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Effect of Modulated Water Application on Shoot Size, Flower and Fruit Production in *Abelmoschus esculentus* L. (Moench)

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Authors' contributions

This work was carried out in collaboration among all authors. Author OTN designed the study and supervised the research. Author CCP managed the literature searches and wrote the protocol. Author UCC performed the statistical analysis and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aim: To study the effect of modulated water application on size of above ground structures of *Abelmoschus esculentus* L. (Moench) and its productivity.
Objective: The objective is to find out which of the four options of modulated water application gave earliness to maturity, size and production for the plant.
Methodology: This work was carried out in a screen house of the department of Botany, Nnamdi Azikiwe University, Awka. Seeds of *Abelmoschus esculentus*, of a local variety (Jokoson) were planted in plastic pots of 30 cm diameter, holding 17 kg of loam soil. The post received water by sprinkling to the tune of 3400 ml after considering the drainage upper limit (DUP) of the soil. The plants received NPK 20:10:10 fertilizer. Modulated water stress treatment was given. Each treatment has five replicate and performed in a complete randomized design (CRD). Analysis of variance (ANOVA) on collected data was performed using SPSS version 20.
Results: Morphological parameter like leaf area and plant height was observed under the options of the modulated water application treatment. Mean Leaf area of plants observed at weekly interval

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showed that treatments affected the growth pattern and anthesis. The result at 49 days after germination gave 1034.35 cm^2, 805.26 cm^2, 900.35 cm^2 and 715.97 cm^2, for T1, T2, T3, and T4 respectively and was significant at $p \le 0.05$. Consequently, the mean number of flowers produced per plant at 49 DAG (Days After Germination) gave 6.00, 4.00, 4.00 and 4.00 for T1, T2, T3, and T4. Also the mean number of flowers which developed into fruits was obtained as 6.00, 4.00, 3.00 and 2.00 for T1, T2, T3, and T4. Correlations factor between the flower productions against fruit production was significant at $p \le 0.01$ (2-tailed) for T3 and T4.

Conclusion: Regular water application at two-day interval throughout (T1) to the crop plant gave earliness, higher number of fruit and vegetative production than the interrupted water application at some developmental stage of the plant.

Keywords: Anthesis; Days after Germination (DAG); plasticity; flower; fruit; Water Use Efficiency (WUE).

1. INTRODUCTION

Plant production is affected by series of internal and external factors. The growth of higher plants is characterized by developmental phases. In animal these changes take place throughout the entire organism, whereas in plant it occurs in a single dynamic region, the shoot apical meristem [1]. During postembryonic development, the shoot apical meristem passes through three or more less well defined developmental stages in obligate sequence. The phases of development are; the juvenile phase, the adult vegetative phase and adult reproductive phase. A combinatorial model has been proposed in which shoot development passes through series which is independently regulated, overlapping programs that modulate the expression of common set of developmental process (juvenile, adult and reproductive). This transition is indicated in the leave. The transition from juvenile to adult of a leaf, is indicated at different region of the same leaf, which can express different developmental programs. Attainment of a sufficiently large size appears to be more important than the plant chronological age in determining the transition to the adult phase. Conditions that retard growth, such as mineral deficiencies, low light, water stress, defoliation and low temperature tend to prolong juvenile phase or cause rejuvenation [2].

When growth is accelerated, exposure to the correct flower-inducing treatment can result in flowering. However, although size seems to be the most important factor, it is not always clear which specific component associated with size is critical. In some *Nicotiana* species, it appears that plants must attain a certain size to transmit a sufficient amount of the floral stimulus to the apex. In addition, the apex may need to undergo a phase transition that renders it more responsive to the floral stimulus [3,4]. Leaves have been shown to play important role in plants for synthesis of metabolites of which flowering is under autonomous control. Excised leaf exposed to short days can cause flowering when subsequently grafted to a non-induced plant maintained in long days [5].

Water availability is one of the most limiting environmental factors affecting crop productivity. In semi-arid tropics, the occurrence of drought or water deficit in the soil is common, whereas crop plants of temperate and tropical regions undergo seasonal periods of water stress, especially during the summer [5,6]. The plant responses to water stress depend on the severity and the duration of stress and the growth stage of the plant. The limitation to cellular and tissue growth is a function of the adequate water availability to the plant. Water deficit develops slowly enough to allow changes in developmental processes, one of which is leaf expansion which is controlled by cell expansion. Plants with high water use efficiency find it difficult to manage drought or water stress.

Abelmoschus esculentus belong to the plants with high water use efficiency (WUE) so; the differentiation in the water application is studied for better understanding of the appropriate water requirement by the plants for production.

2. MATERIALS AND METHODS

2.1 Study Location

This work was carried out in a screen house at the laboratory of department of Botany, Nnamdi Azikiwe University, Awka. Temperature mean of 22°C in the morning and 35°C in the day, while mean day length of 11.9 hours was observed at location of 6’ N and 30’ S.

2.2 Experimental Design

Abelmoschus esculentus, seeds a local variety (Jokoson) were planted in plastic pots of 30 cm diameter, holding 17 kg of loam soil. The post received water by sprinkling to the tune of 3400 ml after considering the drained upper limit (DUP) of the soil. Each pot was perforated at the bottom to aid drainage of excess water. Drained upper limit was determined as the wettest volumetric water content observed for each soil used for the experiment [7]. Five seeds of the plant were planted in each pot and were thinned down to one plant per pot. The plants received NPK 20:10:10 fertilizer. This experimental design was complete randomized design (CRD).

2.3 Water Treatment

Modulated water stress treatment was given as follows;

T1: receives water at two (2) days interval throughout the period of experiment.

T2: receives water at seven (7) days interval up to 42 days and reverted to two (2) days interval till termination of experiment.

T3: receives water at two (2) days interval up to 42days and reverted to seven (7) days interval till termination.

T4: receives water at seven-day interval days till termination of experiment.

2.4 Data Collection and Statistical Analysis

Data on morphological features such as leaf area, number of flower per plant at anthesis and number of fruits formed were collected and reported in Mean ± Standard Error of Mean. Plant heights were taken from the ground base to the shoot tip. Leaf areas of the third fully developed leaves from the shoot tip were taken.

The data collected and generated in this study were organised and presented using SPSS version 20.

3. RESULTS AND DISCUSSION

3.1 Leaf Area

The leaf area obtained during the growth period of plants from 21 DAG to 77 DAG at seven-day interval was represented in Table 1. The table shows normal growth pattern for plants, with declining growth rate from 49 to 56 DAG which shows the peak of the adult reproductive phase of the plants. The modulated water treatments show differences in the leaf area among the treatments. The T1 treatment, which receives water at two-day interval throughout the experiment, had the highest leaf area when compared to other treatments.

3.1.1 Effect of modulated water application on plant leaf

The effect of modulated water application on plant leaf area during after Days after Germination (DAG) is presented in Fig. 2. The response of *Abelmoschus esculentus* leaf area to modulated water application showed that T1 has higher leaf area compared with other treatments; it received water application every two (2) days throughout the experiment. The pattern of leaf area curves shows that T2 was affected by modulated water application, it received water application at seven-day interval till 42 days after germination, and this resulted in less leaf area as the plants. When water application is returned to two-day interval, the adult vegetative phase

Table 1. Mean leaf area per plant from 21 – 77 days after germination

DAG\TR	T1	T2	T3	T4
21	39.55±7.10	59.24±6.1	51.46±8.7	48.29±9.1
28	105.39±15.7	135.91±15.4	136.55±30.4	119.48±25.2
35	430.27±53.62	375.96±60.5	417.46±88.60	347.46±47.9
42	812..78±31.34	516.13±57.36	729.46±145.74	558.25±47.41
49	1034.35±52.77	805.26±41.98	900.35±42.72	715.97±28.53
56	982.92±66.99	832.42±35.75	771.99±126.27	771.97±63.78
63	638.38±61.05	723.76±49.11	581.17±44.62	640.96±45.98
70	638.38±58.25	668.33±138.24	361.52±75.78	479.31±41.86
77	639.97±58.21	544.21±139.20	366.10±76.64	482.6±42.57

TR = treatment DAG = Days after germination and some part of the adult reproductive phase is already affected and the plants cannot make up for the loss in those phase of their development. Under T3, modulated water application affected the growth pattern where the water application was two-day interval till 42 DAG, before returning to seven- day interval of water application, which covers late adult vegetative phases to adult reproductive phases. The adult vegetative phase was affected and was indicated by visible decline in plant leaf area. In T4, water application is at seven-day interval throughout, it showed low metabolism all through the growth period resulting in less leaf area. Water stress was visibly indicated by reduction in plant leaf area throughout the growth period and developmental phases. The growth pattern at T4 treatment from juvenile to adult reproductive phase showed a sort of steady tolerance to water stress compared to T3 that had sharp decrease in the leaf area.

3.2 Plant Height

The plant height was observed during the growth period from 21 DAG to 77 DAG, at seven-day interval. The plant height presented in Table 2 showed the growth pattern for plants and there is observed decline in growth rate of plants from 70 DAG. T4, that is, plants that receives water at seven-day interval throughout the period of experiment, had normal growth pattern but with reduced values compared with other treatments. At 49 DAG T4 had same height with T2, that is, plants that receives water at seven-day interval up to 42 DAG and reverted to two-day interval till termination of experiment. At 56 DAG there is minor difference in height of the plant between T2 and T4. The result showed T3, that is, plant that receives water at two-day interval up to 42 DAG and reverted to seven-day till termination, had lower height compared to T1 and T2 by 77 DAG.

3.2.1 Effect of modulated water application on plant height growth pattern

Plant height growth pattern has been presented in Fig. 2. The growth pattern of the plants under treatments T1, T2, T3, and T4 shows the effect of modulated water application on plant heights of *Abelmoschus esculentus*. T1, T2, T3 and T4 indicated steady growth from germination till maturation. The plants maintained steady growth, but had differential heights between the treatments. The plat heights were taken at seven-day interval from 21 DAG till end of experiment. The T1 treatment had the highest value of plant height at intervals of 35, 42, 49 and 56 DAG. T2 showed reduced plant height between 21 DAG to 42 DAG as a result of seven-day interval of water application. When water application was returned to two-day interval the plant heights appreciated but could not reach that of the T1. Plant height under T2 showed higher values more than T3 from 70 DAG. T3 received water application at two-day interval up to 42 DAG and then received irrigation at seven-day interval from 47 DAG to 77 DAG. There was slight difference between T1 and T3 from 21 to 42 DAG before introducing seven-day of water application. The plants in T3 began having reduced height from 47 DAG as water stress sets in. From 63 DAG there is noticeable decline in growth in T3 compared to T2. The T3 has normal juvenile and adult vegetative phase but has stressed adult reproductive phase. T4 has its irrigation at seven-day interval from throughout the plant growth. T4 and T2 had similar growth pattern within 42 to 49 DAG. From 49 to 77 DAG there is remarkable decline in heights T4 plants seemingly due to water stress. The phases of growth (juvenile, adult vegetative and adult reproductive) in T4 were affected by the modulation of water application to the plants.

Table 2. Mean height of plant from 21 – 77 days after germination

DAG\TR	T1	T2	T3	T4
21	9.26± 0.32955	10.48±0.29732	10.33±.70951	9.66± 0.57845
28	14.80±0.96281	15.94± 0.74525	15.66±0.83988	14.28±1.18634
35	19.92±2.06795	24.86±1.38946	25.50±2.61457	23.34±2.26879
42	47.40±2.25100	37.34±1.56480	80.64±5.37777	57.58±3.05457
49	74.88±1.34253	57.34±2.14070	80.64±3.48348	57.58±3.02248
56	104.28±4.81606	79.04±3.96442	92.38±11.52404	71.24±4.34150
63	115.48±3.71031	95.46±9.61060	100.30±11.96378	80.08±6.44166
70	138.16±9.37788	104.98±14.60687	103.76±12.89491	86.34±10.44870
77	139.96±9.05525	108.42±13.23705	106.90±18.04269	88.38±10.76683

TR = treatment DAG = Days after germination

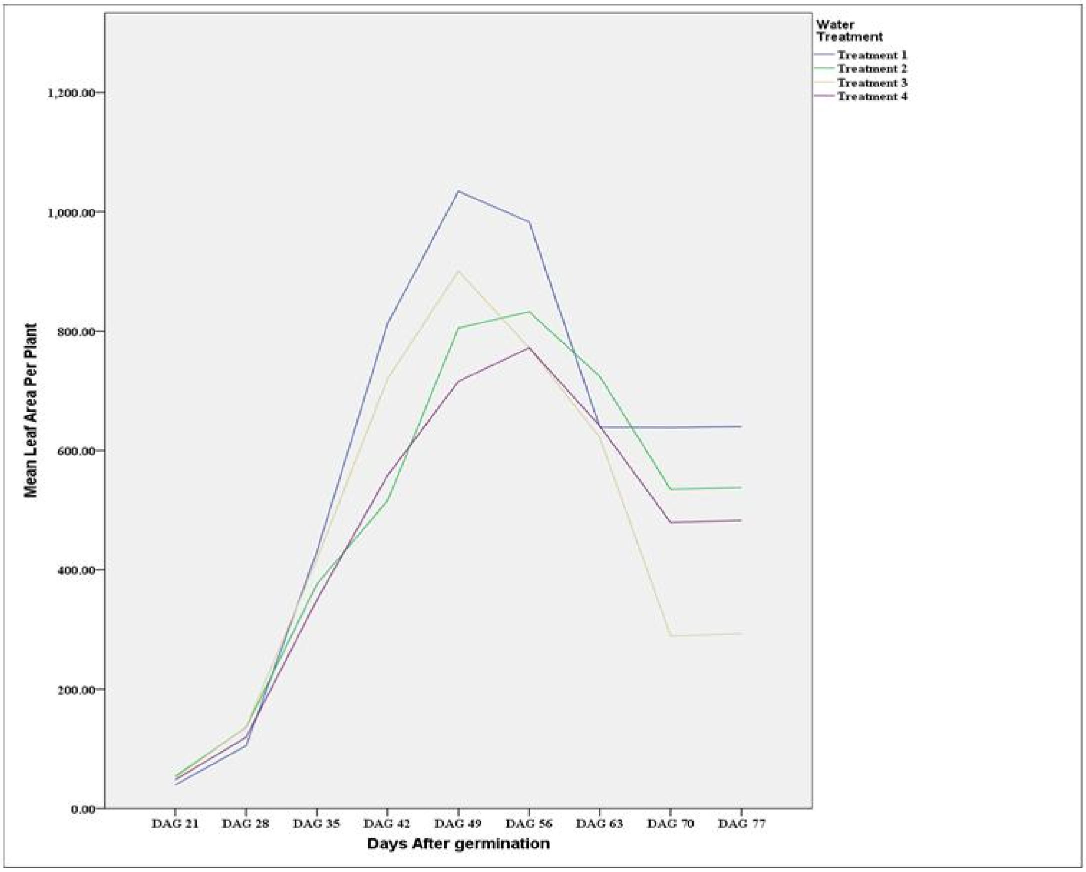

Fig. 1. Effect of modulated water application on plant leaf area during days after germination

3.3 Flower Development

The development of flowers on the upper shoot region began at 49 DAG. The number of flower for each of the treatment at anthesis is shown in Table 3. The table showed that T1 had the highest number of flower while the rest of the treatments, T2, T3, and T4 had the same number of flower produced. The correlation factor showed that at anthesis the leaf area correlated with the number of flowers produced.

Table 3. Mean number of flower at anthesis (49 DAG)

TR	T1	T2	T3	T4
MNFL	6.00	4.00	4.00	4.00
Leaf area (cm)	1034.35	805.26	900.35	715.97

Leaf area at anthesis significant at $p \leq 0.05$
MNFL = mean number of flower at anthesis
TR=Treatments

3.4 Fruit Development

The number of fruits which developed from the flower produced per plant is presented in Table 4. T1 and T2 had all the number flowers produced, develop into fruits. The table showed evidence of inability of some of the flowers produced to develop into fruits as seen for plants that received T3 and T4 treatments. For T3 and T4 the effect of the treatment on the ability of the flowers to translate to fruits was significant at $p \leq 0.01$. Modulated water treatment had induced abortion of flowers in plants under T3 and T4.

Table 4. Mean number of fruits formed from flower

TR	T1	T2	T3	T4
MNFL	6.00	4.00	4.00	4.00
MNFR	6.00	4.00	3.00	2.00

Correlation is significant at $p \leq 0.01$ (2-tailed)
MNFL = mean number of flower per plant MNFR = mean number of fruits from flower
TR= Treatment

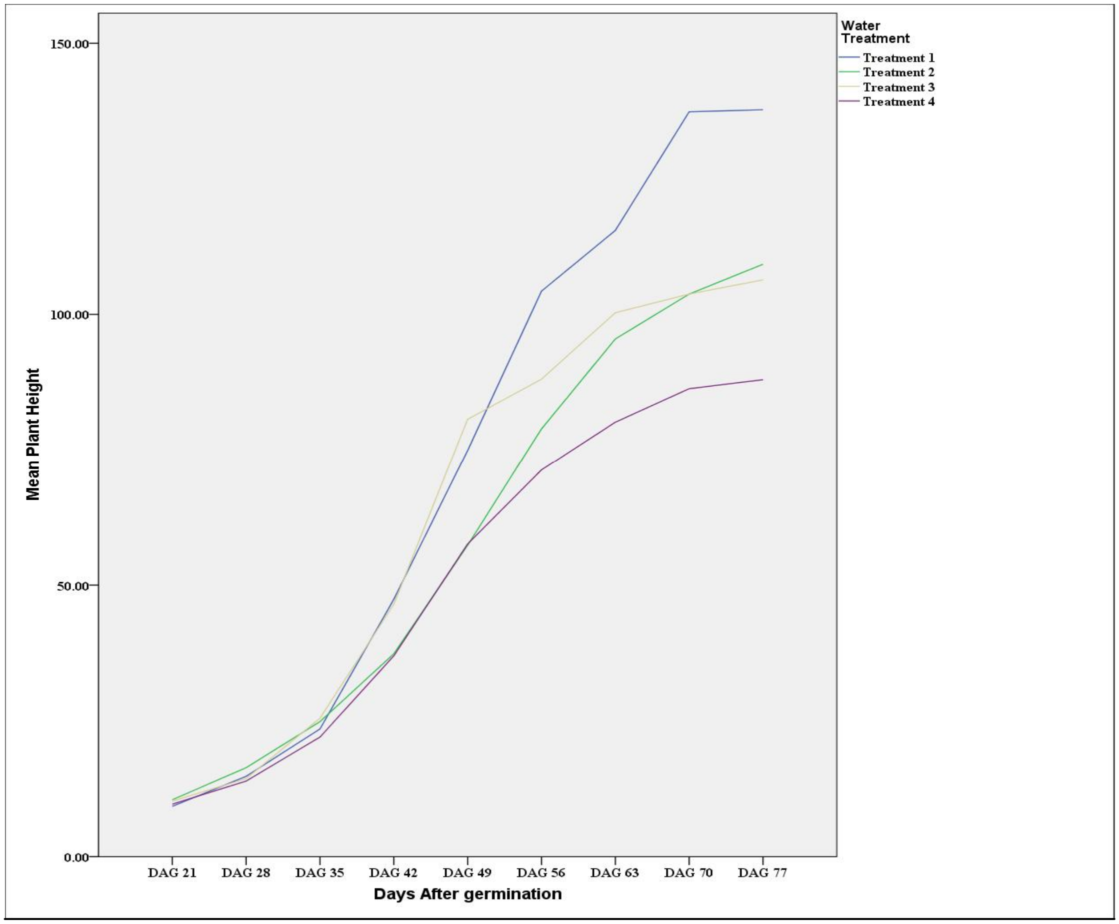

Fig. 2. Effect of modulated water application on plant heights during days after germination

3.5 Discussion

Findings from this study show that morphological features of plant height and leaf area were affected by the treatments. In this case, there is possible reduced photosynthetic rates during leaf development, and can be used as monitor for the process. Increase in photosynthetic rate results in leaf expansion, maximal rate gives full leaf expansion while senescence is as a result of declining rates [8,9]. Thus, the reduced leaf expansion may be due to low cell expansion response consequent of water stress. Noticeably, leaf area at anthesis shows that the treatment with the largest leaf area produced more number of flowers, this is in agreement with the report that size is critical to generate required amount of floral stimulus to the shoot apex on initiation of anthesis [3,4,10]. Also, when growth accelerates, exposure to the correct flower-inducing treatment, in this case water, can result in flowering [2,11]. The small leaf area observed in the treatment T4, indicated that water stress affected the plant production. Consequently, the reduction in production of T4 may be due to accumulation of Abscissic acid and probably ethylene which causes abscission and senescence of plant organs [12]. Loss of leaf area is the most important morphological adaptation and results from a reduced number of leaves, reduced size of younger leaves, inhibited expansion of developing foliage, or leaf loss accentuated by senescence, all of these gives rise to decreased seed yield [13,14,15].

Production of fruits in *Abelmoschus esculentus* in this work showed that alteration in water requirement of the plant has marked effect on it. The effect is visible in flower formation and the ability of the plant to translate the flowers produce into fruits, which is the most useful part of the plant as its edible value in concerned. The different modulated water application effect gave insight to possible stages of the plant that when its water use efficiency is affected the production would also be affected. The loss of fruit in its measurement may be amounting to high kilogram of fresh fruits when estimated at per hectare in a field experiment. When water stress sets in at any developmental stage of the plant, the metabolism of signaling agent for flowering and possibly fruiting is interrupted or aborted completely. Plant metabolic processes cannot have complete reaction pathway when nutrient uptake is affected. Plants take up nutrient when they are in the growth medium for absorption. Even presence of nutrient without the necessary medium for dissolution, would delay or stop uptake for this nutrients.

In water stressed plants, the roots are unable to take up many nutrients from the soil as a result of lack of root activity and dragged rate of ion diffusion and water movement [16,17].

Rao and Ramamoorthy found out that there is about 39% decrease in nitrogen uptake of six improved varieties of wheat when water stress was imposed on them at different growth stages of the plants. They opined that the nitrogen uptake reduction was due to applied stress and it is mainly through the restricted movement of water in such condition [18,19].

The effect of water deficit in plant, especially vegetable crops that have high water use efficiency may be under producing if the wrong water requirement is given. This will also be leading losses that may not be accounted for. It will also be a good recommendation for agriculturists to determine the type of crop to produce depending on the availability of water.

The recommended irrigation of once or twice a week for dry season cultivation of *Abelmoschus esculentus* [20,21] is likely not to give the maximal expected yield as suggested from the findings of this report.

4. CONCLUSION

The result of the work showed that water application on the plants affected plant production. Uninterrupted water application at two-day interval gave higher shoot size, flower and fruit production. Water application at seven-day interval resulted in lowest output. Interrupted water application at early and later growth phase of the plant reduced production of shoot size, number flowers and fruits. This study shows that sprinkling irrigation recommendation should be up to three to more times every week for better production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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