

Original Research Article

EFFECT OF MODULATED WATER APPLICATION ON SHOOT SIZE, FLOWER AND FRUIT PRODUCTION IN *ABELMOSCHUS ESCULENTUS* L. (MOENCH)

ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

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 under a screen house laboratory in the department of Botany, Nnamdi Azikiwe University, Awka. Seeds of *Abelmoschus esculentus*, ~~seeds~~ 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 starting from. 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 showed that treatments affected the growth pattern and anthesis. The result at 49 days after germination gave 1034.35 cm², 805.26 cm², 900.35 cm² and 715.97 cm², for T1, T2, T3, and T4 respectively and was significant at p≤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≤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

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stage of the plant.

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14 *Keywords: Anthesis, Days after germination (DAG), Plasticity, Flower, Fruit, Water use*
15 *efficiency (WUE),*

16 17 **1. INTRODUCTION**

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19 | Plant production is affected by series of internal and external ~~factorseues~~. Water deficit
20 develops slowly enough to allow changes in developmental processes one of which is leaf
21 expansion which is controlled by cell expansion. Plants with high water use efficiency find it
22 difficult to manage drought or water stress. The **development** of higher plants is
23 characterized by **developmental** phases. In animal these changes take place throughout the
24 entire organism, whereas in plant it occurs in a single dynamic region, the shoot apical
25 meristem (1). Water availability is one of the most limiting environmental factors affecting
26 crop productivity. In semi-arid tropics, the occurrence of drought or water deficit in the soil is
27 common, whereas crop plants of temperate and tropical regions undergo seasonal periods
28 of water stress, especially during the summer (5). The plant responses to water stress
29 depend on the severity and the duration of stress and the growth stage of the plant.

30 During postembryonic development, the shoot apical meristem passes through three or
31 more less well defined developmental stages in obligate sequence. The phases of
32 development are; the juvenile phase, the adult vegetative phase and adult reproductive
33 phase. A combinatorial model has been proposed in which shoot development passes
34 through series which is independently regulated, overlapping ~~programmesprograms~~ that
35 modulate the expression of common set of developmental process (juvenile, adult and
36 reproductive). This transition is indicated in the leave. The transition from juvenile to adult of
37 a leaf, intermediate forms is indicated at different region of the same leaf, which can express
38 different developmental ~~programmesprograms~~. –Attainment of a sufficiently large size
39 appears to be more important than the plant chronological age in determining the transition
40 to the adult phase. Conditions that retard growth, such as mineral deficiencies, low light,
41 water stress, defoliation and low temperature tend to prolong juvenile phase or cause
42 rejuvenation (2).

43 When growth is accelerated, exposure to the correct flower-inducing treatment can result in
44 flowering. However, although size seems to be the most important factor, it is not always
45 clear which specific component associated with size is critical. In some *Nicotiana* species, it
46 appears that plants must attain a certain size to transmit a sufficient amount of the floral
47 stimulus to the apex. In addition, the apex may need to undergo a phase transition that
48 renders it more responsive to the floral stimulus (3). Leaves have been shown to play
49 important role in plants for synthesis of metabolites of which flowering is under autonomous
50 control. Excised leaf exposed to short days can cause flowering when subsequently grafted
51 to a non-induced plant maintained in long days (4). Therefore, the limitation to cellular and
52 tissue growth is a function of the adequate water availability to the plant. *Abelmoschus*
53 *esculentus* belong to the plants with high water use efficiency (WUE) so; the differentiation in
54 the water application treatment is studied for better understanding of the appropriate
55 perception by the plants to its production.

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2. MATERIAL AND METHODS

2.1 Study Location

This work was carried out under 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 drainage upper limit (DUP) of the soil (5). Each pot was perforated at the bottom to aid drainage of excess water. 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 with standard error of mean for five replicates of each treatment and~~ 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.

3.2 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 Figure 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.

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107 The pattern of leaf area curves shows that T2 was affected by modulated water application,
108 it received water application at seven-day interval till 42 days after germination, and this
109 resulted in less leaf area as the plants. When water application is returned to two-day
110 interval, the adult vegetative phase and some part of the adult reproductive phase is already
111 affected and the plants cannot make up for the loss in those phase of their development.
112 Under T3, modulated water application affected the growth pattern where the water
113 application was two-day interval till 42 DAG, before returning to seven- day interval of water
114 application, which covers late adult vegetative phases to adult reproductive phases. The
115 adult vegetative phase was affected and was indicated by visible decline in plant leaf area.
116 In T4, water application is at seven-day interval throughout, it showed low metabolism all
117 through the growth period resulting in less leaf area. Water stress was visibly indicated by
118 reduction in plant leaf area throughout the growth period and developmental phases. The
119 growth pattern at T4 treatment from juvenile to adult reproductive phase showed a sort of
120 steady tolerance to water stress compared to T3 that had sharp decrease in the leaf area.

121 3.3 Plant Height

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

132 3.4. Effect of modulated water application on Plant height growth pattern

133 Plant height growth pattern has been presented in Figure 2. The growth pattern of the plants
134 under treatments T1, T2, T3, and T4 shows the effect of modulated water application on
135 plant heights of *Abelmoschus esculentus*. T1, T2, T3 and T4 indicated steady growth from
136 germination till maturation. The plants maintained steady growth, but had differential heights
137 between the treatments. The plant heights were taken at seven-day interval from 21 DAG till
138 end of experiment. The treatment T1 has the highest plant height compared to all other
139 treatments and serves as the control. T2 showed reduced plant height between 21 DAG to
140 42 DAG as a result of seven-day interval of water application. When water application was
141 returned to two-day interval the plant heights appreciated but could not reach that of the T1.
142 Plant height under T2 showed higher values more than T3 from 70 DAG. T3 received water
143 application at two-day interval up to 42 DAG and then received irrigation at seven-day
144 interval from 47 DAG to 77DAG. There was slight difference between T1 and T3 from 21 to
145 42 DAG before introducing seven-day of water application. The plants in T3 began having
146 reduced height from 47 DAG as water stress sets in. From 63 DAG there is noticeable
147 decline in growth in T3 compared to T2. The T3 has normal juvenile and adult vegetative
148 phase but has stressed adult reproductive phase. T4 has its irrigation at seven-day interval
149 from throughout the plant growth. T4 and T2 had similar growth pattern within 42 to 49 DAS.
150 From 49 to 77 DAG there is remarkable decline in heights T4 plants seemingly due to water
151 stress. The phases of growth (juvenile, adult vegetative and adult reproductive) in T4 were
152 affected by the modulation of water application to the plants.

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155 **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

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157 **TR = treatment**

158 **DAG = days after germination**

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

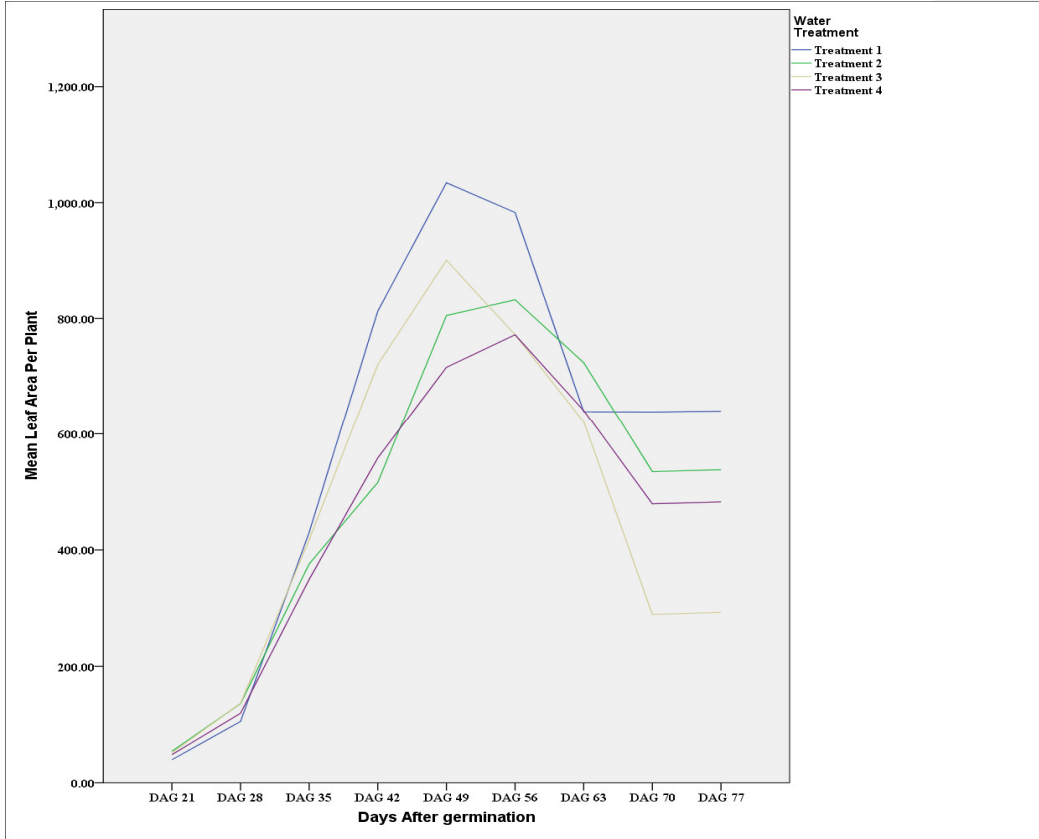
DAG\TR	T1	T2	T3	T4
21	9.26± 0.32955	10.48±0.29732	10.33±.70951	9.66± 0.57845
28	14.80±0.96281	15.94± 0.74525	15.66±0.83988	14.28±1.18634
35	19.92±2.06795	24.86±1.38946	25.50±2.61457	23.34±2.26879
42	47.40±2.25100	37.34±1.56480	80.64±5.37777	57.58±3.05457
49	74.88±1.34253	57.34±2.14070	80.64±3.48348	57.58±3.02248
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

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TR = treatment

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DAG = days after germination



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165 Figure 1. Effect of modulated water application on plant leaf area during Days after
166 Germination

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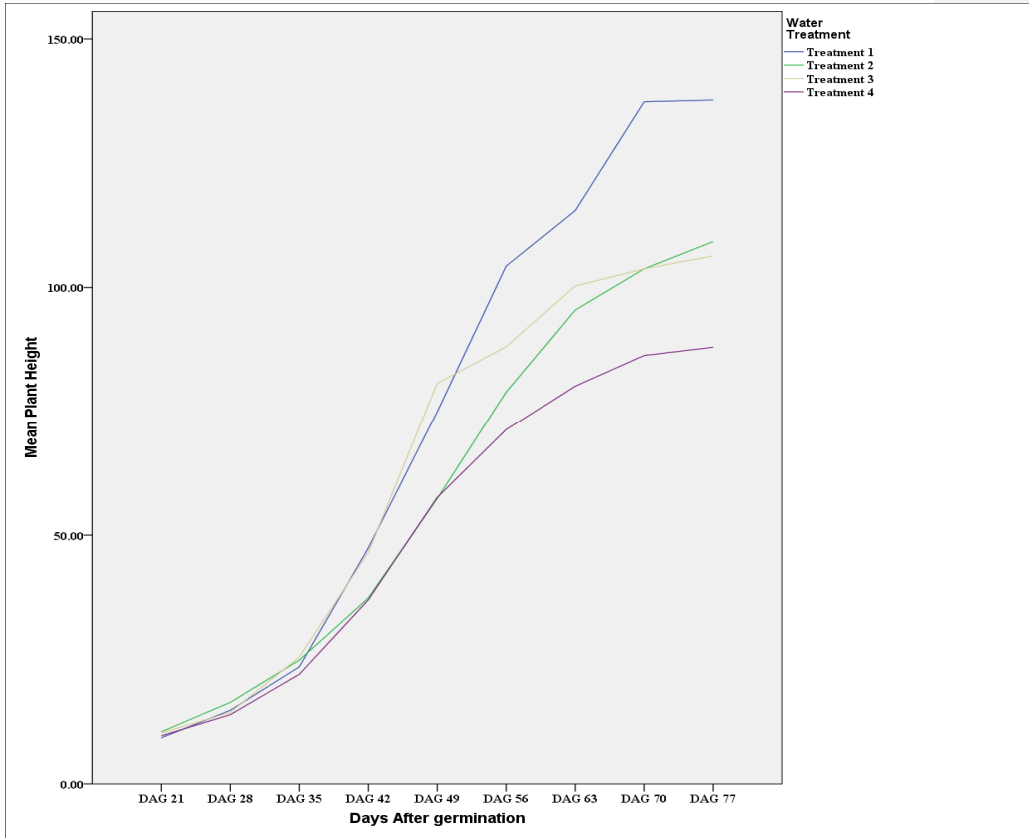
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Figure 2. Effect of modulated water application on plant heights during Days after Germination

3.5. 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.

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

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

201

202 **Leaf area at anthesis significant at $p \leq 0.05$**

203 **MNFL = mean number of flower at anthesis**

204 **TR=Treatments**

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206 **3.6. Fruit Development:**

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

213 **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

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215 **Correlation is significant at $p \leq 0.01$ (2-tailed)**

216 **MNFL = mean number of flower per plant**

217 **MNFR = mean number of fruits from flower**

218 **TR= Treatments**

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224 **3.7 Discussion**

225 **Findings from this study show that morphological features of plant height and leaf**
226 **area** were affected by the treatments. Observable evidence is that leaf expansion was
227 affected by the treatments. In this case, there is possible reduced photosynthetic rates
228 during leaf development, and can be used as monitor for the process. Increase in
229 photosynthetic rate results in leaf expansion, maximal rate gives full leaf expansion while
230 senescence is as a result of declining rates (13). Thus, the reduced leaf expansion may be
231 due to low cell expansion response consequent of water stress. Noticeably, leaf area at
232 anthesis shows that the treatment with the largest leaf area produced more number of
233 flowers, this supports the work of Mc Daniel et al. (1996), that size is critical to generate
234 required amount of floral stimulus to the shoot apex on initiation of anthesis. Also, when
235 growth accelerates, exposure to the correct flower-inducing treatment, in this case water,
236 can result in flowering (2). The small leaf area observed in the treatment T4, indicated that
237 water stress affected the plant production. Consequently, the reduction in production of T4
238 may be due to accumulation of Abscisic acid and probably ethylene which causes
239 abscission and senescence of plant organs (6). Loss of leaf area is the most important
240 morphological adaptation and results from a reduced number of leaves, reduced size of
241 younger leaves, inhibited expansion of developing foliage, or leaf loss accentuated by
242 senescence, all of these gives rise to decreased seed yield (11).

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

256 In water stressed plants, the roots are unable to take up many nutrients from the soil as a
257 result of lack of root activity and dragged rate of ion diffusion and water movement (9).

258 Rao and Ramamoorthy found out that there is about 39% decrease in nitrogen uptake of six
259 improved varieties of wheat when water stress was imposed on them at different growth
260 stages of the plants. They opined that the nitrogen uptake reduction was due to applied
261 stress and it is mainly through the restricted movement of water in such condition (10).

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

266 The recommendation of irrigation of once or twice a week for dry season cultivation of
267 *Abelmoschus esculentus* (7) is likely not to give the maximal expected yield. This study
268 shows that irrigation recommendation should be up to three or more every week.

Comment [H7]: This part should be in the Conclusion item.

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270 **4.0 Conclusion**

271 Plants, especially crops with high water use efficiency do better under optimal regular water
272 supply for its production. Physiological activities are affected when plants undergo
273 interrupted water application as found out from the study; cellular activities, growth, flowering
274 and as well as fruiting are among the physiological activities influenced by water deficit.
275 Ability of plants to recover after being stressed, depends on the developmental stage that is
276 affected by the stress. When juvenile and adult vegetative stage of the plant is affected by
277 stress, the production; flowering and fruiting is definitely affected.

Comment [H8]: This part isn't conclusion.

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279 **COMPETING INTERESTS**

280 **There Is No Competing Interest Amongst the Authors.**

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