

## 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. *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 cm<sup>2</sup>, 805.26 cm<sup>2</sup>, 900.35 cm<sup>2</sup> and 715.97 cm<sup>2</sup>, for T1, T2, T3, and T4 respectively and was significant at  $p \leq 0.05$ . 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  $p \leq 0.01$  (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.

13  
14 *Keywords: Anthesis, Days after germination (DAG), Plasticity, Flower, Fruit, Water use*  
15 *efficiency (WUE),*

### 16 17 **1. INTRODUCTION**

18  
19 Plant production is affected by series of internal and external cues. Water deficit develops  
20 slowly enough to allow changes in developmental processes one of which is leaf expansion  
21 which is controlled by cell expansion. Plants with high water use efficiency find it difficult to  
22 manage drought or water stress. The development of higher plants is characterized by  
23 developmental phases. In animal these changes take place throughout the entire organism,  
24 whereas in plant it occurs in a single dynamic region, the shoot apical meristem (1). Water  
25 availability is one of the most limiting environmental factors affecting crop productivity. In  
26 semi-arid tropics, the occurrence of drought or water deficit in the soil is common, whereas  
27 crop plants of temperate and tropical regions undergo seasonal periods of water stress,  
28 especially during the summer (5). The plant responses to water stress depend on the  
29 severity and the duration of stress and the growth stage of the plant. During postembryonic  
30 development, the shoot apical meristem passes through three or more less well defined  
31 developmental stages in obligate sequence. The phases of development are; the juvenile  
32 phase, the adult vegetative phase and adult reproductive phase. A combinatorial model has  
33 been proposed in which shoot development passes through series which is independently  
34 regulated, overlapping programmes that modulate the expression of common set of  
35 developmental process (juvenile, adult and reproductive). This transition is indicated in the  
36 leaf. The transition from juvenile to adult of a leaf, intermediate forms is indicated at  
37 different region of the same leaf, which can express different developmental programmes.  
38 Attainment of a sufficiently large size appears to be more important than the plant  
39 chronological age in determining the transition to the adult phase. Conditions that retard  
40 growth, such as mineral deficiencies, low light, water stress, defoliation and low temperature  
41 tend to prolong juvenile phase or cause rejuvenation (2).

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

55  
56

57  
58  
59

## 60 2. MATERIAL AND METHODS

61

### 62 2.1 Study Location

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

66

### 67 2.2 Experimental design

68 *Abelmoschus esculentus*, seeds a local variety (Jokoson) were planted in plastic pots of 30  
69 cm diameter, holding 17 kg of loam soil. The post received water by sprinkling to the tune of  
70 3400 ml after considering the drainage upper limit (DUP) of the soil (5). Each pot was  
71 perforated at the bottom to aid drainage of excess water. Five seeds of the plant were  
72 planted in each pot and were thinned down to one plant per pot. The plants received NPK  
73 20:10:10 fertilizer. This experimental design was complete randomized design (CRD)

74

### 75 2.3 Water Treatment

76 Modulated water stress treatment was given as follows;

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

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

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

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

83

### 84 2.4 Data Collection and Statistical Analysis

85 Data on morphological features such as leaf area, number of flower per plant at anthesis and  
86 number of fruits formed were collected and reported in Mean  $\pm$  Standard Error of Mean.

87 Plant heights were taken from the ground base to the shoot tip. Leaf areas of the third fully  
88 developed leaves from the shoot tip were taken.

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

91

## 92 3. RESULTS AND DISCUSSION

93

### 94 3.1 Leaf Area

95 The leaf area obtained during the growth period of plants from 21 DAG to 77 DAG at seven-  
96 day interval with standard error of mean for five replicates of each treatment and  
97 represented in table 1. The table shows normal growth pattern for plants, with declining  
98 growth rate from 49 to 56 DAG which shows the peak of the adult reproductive phase of the  
99 plants. The modulated water treatments show differences in the leaf area among the  
100 treatments. The T1 treatment, which receives water at two-day interval throughout the  
experiment, had the highest leaf area when compared to other treatments.

### 101 3.2 Effect of modulated water application on plant leaf

102 The effect of modulated water application on plant leaf area during after Days after  
103 Germination (DAG) is presented in Figure 2. The response of *Abelmoschus esculentus* leaf  
104 area to modulated water application showed that T1 has higher leaf area compared with  
105 other treatments; it received water application every two (2) days throughout the experiment.

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

### 120 **3.3 Plant Height**

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

### 131 **3.4. Effect of modulated water application on Plant height growth pattern**

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

152

153

154 **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  |

155

156 **TR = treatment**

157 **DAG = days after germination**

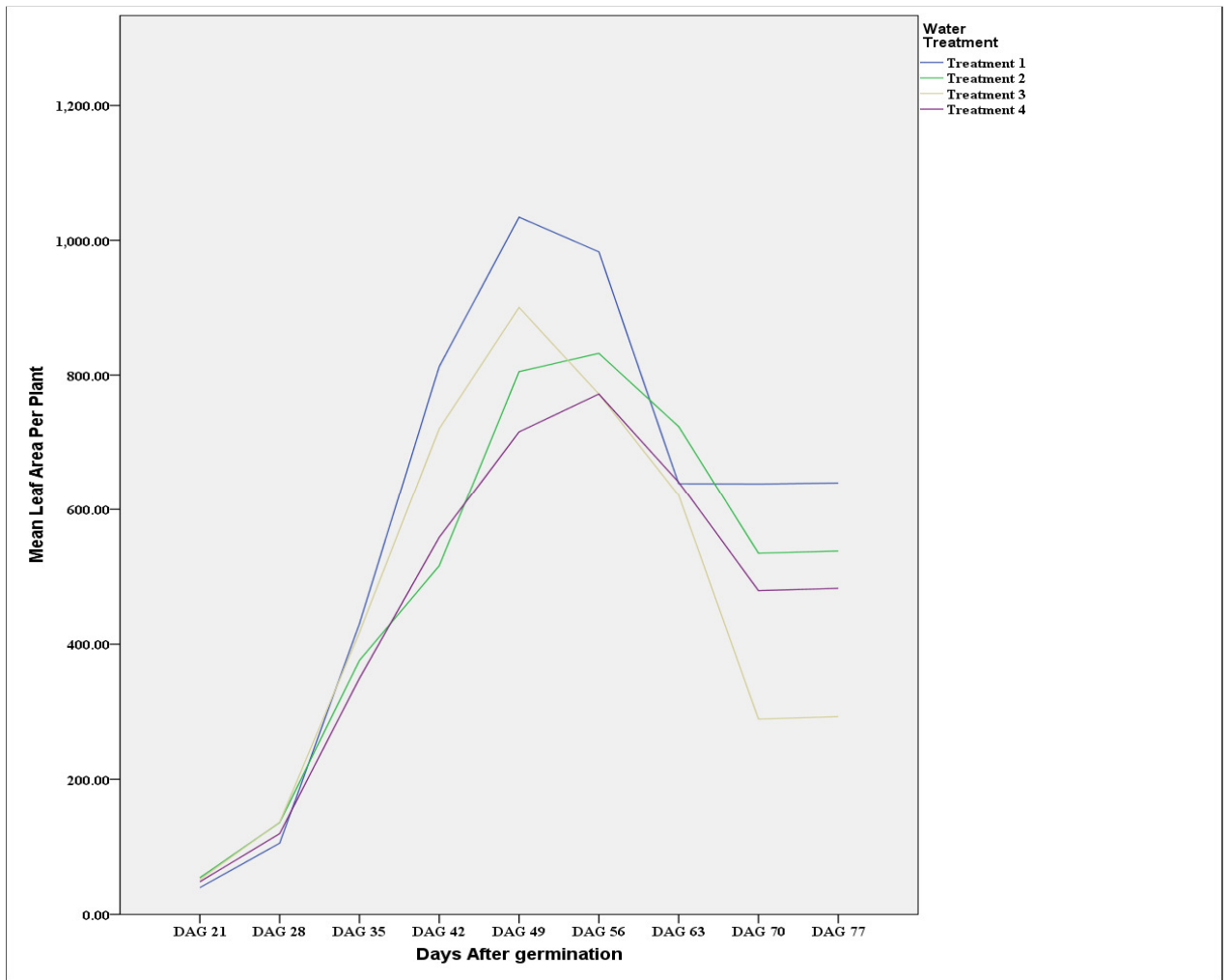
158

159 **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 |

160 **TR = treatment**

161 **DAG = days after germination**



163

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

166

167

168

169

170

171

172

173

174

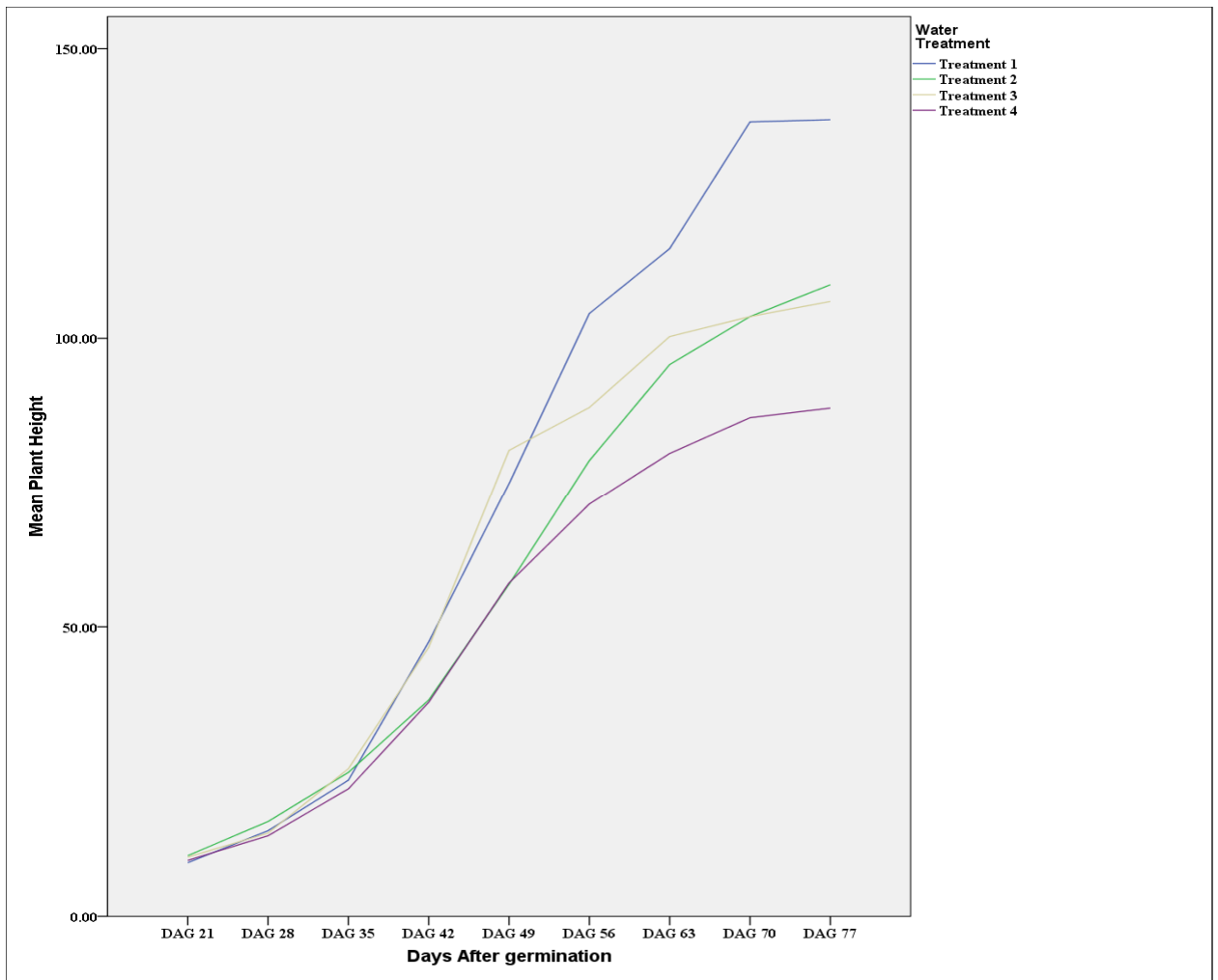
175

176

177

178

179  
180  
181  
182



183  
184  
185

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

186  
187  
188  
189

### **3.5. Flower Development**

190  
191  
192  
193  
194  
195  
196

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.

197

198

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

| <b>TR</b>            | <b>T1</b> | <b>T2</b> | <b>T3</b> | <b>T4</b> |
|----------------------|-----------|-----------|-----------|-----------|
| <b>MNFL</b>          | 6.00      | 4.00      | 4.00      | 4.00      |
| <b>Leaf Area(cm)</b> | 1034.35   | 805.26    | 900.35    | 715.97    |

200

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

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

203 **TR=Treatments**

204

205 **3.6. Fruit Development.**

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

212 **Table 4. Mean number of fruits formed from flower**

| <b>TR</b>   | <b>T1</b>   | <b>T2</b>   | <b>T3</b>   | <b>T4</b>   |
|-------------|-------------|-------------|-------------|-------------|
| <b>MNFL</b> | <b>6.00</b> | <b>4.00</b> | <b>4.00</b> | <b>4.00</b> |
| <b>MNFR</b> | <b>6.00</b> | <b>4.00</b> | <b>3.00</b> | <b>2.00</b> |

213

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

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

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

217 **TR= Treatments**

218

219

220

221

222

### 223 3.7 Discussion

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

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

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

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

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

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

268

269 **4.0 Conclusion**

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

277

278 **COMPETING INTERESTS**

279 **There Is No Competing Interest Amongst the Authors**

280

281

282 **References**

- 283 (1). Taiz, L. and Zeiger, E. (1998). Plant Physiology, Second Edition,  
284 Sinauer Associates Inc. Publishers, Sunderland, Massachusetts, 756p
- 285 (2). Poething, R.S. (1990). Phase change and the regulation of shoot  
286 morphogenesis in plants. *Science*. 250: 923-930
- 287 (3). McDaniel, C.N., Harntuentt, L.K. and Sangrey, K.A. (1996). Flowering  
288 as metamorphosis; Two sequential signals regulate floral initiation in *Lolium*  
289 *temulentum*. *Development* 122:3661-3668
- 290 (4). Zeevaart, J.A.D. and Boyer, G.I. (1987). Photoperiodic induction and  
291 the floral stimulus in *Perilla*. In: Artheton, J.B. (Ed.). Manipulation of  
292 flowering process, Botherworths, London pp26-277
- 293 (5). JLevitt.(1980). Plant Responses to Environmental Stress. Vol 2. New  
294 York: Academic Press.
- 295 (6) Veihmeyer, F.J. and Hendrickson, A.H. (1949). The application of  
296 some basic concepts of soil moisture to orchid irrigation. Proceedings,  
297 Washington State Horticultureal Association. 45:25-41
- 298 (7). Gepstein, S. and Thimmann, K.V. (1981). The role of ethylene in  
299 senescence of cut leaves. *Plant Physiol* 68: 349-354
- 300 (8). Norman, J.C. (1992). Tropical Vegetable Crops. Arthur H. Strockwell  
301 Ltd. Britain 252p

- 302 (9). F.G.J. Viets. (1967).In: Pessaraki M., ed, Handbook of plant and crop  
303 physiology, Marcel Dekker Inc. p643  
304
- 305 (10) A.C.S. Rao, B. Ramamoorthy.(1980).In: Pessaraki M., ed, Handbook  
306 of plant and crop physiology, Marcel Dekker Inc. p643  
307
- 308 (11) J.A. Acosta-Gallegos (1988). Selection of common bean (*Phaseolus*  
309 *vulgaris*) genotypes with enhanced drought toleranceand biological  
310 nitrogen fixation. PhD dissertation (Diss Abstract 88-24816). Michigan  
311 State University, EastLansing, MI. In Handbook of plant and crop  
312 Physiology., Marcel Dekker Inc. p625  
313
- 314 (12) S. Gepstein (1988). Photosynthesis. In: LD Nooden, AC Leopold, eds.  
315 Senescence and Aging in Plants. In: Pessaraki M., ed, Handbook of  
316 plant and crop physiology, Marcel Dekker Inc. p117  
317  
318