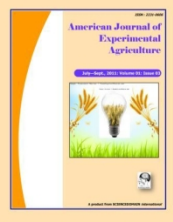

American Journal of Experimental Agriculture
4(5): 515-524, 2014

SCIENCEDOMAIN *international*
www.sciencedomain.org

Effect of Irrigation Intervals on Growth and Yield of Bell Pepper (*Capsicum annuum*) in a Tropical Semi-arid Region

P. A. Adeoye[1,4*], R. A. Adesiji[2], A. J. Oloruntade[3] and C. F. Njemanze[4]

[1]Department of Biological and Agricultural Engineering, University Putra, UPM Serdang, 43400 Daarul Ehsan Selangor, Malaysia.
[2]Department of Civil Engineering, University Putra, UPM Serdang, 43400 Daarul Ehsan Selangor, Malaysia.
[3]Department of Agricultural and Bio-Environmental Engineering Technology, Rufus Giwa Polytechnic, P.M.B. 1019, Owo, Ondo State, Nigeria.
[4]Department of Agricultural and Bioresources Engineering, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author PAA designed the concept of entire project and wrote the first draft of the manuscript which was read through by all authors. Author RAA carried out the soil analysis of the experimental plot and supervised the irrigation scheduling aspect of the work. Author AJO handled all the statistical analysis and interpretation on the data. Author CFN prepared the experimental plot, planted the pepper crop, carried out all the cultural practices and determined all the growth and yield parameters under the supervision of Author PAA. All authors read and approved the final manuscript.

Original Research Article

Received 9th November 2013
Accepted 13th December 2013
Published 9th January 2014

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 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

**Corresponding author: Email: pheterhardey@yahoo.com;*

days and 9 days and a no-irrigation plot to serve as control. Mature bell pepper fruits were harvested on 100 days after transplanting (DAT) 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: Growth parameters; Irrigation Scheduling; pepper yield; semi –arid region.

1. 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 [2]. 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 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 is irrigation 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.

2. 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. (Fig. 1). The city lies in latitude 90º36’50’’N and longitude 60º33’25’’. Minimum temperature in Minna is between 19ºC and 22ºC while maximum ranges between 38ºC and 40ºC. 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. [13].

2.1 Experimental Plot

This study was conducted between November 2011 and August 2012. The experimental plot was laid out using Randomized Complete Block Design (RCBD) with single factorial arrangements. Five soil samples were taken at random from depth 0 -15cm and the soil samples were analyzed for pH, soil organic matter nitrogen, phosphorus, potassium and magnesium content. Also textural classification of the soil samples was also determined. 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 and classifies with USDA textural triangle.

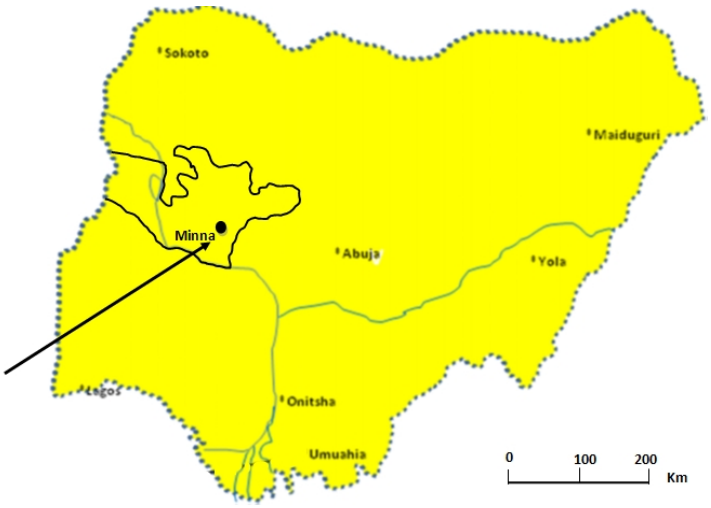

Fig. 1. Map of Nigeria showing niger state and location of Minna (arrowed)

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 1 day, 3 days, 6 days and 9 days 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, Irrigation water was applied in measured quantities with pipe directly to the plots under surface and drip irrigation. The drip emitters, 17mm diameter were placed 45 cm apart and laterals at 125 cm apart. The drips were pressure compensatory and had a discharge rate of 5 l/h. Treatments under drip system were scheduled by considering the wetted area. In capsicum, wetted area was considered as 36% [7]. A water meter was used to measure the amount of water applied on each irrigation operation which normally last for one hour. 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 days after transplanting (DAT). Mature bell pepper fruit was harvested at 100 DAT.

2.2 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 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 (correction coefficient) of the bell pepper which [14] put as 0.62: Therefore,

$$LA = Max.length\ of\ leaf\ X\ Max.\ width\ X\ Leaf\ Coefficient\ (\alpha)$$

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 95% level of significance [15].

3. RESULTS AND DISCUSSION

Results of soil analysis were presented in Table 1. The textural classification is 52.3% sand, 31.1% silt and 16.6% clay, making the soil to be sandy loam using USDA soil textural triangle. 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]. Soil pH is slightly acidic with values ranging from 5.09 -6.42. The average pH (5.83) was below the average value of 6.5 that was recommended as optimum [8] for availability of plant nutrients in soil. Average soil organic matter was 1.60%, nitrogen, phosphorus; potassium and magnesium have average values of 2.48mg/kg,9.64mg/kg,0.66mg/kg and 2.40mg/kg respectively in the soil. These nutrients values make the soil in the experimental plot to be ideal for propagation of bell pepper [8]. Each emitter is having a discharge of 5l/hour and each subplot has an average of 8 emitters, therefore a total of 40 litres of irrigation water is applied to each subplot on each irrigation event.

Table 1. Soil analysis results

Soil samples	pH	SOM (%)	N (mg/kg)	P (mg/kg)	K (mg/kg)	Mg (mg/kg)	Textural class
1	5.63	3.21	3.01	9.21	0.94	1.06	SL
2	6.42	1.04	5.61	8.21	0.83	1.43	SL
3	6.21	0.64	2.30	11.63	0.38	2.00	SL
4	5.09	1.62	0.94	8.44	0.71	4.21	SL
5	5.82	1.49	0.61	10.71	0.42	3.46	SL
Min	5.09	0.64	0.61	8.21	0.38	1.06	
Max	6.42	3.21	5.61	11.63	0.94	4.21	
Mean	5.83	1.60	2.49	9.64	0.66	2.43	
SD	0.52	0.98	1.98	1.48	0.25	1.35	

SOM- Soil organic matter, SL- Sandy loam.

The results of growth parameters are presented in Tables 2. 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. 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 2) except on 3 days irrigation interval. This observation supported the findings of [4,9,16]. They concluded after carrying out field experiments that plant height and yield of bell pepper has no correlation.

Leaf number and leaf area were remarkably 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 ($18.43cm^2$) in plot with 6 days irrigation interval and minimum leaf area of $12.5cm^2$ was recorded in the control plot 9 (Table 2). Statistical analysis ($p<0.05$) however 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 in the plots with 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. From the yield parameters Table 3, irrigation intervals have effect on number of fruit per plant. Highest number of fruit (11.0) was recorded in 3-day irrigation interval and the lowest number of fruits (1.8) recorded from control plot. Significant influence of irrigation interval was also observed in all the treatment ($p<0.05$) except on the plot with 6-day irrigation interval.

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

The results obtained in this research agreed with the results of [1,5,17] for bell pepper. The convergent conclusion of the researchers was that irrigation interval has significant effect on yield of bell pepper but of no significant effect on stem height and number of branches per stem. It was observed by [18] that total plant biomass increased with reducing the irrigation interval up to 5 days, 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 3 days 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 2. Comparison between Mean growth parameters of control Plot and four irrigation treatments, using the LSD test

Treatments	Stem diameter (cm)		Stem height (cm)		Leaf number		Leaf area (cm^2)	
	Mean stem diameter	Deviation from control	Mean stem height	Deviation from control	Mean leaf number	Deviation from control	Mean leaf area	Deviation from control
Control	0.4732	-	35.74	-	73.80	-	12.5	-
Daily irrigation	0.7038	0.2306*	43.10	7.36^{ns}	188.6	114.8*	17.96	7.46*
3 days interval	0.7126	0.2394*	44.96	9.22*	152.4	78.6*	18.05	7.55*
6 days interval	0.6728	0.1996*	40.34	4.61^{ns}	123.4	49.6^{ns}	18.43	7.93*
9 days interval	0.6090	0.1358*	41.00	5.26^{ns}	118.6	44.8^{ns}	11.51	1.01^{ns}

** Significant at 95% confidence level, ns- Not significant at 95% confidence level*

Table 3. Comparison between mean yield parameters of control plot and four irrigation treatments, using the lsd test

	LAI		No of fruit per plant		Fruit weight (g)		Pepper yield (kg/m^2)	
	Mean LAI	Deviation from control	Mean number of fruit	Deviation from control	Mean fruit weight	Deviation from control	Mean pepper Yield	Deviation from control
Control	0.0063	-	1.80	-	7.46	-	220.44	-
Daily irrigation	0.0095	0.0032*	9.80	8.00*	8.27	0.81*	516.07	295.63*
3 days interval	0.0098	0.0035*	11.00	9.20*	8.77	1.31*	618.75	398.31*
6 days interval	0.0077	0.0014^{ns}	4.40	2.60^{ns}	7.78	0.32^{ns}	238.25	17.81^{ns}
9 days interval	0.0068	0.0003^{ns}	5.0	3.20*	7.50	0.04^{ns}	244.54	24.1^{ns}

** Significant at 95% confidence level, ns- Not significant at 95% confidence level*

3.1 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 4.

It can be seen from Table 4 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 [2,17]. 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.

Table 4. The yield of bell pepper harvested from the experimental plots

Sample description	Control	Daily Irrigation	3 days interval	6 days interval	9 days 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	9.00	49.00	55.00	22.00	25.00
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

4. CONCLUSION

It has been established from this study 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 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.

ACKNOWLEDGEMENT

The assistance received by soil and water analytical laboratory of Nigerian Cereal Research Institute, Badeggi, Niger State, Nigeria is hereby acknowledged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dugo GV, Orgas F, Fereres E. Responses of pepper to deficit irrigation for paprika production. Scientia Horti. 2007;114:77–82.
2. Bekele S, Tilahun K. Regulated deficit irrigation scheduling of capsicum in a semi-arid region of Ethiopian. Agricultural Water Management. 2007;89:148-152.
3. Okesusi WT, Olorunwa F. Experimental determination of growth and yield response of bell pepper to irrigation with diary wastewater. Nig. J. Tech. Dev. 2006;6(3):56-65.
4. Gadissa T, Chemeda D. Effects of drip irrigation levels and planting methods on yield and yield components of green pepper in Bako, Ethiopia. Agricultural Water Management. 2009;96:1673–1678.
5. Ngouajio M, Wang G, Goldy RG. Timing of irrigation initiation affects IWUE and yield of bell pepper under plastic mulch. J. Ame. Soc. Hort. Sci. 2008;18:325-344.
6. Komlekcioglu N, Gerceu S, Dikilitas M. Response of pepper (*Capsicum annuum)* to different irrigation frequencies and water amount, growth, yield and fruit characteristics. J Agric. Fac. HRU. 2008;12(4):51-56.
7. Ertek A, Sensory S, Gedik I, Kucukyumuk C. Irrigation scheduling for green pepper grown in field conditions by using class-A pan evaporation values. Ame.-Eurasian J. Agric. Env. Sci. 2007;2(4):249–358.
8. Yahaya O, Alao F, Odigie CJ. Yield, crop-water-use evaluation for pepper production under irrigated cultivation in Akure, Nigeria. Global J. Sc. Frontier Res. Agric & Bio. 2012;12(1):18-22.
9. Akinbile CO, Yussouf MS. Growth and water use pattern of chilli pepper under different irrigation scheduling and management. Asian J. Agric. Res. 2011;5:154-163.
10. Haruna I, Oladiran JA. Effect of flood irrigation on fruit size, colour and seed quality of bell pepper. J. Agric. Tech. 2002;3(2):78-87.
11. Palada MC, Cole WM, Crossman MAS. Influence of effluents from intensive aquaculture and sludge on growth and yield of bell peppers. J. Sus. Agric. 2008;14(4):85–103.
12. Salaudeen MA, Oladokun JD. Response of bell pepper variety to check basin irrigation system in arid zone. Nig. J. Tech. Dev. Res. 2008;7(2):119-126.
13. Nigerian Meteorological Agency (NIMET). Quarterly Whether Report For North Central Nigeria. NIMET, Abuja. 2009;46.
14. Borzhiwa PR. Coefficients for determination of the leaf area in three burley tobacco varieties. J. Cen. Euro. Agric. 2006;7(1):7-12.
15. Clive IR. Experimental Statistics for Agriculture and Horticulture. Cambridge University Press Cambridge. 2010:353.
16. Halim AE. Impact of alternate furrow irrigation with different irrigation intervals on yield, water use efficiency and economic return of corn. Chilean J. Agric. Res. 2013;73(2):175-180.
17. Manuel FI, Nwonuala A, Davis DD. Growth response of fluted pumpkin (*Telfairia occidentalis*) to combination of irrigation intervals and spent mushroom substrate in the Niger Delta Region of Nigeria. African J. Biotech. 2012;11(14):3346-3351.

18. Paul JC, Mishra JN, Pradhan PL, Panigrahi B. Effect of drip and surface irrigation on yield, water use efficiency of *capsicum annuum* grown under mulch and non-mulch conditions in eastern coastal India. European J. Sus. Dev. 2013;2(1):99-108.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=394&id=2&aid=3156