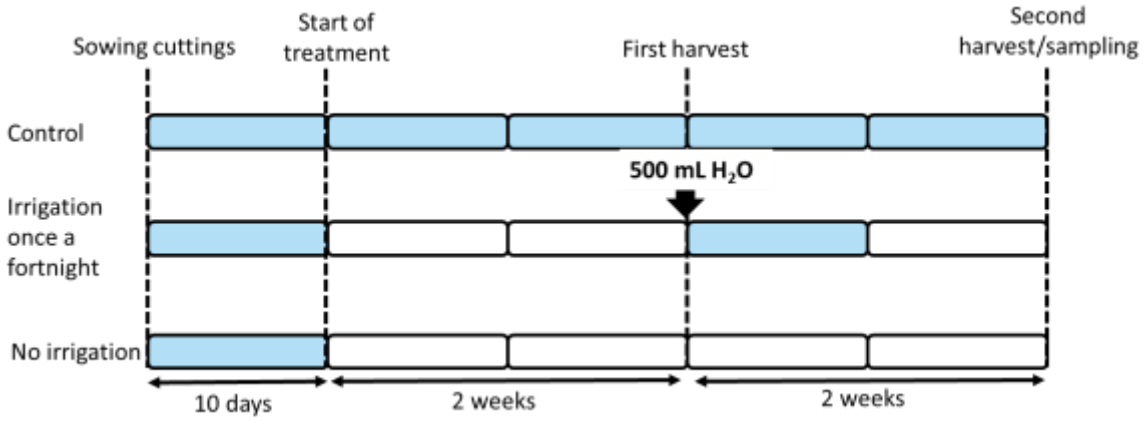


Figure 1: Experimental timeline showing treatments and harvests: blue regions represent irrigated, while clear regions represent no irrigation

2.2 Growth measurement

2.2.1 Plant height

One plant was selected in each pot and tagged for the measurement of height. The height of the selected plants was measured on a weekly interval from the start of treatment. The measurement was performed from the ground to the top (apex) of the leaves using a meter rule and expressed as in centimetres (cm).

2.2.2 Number of leaves

Plants in all replicates were tagged and the number of leaves counted on each. The leaves were counted manually on a weekly interval from start of treatment. The mean were then calculated and expressed as number of leaves per plant.

2.2.3 Leaf Area (cm^2)

Leaf area was determined by the tracing method, whereby the leaves were placed on a graph paper and traced out and the area determined by adding total number of full squares (1 cm^2 each) and half squares (Radzali et al. 2016) as follows:

$$Leaf\ area = full\ squares + (half\ squares\ x\ 0.5) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

2.3 Physiological parameters

2.3.1 Chlorophyll concentration

Leaf discs (1 cm in diameter) were excised, and immersed in 10 mL of 95 % ethanol and the bottles wrapped in aluminium foil to keep the samples out of light and the samples were kept in cold conditions (4 ^oC) for 24 hours to extract the chlorophyll. The absorbance of the ethanolic extracts were then measured at 648.6 and 664.2 nm using a spectrophotometer. Thereafter the concentrations of chlorophyll a, b and a+b, were calculated using the following equations (Lichtenthaler 1987):

$$Chla = 13.36A_{664.2} - 5.19A_{648.6} \quad (3)$$

$$Chlb = 27.43A_{648.6} - 8.12A_{664.2} \quad (4)$$

$$Chl\ a+b = 5.24A_{664.2} + 22.24A_{648.6} \quad (5)$$

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2.3.2 Leaf thickness (g/cm^2)

A leaf was selected from each replicate (the leaf used for leaf area measurement) and its leaf mass per unit area was measured, that is, mass of a specific leaf divided by its area (Negrão et al. 2017). The mean was then expressed as the leaf's thickness.

$$Leaf\ mass\ ratio = \frac{M}{A} \quad (6)$$

Where M = mass of specific leaf, A = area of specific leaf

2.4 Data analysis

All data collected on all parameters were compiled and analysed statistically using the SPSS version 21 statistical package (IBM Corp. USA). Data were subjected to analysis of variance and means were separated using Tukey HSD test at $\alpha = 0.05$.

3 Results

3.1 Effect of water deficit on the growth of water leaf before and after harvesting

3.1.1 Effect on shoot mass

The effect of water deficit on the fresh and dry shoot mass of water leaf at two harvest times is presented in Figure 2. Under control conditions (sufficient water), there was no significant change in shoot fresh mass from first to second harvest, but water deficit (T1 and T2) induced significant reductions ($p<0.05$) in shoot fresh mass during both harvest times. However these differences were more pronounced during the second harvest than the first (Figure 2A). During the first harvest the fresh mass decreased by 33 % and 2.1 folds under T1 and T2 treatments, respectively, while at second harvest the decrease was 2.4 and 4.6 folds under T1 and T2 respectively. This shows that harvesting during water deficit has more deleterious effects on the plants growth than when they are not harvested. In terms of dry mass (DW) accumulation, during the first harvest, the same trend as with fresh mass was observed, except that during the first harvest there was no significant reduction in dry mass under mild water stress (T_1), whereas a 34 % reduction was observed under severe stress (T2). At second harvest dry mass reduction was more pronounced in T2 (3.1 folds) than in T1 (39 %). This further supports the notion that harvesting has an additive effect on water stressed plants.

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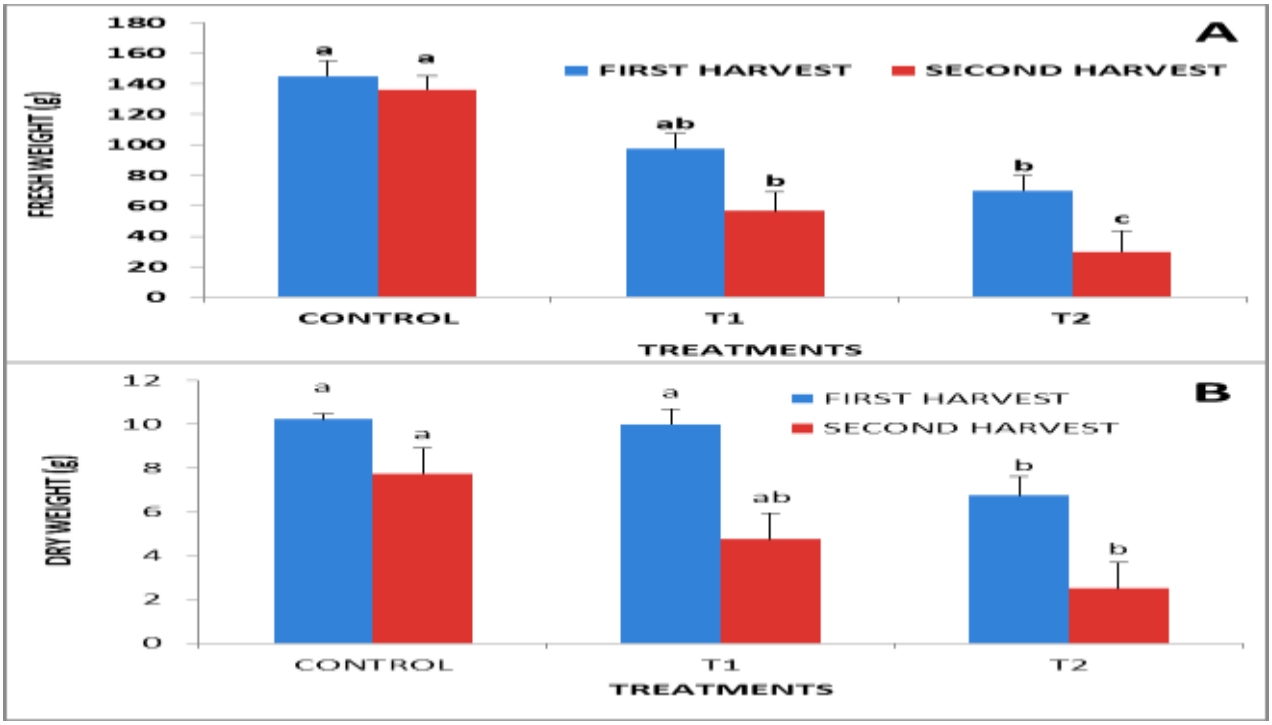


Figure 2: Effect of water deficit on the fresh shoot mass (A) and dry shoot mass (B) of waterleaf plants at first and second harvest.
The bars represent means ± SE (n = 4). Bars with the same letter for each week are not significantly different ($p \leq 0.05$). T1 = fortnightly irrigation, and T2 = no irrigation.

3.1.2 Effect of water deficit on plant height, number of leaves and leaf area

The effect of water deficit on plant height, number of leaves, and leaf area before and after harvest harvesting is presented in Figure 3. It was observed that the two water deficit levels had no significant effect on plant height before and after the first harvest (i.e. at ST, BH1 and AH1). However by the second harvest, water stress had induced significant differences ($p<0.05$) in the growth of the plants with a 35 % reduction under severe water deficit (Figure 3A). Irrigation regime had no significant differences on the number of leaves of the plants although the number of leaves decreased in the severe water stressed plants at the second harvest (19 % reduction, Figure 3B). Leaf area did not significantly change before and after the first harvest, but by the second harvest the leaf area of the stressed plants significantly decreased from control levels with no change in the severely stressed plants after the first harvest to the second harvest (3-fold reduction, Figure 3C).

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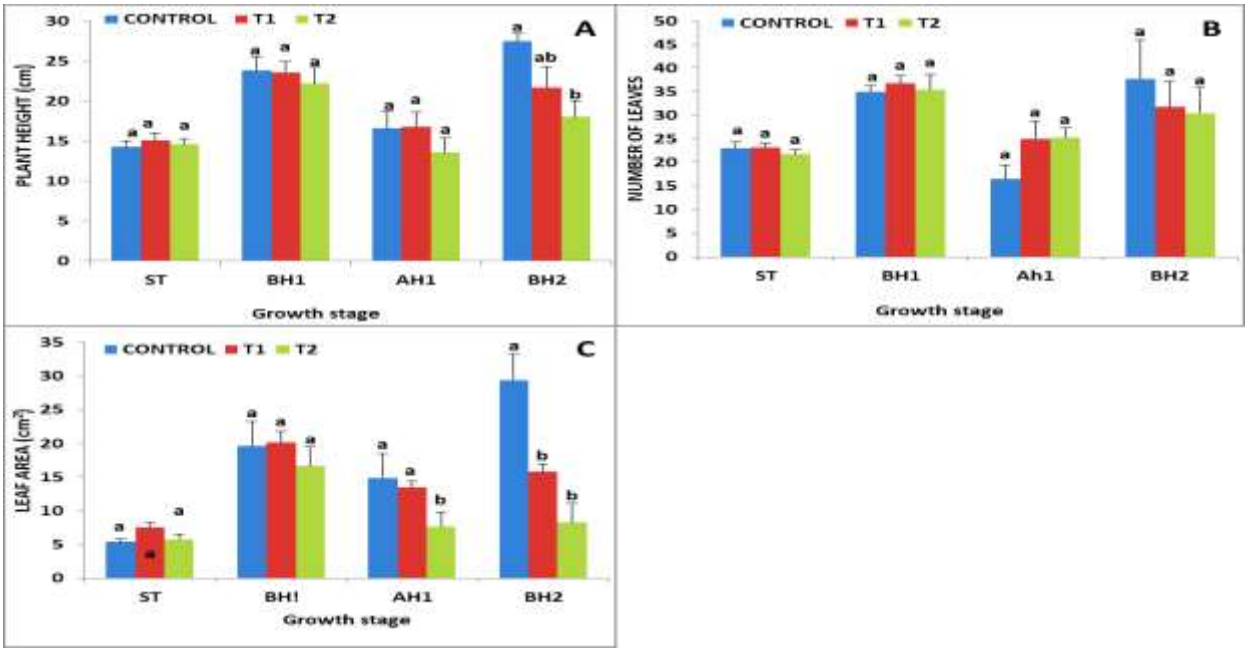
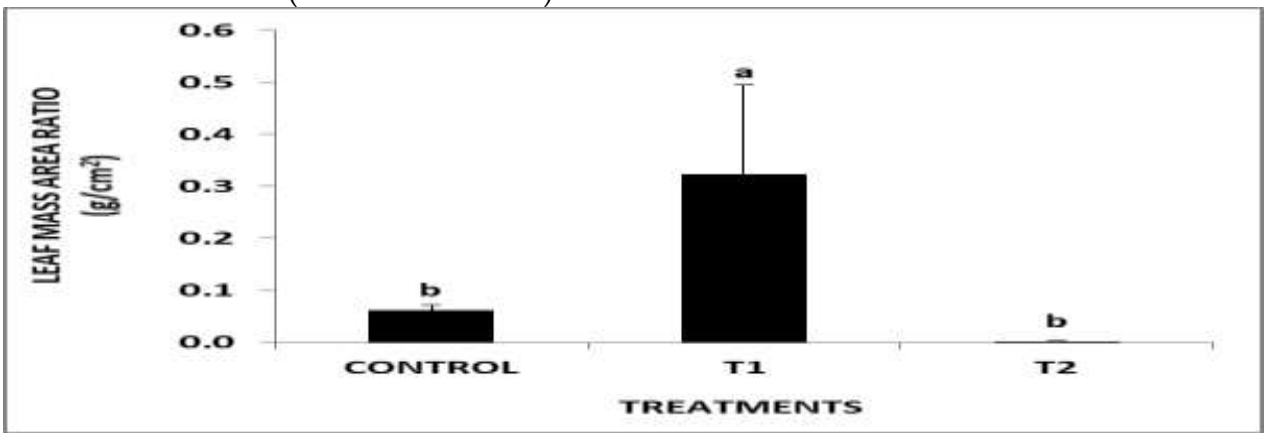


Figure 3: Effect of water deficit on the plant height (A), number of leaves (B) and leaf area (C) of water leaf plants at two harvest times.
The bars represent means ± SE (n = 4). Bars with the same letter for each growth stage are not significantly different ($p \leq 0.05$). T1 = once/two week irrigation, and T2 = no irrigation, ST = start of treatment, BH1 = before first harvest, AH1 = after first harvest, BH2 = before second harvest.

3.2 Effect of water deficit on physiological parameters of water leaf

3.2.1 Effect of water deficit on leaf mass area ratio

The effect of water deficit on leaf mass area is presented in Figure 4. The leaf mass area was determined at the time of second harvest and showed that T1 plants had the highest mass to area ratio indicating increased leaf thickness (5-fold increase) under the treatment, whereas it declined (>30 fold decrease) under severe water stress.



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Figure 4: Effect of water deficit on leaf mass area ratio of waterleaf plants grown under water deficit conditions.
The bars represent means ± SE (n = 4). Bars with the same letter are not significantly different ($p \leq 0.05$). T1 = once/two week irrigation, and T2 = no irrigation.

3.2.2 Effect of water deficit on chlorophyll concentration

The concentration of Chl *a*, Chl *b*, Chl *a*/*b* ratio and total Chl (Chl *a*+*b*) in control and stressed plants is presented in Figure 5. Chl *a*, Chl *b*, and Chl *a*+*b* concentrations significantly increased under T1 (75, 74 and 90 %, respectively), but remained unaltered under T2, when compared to control (Figure 5 A, B and D). Chl *a*/*b* significantly increased under the two water stress treatments T1 and T2 (12 and 27 % increase respectively) (Figure 5C).

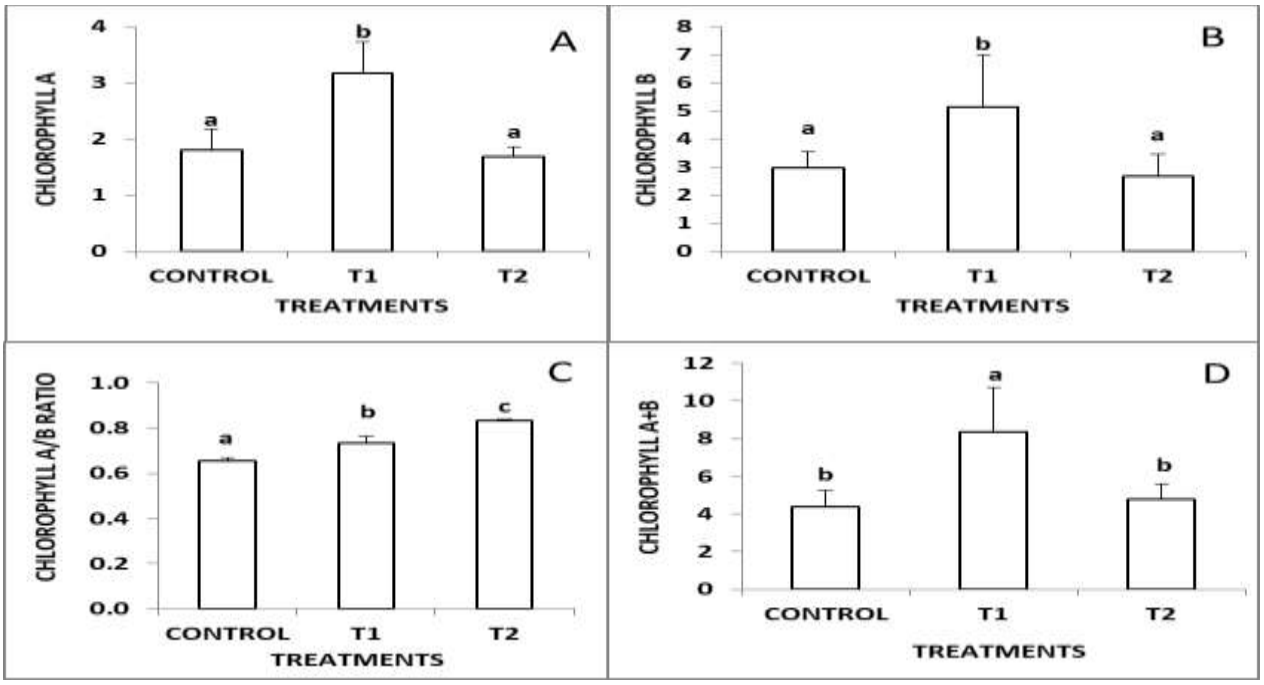


Figure 5: Effect of water deficit on chlorophyll a (A), chlorophyll b (B), chlorophyll a/b ratio and total chlorophyll (D).
The bars represent means ± SE (n = 4). Bars with the same letter are not significantly different ($p \leq 0.05$). T1 = once/two week irrigation, and T2 = no irrigation.

4 Discussion

The present study was carried out to evaluate the effect of water deficit on the growth and physiological parameters of water leaf, an important nutritional and medicinal leafy vegetable. The plants were subjected to control (regularly watered as needed), and two water deficit conditions, irrigated once (T1) in two weeks, and zero irrigation (T2). These two stress levels were chosen because water leaf is a succulent plant and can survive through the water deficit conditions of the dry season. However it is not known whether after harvesting under this condition the plant's resilience to such adverse environmental

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condition would be preserved. To test this, plants were subjected to water deficit conditions. At first harvest, the fresh mass of the shoot (edible part) under T1 did not significantly change from controls, but significantly dropped under severe water stress. However, by the second harvest the fresh mass significantly decreased under both water deficit treatments, indicating that harvesting drastically reduces the resilience capacity of waterleaf against adverse environmental conditions. Consequently, leafy vegetables that are normally harvested multiple times before they phase out (with cumulated yield increments) (Berinyuy and Fontem 2011), may only produce two significant harvests, leading to huge cumulative yield loss.

The survival of plants under adverse environmental conditions depends on their ability to synthesize and accumulate biomass through photosynthesis, which is evident in increased dry matter content, or cellular expansion as evident in change in height, leaf area and number of leaves (Yordanov et al. 2003). Thus increase in these traits under stress would indicate stress tolerance (Negrão et al. 2017). Water deficit or drought stress is a very significant factor in limiting crop production, as crop production dependents primarily on water availability. Water deficit arises from drastic reduction of soil water content creating an imbalance in the water potential between the soil and root cells, which limits water uptake (Yordanov et al. 2003). Under this condition, the plant will signal leaves via an ABA-dependent pathway to limit water loss by inducing stomatal closure, which will help the plant conserve water, but may end up being deleterious to the plant as the CO_2 diffusion will be impeded leading to a drop in net photosynthetic output (biomass production), eventually leading to growth reduction (Osakabe et al. 2014). However, in succulent plants such as water leaf, the photosynthesis type is the facultative crassulacean acid metabolism (CAM) induced during drought stress (Herrera et al. 2015), in which stomata open only at night to allow CO_2 diffusion which will be used for malate synthesis and storage in the vacuoles. During the day this malate is decarboxylated and the CO_2 released utilized in the Calvin cycle for biomass production (Gilman and Edwards 2020). This CAM photosynthetic pathway is deemed crucial for enhanced crop production in inhospitable environments (Davis et al. 2019). With this xerophytic habit, waterleaf is able to survive prolonged periods of drought during the dry season.

In the present study, it is possible that this trait helped maintain growth of water leaf under mild stress (irrigation every fortnight) around control levels, and reduced it by only 34% under severe stress (Figure 1B). However fresh mass was more affected by both stress levels because drought stress often reduces cell division and expansion, leading to reduction in size of the plant, especially leaf area, and plant height (Yordanov et al. 2003). Due to this size reducing effect of water deficit, there was a significant reduction in leaf area and plant height of water leaf. This reduction was more pronounced during the first harvest than at the second. There exist a positive correlation between leaf area and photosynthetic biomass production. The greater the leaf area the more the photosynthetic output (Basu et al. 2016). Hence greater leaf area coincided to higher dry mass accumulation during the first harvest, while reduced leaf area coincided to reduced biomass production under severe stress and at the second harvest (Figures 2 and 3).

Increase biomass production through photosynthesis will be sustained only when the components of the photosynthetic machinery are in order, for stress often compromises the efficiency of the system, reducing for example the amount of pigments such as chlorophyll that are primarily involved in light absorption to drive the photosynthetic processes (Mirkovic et al. 2017). Reduced chlorophyll will imply a reduction in excitation energy transfer through the system and therefore reduced carbon fixation as exemplified in buckwheat (*Fagopyrum tataricum*) under drought stress (Xiang et al. 2013). In the present study, chlorophyll remained unaltered under severe water deficit, but significantly increased under mild stress. This will signify that the reduction in biomass under severe water stress is not due to light-absorbing pigment degradation, but may be attributed to other limiting factors such as resistance to CO_2 diffusion across the mesophyll cells (Nadal and Flexas 2018).

One of the main adaptive strategies to resist drought stress and conserve water in many plants is thickening of the leaves (Júnior et al. 2019). This helps the plants get succulent thereby conserving water for its metabolic processes. This was assessed by determining the leaf mass area ratio. This ratio significantly increased in plants under mild stress, but significantly decrease in plants under severe stress the parameter was assess after the first harvest signifying that the resilience of water leaf to drought stress owes to increased leaf succulence which is lost after harvesting under severe water stress. This succulence has been shown to be very important for the adaptation of plants to drought stress including sugar cane (Júnior et al. 2019; Zhang et al. 2015).

In conclusion waterleaf has adaptive mechanisms to with stand prolonged water deficit conditions including leaf succulence, induced CAM photosynthesis and sustained photosynthetic machinery. However, harvesting tends to reduce the ability to withstand these adverse conditions, with a consequential reduction in shoot mass after harvesting leading to significant cumulative loss in yield (shoot mass). Therefore if waterleaf production during the off season has to be profitable, irrigation after each harvest will improve yield.

Author contributions

Conceived the research: DVMA, ACA and PMM
Carried out the research: DVMA and ACA
Data analysis: DVMA, PTT, and ACA
Wrote the manuscript: DVMA, PTT, ACA, and PMM

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5 References

Airaodion AI, Adeniji AR, Ogbuagu EO, Ogbuagu U, Agunbiade AP (2019) Hypoglycemic and hypolipidaemic activities of methanolic extract of Talinum triangulare leaves in Wistar rats. International Journal of Bio-Science and Bio-Technology 11: 1-13.

Aja P, Okaka A, Onu P, Ibiam U, Urako A (2010) Phytochemical composition of *Talinum triangulare* (water leaf) leaves. Pakistan Journal of Nutrition 9: 527-530.

Alozie YE, Ene-Obong HN (2018) Recipe standardization, nutrient composition and sensory evaluation of waterleaf (*Talinum triangulare*) and wild spinach (Gnetum africanum) soup "afang" commonly consumed in South-south Nigeria. Food Chem. 238: 65-72.

Basu S, Ramegowda V, Kumar A, Pereira A (2016) Plant adaptation to drought stress. F1000Research 5

Berinyuy JE, Fontem D (2011) Evaluating post harvest opportunities and constraints to utilization and marketing of African leafy vegetables in Cameroon. African Journal of food, agriculture, Nutrition and Development 11.

Davis SC, Simpson J, Gil-Vega KdC, Niechayev NA, Tongerlo Ev, Castano NH, Dever LV, Búrquez A (2019) Undervalued potential of crassulacean acid metabolism for current and future agricultural production. J. Exp. Bot. 70: 6521-6537.

Fawusi MOA (1979) Germination of Talinum triangulare L. seeds as affected by various chemical and physical treatments. Ann. Bot. 44: 617-622.

Gilman IS, Edwards EJ (2020) Crassulacean acid metabolism. Curr. Biol. 30: R57-R62.

Gizaw MS, Gan TY (2017) Impact of climate change and El Niño episodes on droughts in sub-Saharan Africa. Climate Dynamics 49: 665-682.

González-Rodríguez T, Cisneros-Hernández I, Acosta Bayona J, Ramírez-Chavez E, Martínez-Gallardo N, Mellado-Mojica E, López-Pérez MG, Molina-Torres J, Délano-Frier J (2019) Identification of factors linked to higher water-deficit stress tolerance in Amaranthus hypochondriacus compared to other grain amaranths and A. hybridus, their shared ancestor. Plants 8: 239.

Herrera A, Ballestrini C, Montes E (2015) What is the potential for dark CO2 fixation in the facultative crassulacean acid metabolism species *Talinum triangulare*? J. Plant Physiol. 174: 55-61.

Ikewuchi CC, Ikewuchi JC, Ifeanacho MO (2017) Bioactive phytochemicals in an aqueous extract of the leaves of Talinum triangulare. Food science & nutrition 5: 696-701.

Júnior SdOM, de Andrade JR, dos Santos CM, Silva JAC, d Santos KP, Silva JV, Endres L (2019) Leaf thickness and gas exchange are indicators of drought stress tolerance of sugarcane. Emirates Journal of Food and Agriculture: 29-38.

Liang D, Zhou Q, Gong W, Wang Y, Nie Z, He H, Li J, Wu J, Wu C, Zhang J (2011) Studies on the antioxidant and hepatoprotective activities of polysaccharides from *Talinum triangulare*. J. Ethnopharmacol. 136: 316-321.

Lichtenthaler HK (1987) [34] Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. Methods Enzymol. Elsevier, pp 350-382.

Mirkovic T, Ostroumov EE, Anna JM, Van Grondelle R, Scholes GD (2017) Light absorption and energy transfer in the antenna complexes of photosynthetic organisms. Chem. Rev. 117: 249-293.
Nadal M, Flexas J (2018) Mesophyll conductance to CO2 diffusion: effects of drought and opportunities for improvement. Water scarcity and sustainable agriculture in semiarid environment. Elsevier, pp 403-438.
Negrão S, Schmöckel S, Tester M (2017) Evaluating physiological responses of plants to salinity stress. Ann. Bot. 119: 1-11.
Oladoye C, Liu G (2022) Waterleaf, a Potential Leafy Vegetable for Florida: HS1434, 2/2022. Edis 2022
Oluwole SO, Ogun ML, Balogun OA (2018) Effects of different watering regimes on the growth of *Talinum triangulare* Jacq. (Waterleaf). Journal of Research and Review in Science 5: 14-23.
Osakabe Y, Osakabe K, Shinozaki K, Tran L-SP (2014) Response of plants to water stress. Frontiers in plant science 5: 86.
Radzali MH, Kamal NAM, Diah NM (2016) Measuring leaf area using Otsu segmentation method (LAMOS). Indian Journal of Science and Technology 9(48)
Schneekloth J, Bauder T, Hansen N (2009) Limited irrigation management: principles and practices. Crop series. Irrigation; no. 4.720.
Stagnari F, Galieni A, Pisante M (2016) Drought stress effects on crop quality. Water stress and crop plants: a sustainable approach 2: 375-392.
Swarna J, Ravindhran R, Lokeswari T (2015) Characterization of *Talinum triangulare* (Jacq.) Willd. germplasm using molecular descriptors. S. Afr. J. Bot. 97: 59-68.
Tabot PT, Mebong MP, Wase OS (2020) effect of drought stress on early seedling growth and ecophysiology of beans, pepper, tomato and water melon grown in screenhouse-potted soil. World Journal of Advanced Research and Reviews 07:274-284.
Xiang D-B, Peng L-X, Zhao J-L, Zou L, Zhao G, Song C (2013) Effect of drought stress on yield, chlorophyll contents and photosynthesis in tartary buckwheat (*Fagopyrum tataricum*). J. Food Agric. Environ 11: 1358-1363.
Yordanov I, Velikova V, Tsonev T (2003) Plant responses to drought and stress tolerance, Bulgarian. J. Plant Physiol: 187.
Zhang F-J, Zhang K-K, Du C-Z, Li J, Xing Y-X, Yang L-T, Li Y-R (2015) Effect of drought stress on anatomical structure and chloroplast ultrastructure in leaves of sugarcane. Sugar Tech 17: 41-48.