

EFFECT OF IRRIGATION INTERVALS ON GROWTH AND YIELD OF BELL PEPPER (*Capsicum annuum*) IN A TROPICAL SEMI-ARID REGION.

ABSTRACT

A field experiment was conducted to investigate the effect of different irrigation intervals on growth parameters and yield of bell pepper (*Capsicum annuum*) in Minna, a semi-arid zone city, north central Nigeria. The experiment was conducted using Randomized Complete Block Design with single factorial and four replications on 12m by 12m plot of sandy clay loamy soil. A 2m by 2m nursery plot was used and good seedlings were transplanted on 48 days after planting (DAP) to permanent plot. The plot was divided into main plots and sub-plots with buffer zone provided between the plots. Irrigation intervals used were daily, 3 days, six days and 9 days and a no-irrigation plot to serve as control. Mature bell pepper fruits were harvested on 100 DAP and used for yield determination. Growth parameters measured were stem height and diameter, number of leaf, leaf area, leaf area index, number and size of fruits which were used to determine the final yield per hectare. Results showed that the irrigation intervals used has impacts on growth parameters and yield of bell pepper. Statistical analysis with ANOVA and Least Significant Difference ($p < 0.05$) shows significant influence of irrigation intervals on yield and some growth parameters. For instance, maximum yield of 30.93ton/ha was recorded in plot with 3-day irrigation interval while minimum yield (11.02ton/ha) was recorded from the control plot and 11.91ton/ha from plot with 6-day irrigation interval. The irrigation interval also has remarkable influence on stem diameter but with little effect on stem height and leaf number. The overall results revealed that 3-day irrigation interval appeared to be optimum interval to guarantee good yield from bell pepper plot and 6-day and 9-day intervals appeared to instill much water stress on bell pepper plant. However, this observation is subject to local evapotranspiration which in turn is determined by weather conditions. It is therefore recommended that similar experiment be conducted in Minna under a controlled environment.

Keywords: Irrigation Scheduling; Leaf Area, pepper yield; Stem Diameter.

INTRODUCTION

The principal limiting factor for farmers in arid and semi-arid regions is water. Crop lands in these areas are restricted by water availability and farmers grow crops that are able to adapt to drought conditions. In some regions this has led to an increase of monocrops that are more resistant to water deficits and irrigation becomes somewhat inevitable [1]. As a result of the water scarcity, efficient use of water by irrigation is becoming increasingly important and alternative water application methods such as drip and sprinkler which contribute substantially to the best use of water for agriculture and improving irrigation efficiency therefore becomes very popular. Water use efficiency (WUE), in irrigated agriculture was described by [2] as maximizing the returns and minimizing the environmental impacts for every megalitre (ML) of water used for irrigation purposes. Irrigation should begin when the crop comes under water stress severe enough to reduce crop yield or quality. The level of stress that will cause a reduction in crop yield or quality depends on the kind of crop and its stage of development; it varies during the growing season as the crop matures [3]. For instance, corn tolerates more stress without causing a yield reduction when the stress occurs during the vegetative stage as opposed to the pollination stage. Thus, determining when to irrigate is a scheduling decision that should take into account the crop's sensitivity to stress. Irrigation scheduling requires knowledge of the soil, the soil-water status, the status of crop stress, and the potential yield reduction if the crop remains in a stressed condition [4].

Adequate amount of water is needed at the right time in order to get higher crop yield and should be applied to farmlands. Therefore, it is vital to determine the water consumptions of plants and periods that plants are susceptible for water beside the irrigation intervals in order to increase crop yield in a

limited area [5]. Water requirement of plants from seed sowing to the harvest varies depending on plant species and plant growth stages. When plants are water stressed they close their stomata and cannot photosynthesize effectively. Water shortages therefore hinder crop growth while too much water can cause large yield reductions too in bell pepper field [6]. It is pertinent that the grower must therefore determine the water needs of the crop to avoid production or quality losses. This requires an understanding of the movement and storage of water in the root zone of the crop and the rate of water use by the crop [7].

Bell pepper (*Capsicum annuum*) has been classified as susceptible to water stress, with blossom stage being the most sensitive period [8]. For high yield, adequate water supply and relatively moist soils are required during the total growing period of bell pepper. Reduction in water supply during the growing period has an adverse effect on yield and the greatest reduction in yield occurs when there is a continuous water shortage until the fluorescence stage [9]. The period at the beginning of the flowering is most sensitive to water shortage and soil water depletion in the root zone during this period should not exceed 25% [3]. Water shortage just prior and during early flowering reduces the number of fruits. Controlled irrigation is therefore essential in bell pepper plot for high yields because the crop is sensitive to both over and under irrigation at this crucial stage [10]. For this reason, the crop must be supplied with adequate water to ensure vigorous growth, good flowering conditions and higher yield [1, 3, 11].

The people living in Minna, Nigeria are predominantly farmer with quite a larger percentage of them specializing in bell pepper production. The crop (bell pepper) is known to respond quickly and sharply to shortages of water and sometimes also respond negatively if too much water is added to its field either by through rainfall or by irrigation. It therefore becomes necessary to conduct a study to know optimum irrigation interval and quantity of water needed by bell pepper to thrive and fruit profitably. Several efforts have been made by researchers, in Minna [3, 10, 12] to study the response of bell pepper to irrigation when propagated under flooding system of irrigation. However, these researches were not able to answer the question of how much water is needed by the crop when irrigation is needed and at what interval the irrigation be carried out and thus need to be determined. The past researches focused on yield of bell pepper even when too much water is added and not even at a regular interval. There is a need to study the yield and growth response of bell pepper under irrigation with measured volume of water at a regulated irrigation interval. The objectives of this study are therefore to determine the effect of irrigation on growth of bell pepper; and to evaluate the yield potential of bell pepper under different irrigation intervals.

MATERIALS AND METHODS

The study area for this study is *Tudun Fulani, Bosso* Local Government Area of Niger State, Nigeria Minna, capital of Niger State, a semi – arid town in North central Nigeria. (Figure 1). The city lies in latitude 9° 36' 50"N and longitude 6° 33'25". Minimum temperature in Minna is between 19°C and 22°C while maximum ranges between 38°C and 40°C. Precipitation separates the town into two major seasons, wet season which spans from May to October and dry season from November to April. Average annual precipitation is 1300mm with highest rainfall in August. An average daily sunshine hour is 9.2 and evapotranspiration ranges from about 25mm in august to 90mm in March. Annual groundwater recharge in Minna is about 13% of total annual precipitation [13].

Experimental Plot

The experimental plot was laid out using Randomized Complete Block Design (RCBD) with single factorial arrangements. Bell pepper was raised on a nursery plot of 2m by 2m plot of land. The textural classification of the soil on the nursery and permanent sites were determined using sieve analysis. The result revealed that the soils were sandy clay loam with textural classification of 56.4% sand, 22.88% silt and 22.72% clay.

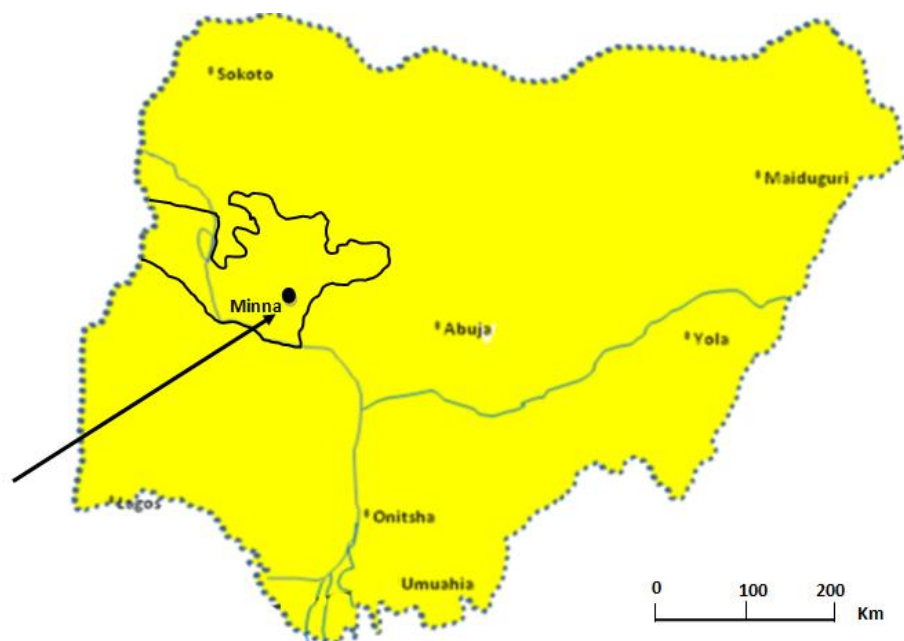


Figure 1: Map of Nigeria Showing Niger State and Location of Minna (arrowed)

Planting on raised nursery bed was done mid-July and at 48days after planting (DAP), healthy seedlings were selected and transplanted on the field plot. A field plot of 12m by 12m main plot was prepared and a control plot of 12m by 2m was marked out. A buffer zone of 1m was provided between plots. The remaining plot was divided into four sub-plots of 4.5 by 6m each for the four treatments of 1day, 3days, 6days and 9days irrigation intervals. For replications, each of the sub-plots was further divided into four sub-sub plots of 2.25m by 3m each with a buffer zone of 0.5m between each of them. In the plot, a planting space of 45.7cm was given within row and 60cm space was given between rows. For each of the treatments and replicates, 20 litres of water was added on each irrigation day using portable sprinkler irrigation except on the control plot which was propagated under rain-fed condition. The water quantity was chosen based on agronomical requirements of bell pepper of effective rooting zone depth of 0.31m and wetting diameter of 41.67m/km [7]. Normal pepper cultural practices and pest management practices recommended by Niger State Agricultural Development Program were followed. 1kg of NPK 15, 15, 15 was applied to each of the sub-plot and control plot at 35 DAP. Mature bell pepper fruit was harvested at 100 DAP.

Determination of Crop Data

Stem diameter was measured with A digital vernier caliper (Solar ABSOLUTE Digimatic Caliper, Model CD-S6"C, Mitutoyo Corporation, Japan) on five randomly selected pepper stands on each plot. The measurements were done during one month, two months and three months growth stage of the pepper and the average calculated for statistical analysis. The same method was used for the stem height but the measurement was done with a measuring tape. Five standing bell pepper stands were randomly selected from each plot and the average plant height for each treatment was determined. Leaf area was determined with mathematical formulae based on the leaf length (leaf base to leaf apex) measured as the maximum length of leaf multiplied by maximum width and the leaf coefficient of the crop:

$$LA = \text{Max.length of leaf} \times \text{Max. width} \times \text{Leaf Coefficient } (\alpha)$$

After measuring leaf area, leaf Area Index (LAI) which is the ratio of the total area of all leaves on a plant to the area of ground covered by the plant was determined per plant by dividing its leaf area by the area of ground covered by the plant. During fruiting stage, the weight of each matured fruit was measured using digital balance of accuracy t 0.001 grams (Model AR3130, Ohaus Corp., Pinebrook, NJ) digital weighing balance. The diameter of the biggest and the smallest fruits harvested from each

experimental plot was also measured using the same digital balance. The data obtained for various variables were subjected to statistical analysis using Analysis of Variance (ANOVA) technique. The means were compared using Least Significant Difference (LSD) test at 5% level of significance [14].

RESULTS AND DISCUSSION

The results of plant parameters are presented in Tables 1a and 1b. The results show that interval of irrigation from the tables has effect on all the plant parameters. For instance, the pepper stem diameter varies as the irrigation interval changes with 3 days irrigation interval having the biggest stem diameter. Statistical analysis ($p < 0.05$) revealed that the change in irrigation interval has a significant effect on the stem diameter of the bell pepper (Table 2 and Table 3). From Table 1a, stem height also varies with change in interval of irrigation. The tallest height was observed in the plot with 3 days irrigation interval while the control plot has the least height. However, statistical analysis ($p < 0.05$) shows that the change in interval of irrigation has no significant effect on plant height (Table 3 and Table 4) except on 3 days irrigation interval. This observation supported the findings of [4, 9, 15]. They concluded after carrying out field experiments that plant height and yield of bell pepper has no correlation.

Table 1a: Growth Parameters of Bell Pepper.

Treatments	Stem diameter (cm)		Stem height (cm)		Leaf Number		Leaf Area (m ²)	
	Treatment total	Treatment mean	Treatment total	Treatment mean	Treatment total	Treatment mean	Treatment total	Treatment mean
Control	2.366	0.4732	178.7	35.74	369.0	73.80	62.71	12.54
Daily irrigation	3.519	0.7038	215.5	43.10	943.0	188.6	89.78	17.96
3 days interval	3.563	0.7126	224.8	44.96	762.0	152.4	90.25	18.05
6 days interval	3.364	0.6728	201.7	40.34	617.0	123.4	92.15	18.43
9 days interval	3.045	0.6090	205.0	41.00	593.0	118.6	57.57	11.51
Total	15.857	0.6343	1025.7	41.028	3,284	131.36	392.46	15.70

Leaf number and leaf area from Table 1a were remarkable affected by change in irrigation interval. While daily irrigation interval shows the maximum leaf number and control plot recorded the least leaf number, leaf area was highest (92.15m²) in plot with 6 days irrigation interval and minimum leaf area of 63.71m² was recorded in the control plot. Statistical analysis ($p < 0.05$) however from Table 3 only shows significant effect on leaf number at daily irrigation plot and the plot with 3 days irrigation interval while there is no significant effect between number of leave per plant and 6 and 9 days irrigation intervals. A significant correlation has been established by [2] between bell pepper yield and yield components like number of fruit per plant and leaf number. Therefore any agronomical practices that are having effect on leaf number may eventually affect the yield of bell pepper.

Table 1b: Growth Parameters of Bell Pepper.

Treatments	Leaf Area Index	Average Fruit Number	Average Fruit Weight (g)	Pepper Yield (kg/m ²)
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	Treatment total	Treatment mean	Treatment total	Treatment mean	Treatment total	Treatment mean	Treatment total	Treatment mean
Control	0.0313	0.0063	9.00	1.80	37.28	7.46	1102.22	220.44
Daily irrigation	0.0377	0.0075	49.00	9.80	38.85	7.77	2580.35	516.07
3 days interval	0.0375	0.0075	55.00	11.00	41.06	8.21	3093.74	618.75
6 days interval	0.0384	0.0077	22.00	4.40	41.79	8.36	1191.26	238.25
9 days interval	0.0241	0.0048	25.00	5.00	35.51	7.10	1222.71	244.54
Total	0.1690	0.0068	160.0	6.40	194.49	7.78	9190.28	367.61

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163 **Table 2: Analysis of Variance (RCBD) of Stem Diameter**

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Tabular F 5%
Replication (r)	4	0.0165	0.00413		
Treatment (t)	4	0.1950	0.04875	16.14*	3.01
Error	16	0.0483	0.00302		
Total	24	0.2598			

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* Significant at 5% level

165 It can be seen from Table 1b that plot with 3 days irrigation interval thrives better with respect to fruit
166 number and fruit weight than other plots with different irrigation intervals though closely followed by
167 plot with daily irrigation interval. In all the yield parameters from the table 1b, expectedly, minimum
168 values were recorded from control plot and the plot with 6 days irrigation interval. Statistics ($p < 0.05$)
169 shows that the irrigation interval at daily and 3 days irrigation interval have significant effects on fruit
170 number per plant and yield but shows no significant relationship between the yield parameters and
171 irrigation intervals of 6 and 9 days (Table 3).

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180 **Table 3: Comparison between Mean Crop Parameters of Control Plot and Four irrigation**
181 **Treatments, Using the LSD Test**

Treatments	Stem diameter (cm)		Stem height (cm)		Leaf Number		Pepper Yield (kg/m ²)	Fruit Number/plant		
	Mean stem diameter	Deviation from control	Mean stem height	Deviation from control	Mean Leaf Numbe	Deviation from control	Mean Pepper Yield	Deviation from control	Mean Fruit Number	Deviation from control
Control	0.4732	-	35.74	-	73.80	-	220.44	-	1.80	-
Daily irrigation	0.7038	0.2306*	43.10	7.36 ^{ns}	188.6	114.8*	516.07	295.63*	9.80	8.00*
3 days interval	0.7126	0.2394*	44.96	9.22*	152.4	78.6*	618.75	398.31*	11.00	9.20*
6 days interval	0.6728	0.1996*	40.34	4.61 ^{ns}	123.4	49.6 ^{ns}	238.25	17.31 ^{ns}	4.40	2.60 ^{ns}
9 days interval	0.6090	0.1358*	41.00	5.26 ^{ns}	118.6	44.8 ^{ns}	244.54	24.10 ^{ns}	5.00	3.20*

* Significant at 5% confidence level, ns- Not significant at 5% confidence level

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184 **Table 4: Analysis of Variance (RCBD) of Plant Height**

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Tabular F 5%
Replication (r)	4	131.095	32.77		
Treatment (t)	4	240.954	60.24	1.97 ^{ns}	3.01
Error	16	488.076	30.51		
Total	24	860.125			

185 ns - Not significant at 95% Confidence Level

186 Generally analysis of variance ($p < 0.05$) shows that the interval of irrigation tested in this research has
187 significant effect on fruit number and the general yield (Table 5 and Table 7) but shows no significant
188 effect on leaf area of bell pepper, Table 6.

189 **Table 5: Analysis of Variance (RCBD) of Number of fruits per plant**

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Tabular F 5%
Replication (r)	4	26.00	6.50		
Treatment (t)	4	299.2	74.80	17.92*	3.01
Error	16	66.80	4.175		
Total	24	392.0			

190 * Significant at 95% Confidence Level

191 The results obtained in this research agreed with the results of [1, 5, 16] for bell pepper. The
192 convergent conclusion of the researchers was that irrigation interval has significant effect on yield of
193 bell pepper but of no significant effect on stem height and number of branches per stem.

Table 6: Analysis of Variance (RCB) of Leaf Area

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Tabular F 5%
Replication (r)	4	187.03	46.76		
Treatment (t)	4	227.80	56.95	2.54 ^{ns}	3.01
Error	16	358.37	22.40		
Total	24	773.20			

ns - Not significant at 95% Confidence Level

It was observed by [17] that total plant biomass increased with reducing the irrigation interval up to 5days, due to more nutrients uptake and higher photosynthesis rates. Irrigation is most important at the time of flower and fruit production. The plants under water stressed conditions tends to shorten their life span and try to complete their life cycle in haste which causes minimum flowering and fruiting of plants with long irrigation interval. The results clearly indicated those treatments other than daily and 3days of intervals caused more stress to the plants which lead to the reduction in plant height, number of leaves, leaf area and less production of chlorophyll.

Table 7: Analysis of Variance (RCBD) of Fruit Yield

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Tabular F 5%
Replication (r)	4	39619.34	9904.84		
Treatment (t)	4	693238.61	173309.65	9.97*	3.01
Error	16	278282.50	17392.66		
Total	24	3378449.86			

* Significant at 95% Confidence Level

Effect of Irrigation Interval on Yield of Bell Pepper.

Yield is the most important component of plant performance under a set of growing conditions as any physiological and agronomical parameters at a given stage of growth would be of use when its effect is reflected on the yield of the crop. In this experiment, yield was defined as the weight of bell pepper harvested from the plots at maturity in ton per hectare (ton/ha) as presented in Table 8.

Table 8: The Yield of Bell Pepper Harvested from the Experimental Plots.

Sample description	Control	Daily	3 days	6 days	9 days
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		Irrigation	interval	interval	interval
Weight of biggest fruit (g)	12.29	13.61	18.03	18.12	11.63
Diameter of biggest fruit (cm)	2.14	3.14	3.03	2.97	2.95
Length of biggest fruit (cm)	3.14	5.38	5.02	7.86	4.85
Weight of smallest fruit (g)	3.92	1.54	2.02	2.27	1.13
Diameter of smallest fruit (cm)	2.17	1.60	1.44	1.83	1.68
Length of smallest fruit (cm)	5.13	2.30	2.95	1.96	3.38
Total number of fruits	9	49	55	22	25
Total yield (kg/m ²)	1.102	2.580	3.093	1.191	1.222
Total yield (ton/ha)	11.02	25.80	30.93	11.91	12.22

It can be seen from Table 8 that maximum yield of 30.93ton/ha was harvested from the plot with 3 days interval while the minimum yields (11.02ton/ha and 11.91ton/ha) were recorded from control plot and plot with 6 days irrigation interval respectively. This result is similar to the results obtained by [2,16]. It was submitted by these researchers that for bell pepper to thrive well and have a good yield, the interval of irrigation must be between 2 days and four days.

CONCLUSION

This study established that irrigation intervals have effects on growth parameters and yield of bell pepper. Parameters affected are stem diameter, leaf area and leaf area index but with little effects on number of leaves and stem height. The results of the experiment also indicated that irrigation water amount and frequency determine water use efficiency and final yield from bell pepper plot. Since overall yield revealed that 3-day irrigation interval guaranteed optimum performance of bell pepper in terms of yield. However, the experiment was carried out in an open environment where weather and natural rainfall have some effects. It is therefore recommended that the same research be carried out in a controlled environment (greenhouse) to be able to adequately ascertain the optimum irrigation interval for bell pepper

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