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IMPROVING WATER USE EFFICIENCY INPEPPER (*CAPSICUM ANNUUM L.)* PRODUCTION UNDER DRIP IRRIGATIONIN ILARO, OGUN STATE, NIGERIA

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Abstract:
Irrigation scheduling is pivotal for precision and sustainable farming, optimum crop growth and yield, as well as water use efficiency (WUE), especially in water-limited areas. The study aims to determine water use efficiency, as well as the effect of water stress on the yield of pepper under drip irrigation system. The study was conducted at the Agricultural and Bio-environmental Engineering Research Farm of the Federal Polytechnic Ilaro, Ogun State, Nigeria. Four irrigation treatments were investigated. The experiment had four irrigation levels. The first irrigation application treatment (A) consists of 100% of actual crop evapotranspiration (ET). The second (B) was 75% ET. The third (C) was 50% ET and fourth (D) consist of 25% ET. The experiment was arranged in a randomized complete block design (RCBD) with four replications and 2 varieties of pepper: Capsicum annum and Capsicum frutescens. Irrigation applications were applied for 3 weeks after transplanting and thereafter continued for the whole growing season. Parameters such as such soil, agronomic and crop's consumption water use were measured and the results subjected to statistical analysis. The results indicated that there was a significant difference between the WUE, yields and growth parameters under different levels of irrigation in the two pepper varieties. The results showed that water use efficiency, yields and other agronomic parameters such as plant height, number of leaves and fruit length and weight were higher during the studies periods for both pepper varieties under treatments A and B compared with other treatments C and D respectively. However, there was no significant difference in WUE of treatments A and B. Statistical analysis among the agronomic parameters showed a significant difference ($p<0.05$) in all the treatments. It was concluded that irrigating at 75% ET in the study area will result in water saving and maximum sustainable production of these pepper varieties.

Keywords: *Drip, Irrigation, Pepper, Production, Water, Efficiency, Sustainable*

Introduction

Peppers (Capsicum annuum L.) belong to the family Solanaceae. It is an important crop majorly consumed all over the world. It is a native of tropical South America specifically Brazil which is understood to be the natural home of peppers (Raphael *et al.*, 2019). According to Alao *et al.,* (2017), present world production of peppers is about 19 million tons fresh fruit from 1.5 million hectare (ha). The fruits are considered to be vegetable and consumed all over the world as a spice. It is widely cultivated in every country of the world (Adewoyin *et al.,* 2010). There are about 25-30 species of Capsicum, *Capsicum annuum* is the most widely cultivated species (Quartey *et al.,*2014). The production of peppers has increased in recent years with Nigeria known to be one of the highest producers in the world (Erinle, 1989). The favorable climatic conditions of Nigeria support the growth and production. Peppers are tropical crops and grow best at temperatures between 18 and 30°C. The crop can acclimatize to different soil types but grow better in a well-draining sandy soil. The soil should have a pH between 6 and 7. Peppers are planted in a raised bed and in area that receives full sun for most of the day (Raphael *et al.*, 2019). Water resources considered bountiful have now come under increasing pressure due to rapidly increasing population and competing demand from other water consuming sectors. As a result, water-saving agriculture is becoming the most effective way to solve problem of water shortage and competition in agriculture. Drip irrigation is an acknowledged technique for achieving high efficiencies in water use of crops by wetting only a limited part of the root zone (Assouline *et al*, 2002). This system of irrigation contributes to sustainable use of water resources for agriculture. With the system of drip irrigation, water and nutrients can be applied directly to the crop at the root level, having positive influences on yield and water savings and thus, increasing the irrigation performance (Owusu-Sekyere*et al.,* 2010; Nagaz *et al.*, 2012). Efficient use of water for irrigation is becoming increasingly necessary. The aspect of agronomic management of water utilization by the crop is generally described as water-use efficiency (WUE). This WUE can be achieved by applying deficit irrigation, irrigation scheduling and other improving agricultural practices aimed at increasing the crop yields (Quezada *et al.*, 2011; Fagbayide *et al.*, 2018). Also, in terms of water and increased yield, drip irrigation has been proved to be a success (Bhardwaj, 2001).

Background Study

Pepper can be grown as a rain-fed crop or raised entirely under irrigation in areas with very low amount of rainfall. The moisture content of the soil and the prevailing temperature has important effects on the growth and yield of pepper. The amount of stored soil moisture for cultivation of peppers may not be adequate for higher yield under varied soil and agro-climatic conditions. Inadequate water result in water stress crop. Precise water use consumption of pepper must be known and sustained for its growth, development and yield. Water stress affects growth, chlorophyll contents, photosynthetic rate, transpiration, and stomata conductance. It also has effects on yield because whenever actual evapotranspiration (ETa) is less than maximum evapotranspiration (ET_{max}.), evapotranspiration deficit (ETd) occurs and yield is reduce below the maximum yield (Ymax.) (Alatise, 2002). Water deficit is an important factor in determining the responses and adaptations of a specie to water stress. Pepper (Capsicum annum L.) for fresh market production is rather very common in areas like Ilaro, Ogun State, a region where water supplies for irrigation are rather becoming dwindling due to climatic changes (Nagaz *et al.*, 2012). Attempts had been made to grow pepper under deficit irrigation in some places in Nigeria but none of this attempt has been made in Ilaro areas of Ogun State, Nigeria. Doorenbos and Kassam (1979) classified pepper as a crop sensitive to water stress and it is grown mainly during rainy season. Such sensitivity has been documented in several reports that studied the yield reductions effected by water stress (Delfine *et al*., 2001; Sezen *et al*., 2006). For high yields, an adequate water supply and relatively moist soils are required during the entire growing season. A significant yield reduction was reported by limiting the amount of water supplied during different growing periods such as vegetative, flowering or fruit settings (Doorenbos and Kassam, 1979). Sound knowledge of the water stress status is required for optimum irrigation scheduling. Likewise, efficient system of water management must be adopted by the irrigation farmers through techniques that apply water to crops based on crop coefficients that correspond to the actual water requirements at the growing conditions (Zegbe-Dominguez *et al.*, 2003; Awodun, 2007; Nagaz *et al.*, 2012). Therefore, the objective of this study is to determine water use efficiency and productivity of peppers under drip irrigation system in south western Nigeria by applying different water application as a function of crop evapotranspiration.

Materials and Methods

Study Areas

The field experiment was conducted at the Research Farm of the Department of Agricultural and Bio-Environmental Engineering, Federal Polytechnic, Ilaro, Ogun State, Nigeria during 2018/2019 and 2019/2020 dry seasons, respectively. Ilaro is situated within the tropical region of Nigeria on latitude 6°53'11.5" N and longitude 3°1'13.8" E and at altitude of 89 m above sea level. The climates of Ilaro were characterized with two distinct seasons. The rainy season commences in April and ends in early November while dry season starts from early November to March. Mean annual rainfall in Ilaro is 1256 mm. Mean temperature during wet and dry seasons in Ilaro are 23.6 and 34.2 °C respectively. Soils in Ilaro are characterized as fine sandy clay loam. The soil physical and chemical properties were determined using standard methods. Details are shown in Table 1 below.

Table 1: Soil physical and chemical properties of the study site

Parameters	Mean (STD)
Sand (%)	76.68 (± 0.22)
Silt (%)	9.84 (± 0.05)
Clay (%)	13.48 (± 0.16)
Textural Class	Loam sand
Organic matter (%)	2.28 (± 0.05)
Organic carbon (g/Kg)	1.32 (± 0.03)
pH (H_20)	6.2 (± 0.04)
P (%)	10.36 (± 0.13)
N (%)	0.43 (± 0.36)
Total porosity (%)	48.24 (± 1.37)
Bulk density (Mg/m^3)	1.43 (± 0.03)
EC (dS/m)	8.10 (± 1.22)
Mg (Mol/Kg)	1.89 (± 0.46)
Ca (Mol/Kg)	7.91 (± 0.21)
Na (Mol/Kg)	0.69 (± 0.03)
K (Mol/Kg)	0.76 (± 0.11)

Experimental treatments description and water application

Four irrigation treatments were investigated. The first irrigation application received water at 100% of crop evapotranspiration (ETc), the second (B) received water at three-quarter (75% Etc), the third (C) received water at half (50% ETc) while the fourth (D) received water at one-quarter (25% ETc). The experiment was arranged in a 4 x 4 x 2 randomized complete block design (RCBD) consisting of 4 treatments, 4 replicates and 2 varieties. The two pepper varieties locally known as Atarodo and Sombo (Capsicum annum and Capsicum frutescens). Capsicum annum and Capsicum frutescens were obtained from the National Institute of Horticulture (NIHORT), Ibadan, Nigeria to certify the seeds viability. The seeds of the peppers used were nursed for five weeks at the farm site. Pepper seeds were transplanted manually 5 weeks after planting (WAP) at a spacing of 40 cm x 50 cm between stands given plant population of 50,000 stands per hectare (Akinbile and Yusoff, 2011). Irrigation was applied continually at near field capacity in all the plots for 3 weeks after transplant (WAT).This was to ensure uniform crop establishment. Poultry manures were applied in all treatments using standard practices. No chemical fertilizers were applied throughout the growing season. Manual methods of weed control was adopted in controlling the weeds.

Each block (treatment) consist of three drip lines of 12.0 m long, spaced 40 cm apart. The drip irrigation is a gravity irrigation system; consist of an electrically operated submersible pump of 10 horse power (HP) to pump water from bore hole to reservoir tank of capacity 25 m^3. The system also included: one screen filter, flow meter, pressure gauge, main line of 32 mm diameter pipe (high density polyethylene), sub-main line of 25 mm diameter PVC pipeline, lateral of 16 mm diameter pipe (low density polyethylene plastic), control valves and 2 litre / hour pressure compensating drippers inserted into the 16 mm lateral spaced at 50 cm apart. The water source for irrigation was a bore hole sited about 300 m away from the experimental plot. The water yield and quality was adequate for irrigation demand of the crop under investigation. The irrigation schedule was fixed. Irrigation was performed every day by varying the water depth applied as a function of the crop evapotranspiration, except periods that had rainfalls. Rainfalls were measured with the aid of pluviometer during the experiment. The values of crop evapotranspiration (ETc) for the two pepper varieties was estimated for daily time step by using reference evapotranspiration (ETo) combined with a pepper crop coefficient (Kc) using the dual crop coefficient approach (using equation 1);

$$ETc = Kc \times ETo \qquad (1)$$

Where ETc is the crop evapotranspiration, Kc is the crop coefficient and ETo is the reference crop evapotranspiration. ETo was computed from daily climatic data collected from the automatic weather station about 600 meters away from study by using FAO-56 Penman-Monteith method (ETo-PM). Moreover, the changes in moisture contents during the study period were monitored using digital moisture meter (Model: Lutron PMS 714) developed in Australia. The moisture meter was calibrated against gravimetric method. The average absolute error (percent difference between the Lutron PMS – 714 and gravimetric) was 15 %.

***Agronomic and Yield Measurements*:**

Measurement of mean plant height (with meter rule), mean stem diameter (with vernier caliper) and determination of mean and number of branches were carried out on five randomly selected plants on weekly basis starting from 3 WAP (i.e. 8 weeks after planting) to the (18 weeks after planting). On each treatment, five leaves were selected from different parts of the plants for replication. Measurements of the longest part along the pentiole and widest breadth across the selected leaves were carried out using a transparent rule. The leaf area was obtained by multiply a factor 0.75 with product of length and breadth measured. Harvestable yields of the two peppers varieties were determined on weekly interval starting when harvesting began at 10 WAP (i.e. 15 weeks after planting). Fresh peppers were harvested manually. Number of fruits per treatment was determined by counting the number of harvested fruits from the plots. The mean fruits length and mean fruits diameter were measured with a veneer caliper while the mean fruits weights were measured with an electronic analytical balance.

Statistical Analysis

Data collected on the growth and yield parameters were subjected to statistical analysis to determine the mean values, standard deviations, and coefficient of variation. Analyses of variance (ANOVA) were conducted to evaluate the effect of water application using drip irrigation on plant growth indices and yield.

Results and Discussion

Climatic Data

During the cropping season, the average temperature was 32.2 °C, average relative humidity was 56.5% and average wind speed was 3.0 m/s. It was drought period with total accumulated precipitation of 128.9 mm. Therefore, little apply depth of water could present positive response to any crop grown. Figure 1 shows the climatic data observed during the cultivation period with the highest rainfall of 71.3 mm observed in the month of October, 2019.

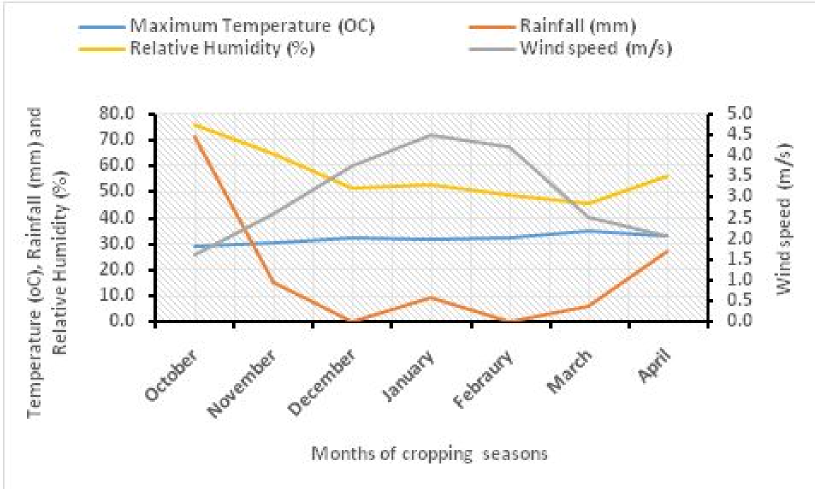

Figure 1:Month temperature (ºC), relative humidity (%), rainfall (mm) and wind speed (m/s) during the cropping period.

Soil Moisture Stored

Figures 2a and b show the average moisture stored in soil depth of 0 cm to 30 cm commencing from 8 weeks after planting in the experimental plots. The soil moistures were monitored with the digital moisture meter and the results clearly indicat that highest moistures were stored in plots with treatment A (100 ETc) because of the depth of water applied (100 ETc). The least average moisture values were obtained in plots with treatment D which has the least water application (25 ETc).

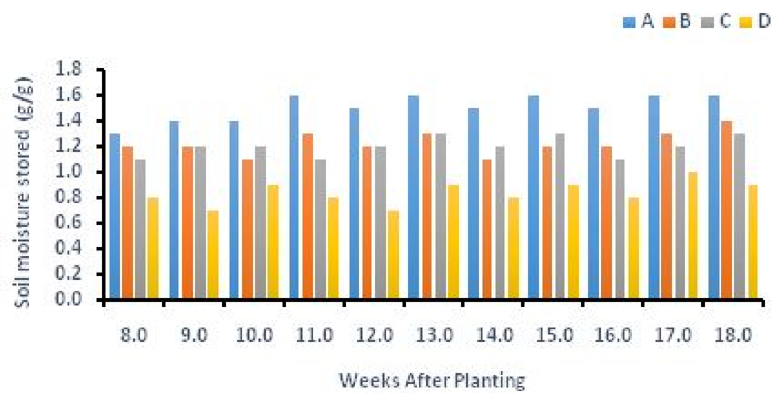

Figure 2a: Soil moisture stored WAP under different treatments in Sombo pepper variety

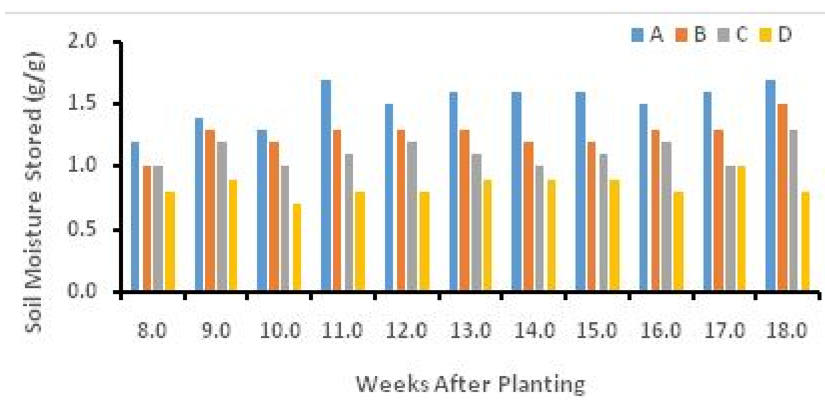

Figure 2b: Soil moisture stored WAP under different treatments in Atarodo pepper variety.

Agronomic Parameters

Response of plant height to variable water application

Figures 3 (a and b) show the response of plant height to variable water application for the two pepper varieties during cropping seasons. The study shows that plant height was affected by irrigation treatments. From the figures (3 and b), there was gradual and steady increase of plant heights in all the treatments from the two pepper varieties during the cropping seasons. In the two pepper varieties under consideration, treatment A has the highest plant height from the observation standpoint when compared with others. Treatment A has highest average plant heights of 192.5 and 158.3 cm with the least value of 132.1 and 115 cm obtained for treatment D in Atarodo (Capsicum annum) and Sombo (Capsicum frutescens) respectively. It could be inferred that the more irrigation water applied, the higher the plant height obtained. There was no significant difference in plant height in all the treatment plots at 5% level. According to Sezen *et al.* (2011) significant decrease irrigation water applied resulted in decrease in plant height.

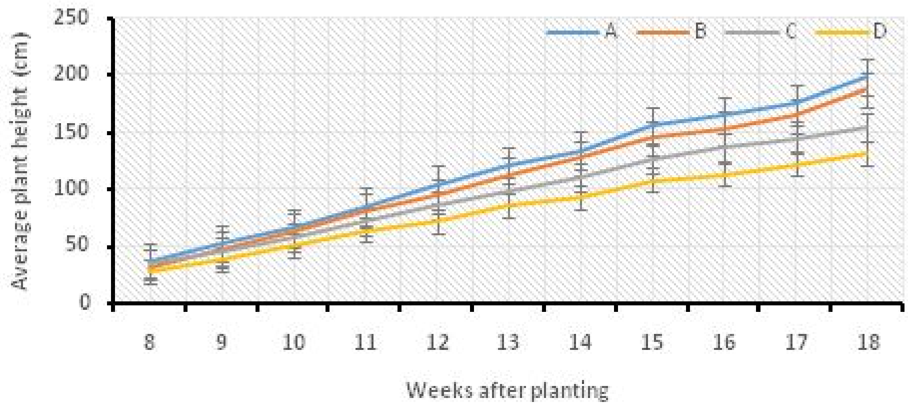

Figure 3a: Average Plant Height against Week after Planting in all treatments in Sombo variety

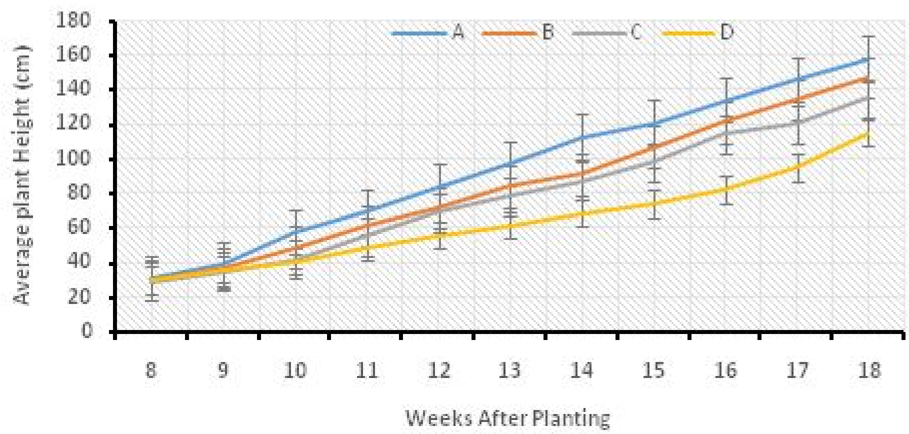

Figure 3b: Average Plant Height against Week after Planting in all treatments in Atarodo variety.

Stem Diameter

Table 2 shows the results of average stem diameter in all the treatments in the two pepper varieties. It was observed that there was an increased in the stem diameters with an increased water applied in Atarodo (Capsicum annum) variety during cropping season. However, in Sombo (Capsicum frutescens), increased water applied did not translate to increase stem diameter. Also, in Atarodo (Capsicum annum) variety, treatment A has the highest stem diameter and least was recorded in treatment D whereas in Sombo (Capsicum frutescens) variety, treatment B has the highest stem diameter with least values recorded in treatment D. The highest stem diameter of 2.1 and 2.4 cm and minimum values of 1.9 and 1.7 cm were obtained in Sombo (Capsicum frutescens) and Atarodo (Capsicum annum), respectively during the cropping season. The results obtained was similar to findings of Campiglia *et al.* (2010) and Akinbile and Yusoff (2011) where it was concluded that soil nutrients especially nitrogen could influence growth and development of crop apart from quantity of applied water.

Table 2: Average stems diameters (cm) in all the treatments against week after planting.

Treatments	8	9	10	11	12	13	14	15	16	17	18
						Weeks After planting					
Sombo (Capsicum frutescens)											
A	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.7	1.9	2.0
B	0.8	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.9	2.0	2.1
C	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.6	1.8	1.9
D	0.7	0.8	0.9	1.0	1.1	1.1	1.2	1.5	1.6	1.7	1.8
Atarodo (Capsicum annum)											
A	0.9	1.1	1.2	1.3	1.4	1.6	1.8	1.9	2.1	2.2	2.4
B	0.8	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2.0	2.1
C	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.9	2.0
D	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7

The Leaf Number

The average number of leaves was directly related to quantity of water applied in the experimental plots. The average number of leaves in Sombo (Capsicum frutescens) variety ranged from 54 to 38 with treatment B having the highest leaf numbers and least leaf numbers recorded in treatment D. In Atarodo (Capsicum annum) variety, treatment B has highest leaf numbers of 47 and minimum leaf number of 32 (Table 3). According to Akinbile and Yusoff, (2011), water and nutrients applications variably influenced the growth parameters especially the luxuriant parts such as leaf.

Table 3: Average number of leaves in all the treatments against week after planting

Treatments	8	9	10	11	12	13	14	15	16	17	18
						Weeks After planting					
Sombo (Capsicum frutescens)											
A	13	15	20	24	28	32	35	39	42	46	51
B	15	18	22	27	31	34	37	40	44	49	54
C	12	14	16	19	21	24	29	33	38	41	44
D	10	13	14	18	21	25	27	30	32	35	38
Atarodo (Capsicum annum)											
A	13	15	18	21	23	25	27	29	32	37	41
B	14	17	21	23	25	27	30	34	37	41	47
C	10	12	15	18	10	22	24	26	30	34	37
D	8	11	13	16	18	20	22	25	27	30	32

Fruit's number

Increased fruit number was observed as water application increased in both varieties during the cropping seasons (Figures 4a and b), however, there was no significant difference in fruit number at 5% level in both seasons. Increase in fruit number is one of the most significant factors affecting yield. According to Sezen *et al. (*2011), in other to avoid deprived fruit size and shape with increased yield, a uniform water supply is required throughout the crop growing season. During this study, it was observed that treatment A with high water application produced the highest average fruit number of 32.2 and 37.1 in Sombo (Capsicum frutescens) and Atarodo (Capsicum annum), respectively. The lowest average fruits numbers of 13.6 and 12.1 were recorded in treatment D in both varieties during the cropping season. Hence, there is positive response in number of fruits produced due to quantity of applied water (Alao *et al.*, 2017).

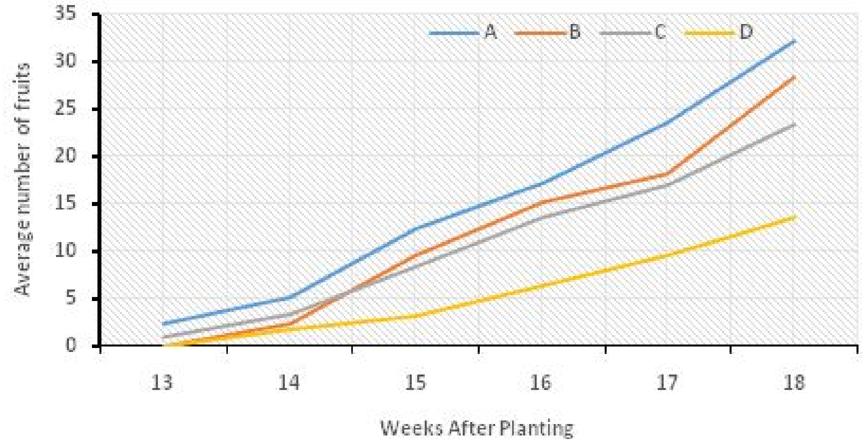

Fig. 4a: Average fruit number response to variable water application in Sumbo variety during the cropping season.

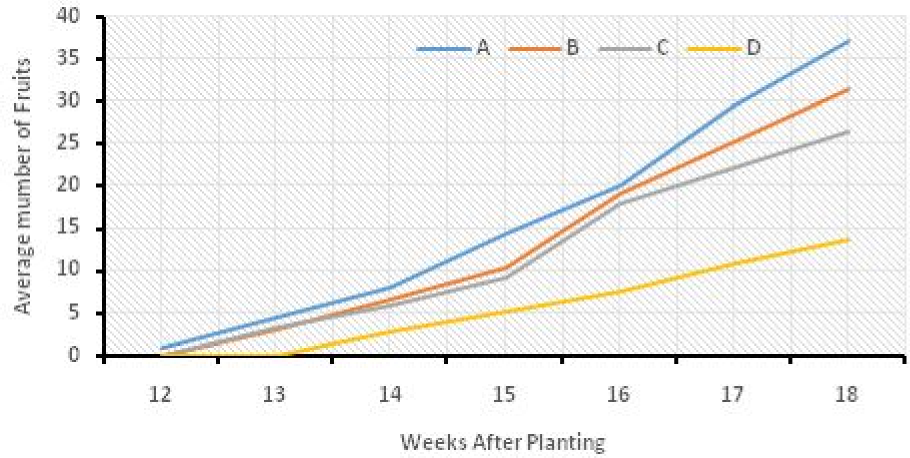

Fig. 4b: Fruit number response to variable water application in Atarodo variety

Fruit's Parameters

Table 4 shows the response of fruit's length and other fruit parameters to variable water application. It was observed that, there was a progressive increase in mean: fruit length, fruit width, fruit weight and fruit yield due to increased level of water applied. In Sombo (capsicum frutescens), the mean fruit length varied from 9.6 to 10.1 cm; mean fruit width varied from 1.0 to 2.2 cm; mean fruit weight varied from 6.06 to 14.89 kg and mean fruit yield varied from 4.85 to 21.20 t/ha. Highest average values of fruit yield were obtained in treatment A and least in treatment D. However, in the case of Atarodo (Capsicum annum) variety, the mean fruit length ranged from 2.7 to 3.6 cm; average fruit width ranged from 1.7 to 2.2 cm; mean fruit weight ranged from 7.12 to 11.75 kg and average fruit yield varied from 3.10 to 19.75 t/ha. Treatment A produced the highest average values and least values were obtained in treatment D. There was no significant difference in fruit length on all the treatment plots at 5% level. The results obtained were similar to findings of Dagdelen *et al.* (2004). It was observed that inadequate water supply reduces the length and the weight of pepper fruits from the results. Therefore it can be inferred that increased water application through irrigation will result in an increase in the length of the pepper fruits. This corollary also collaborate the findings of Ngouajia *et al.* (2008) that irrigation treatments influenced pepper fruit number, yield, and fruit size.

Table 4: Response of fruit length, fruit weight, fruit width, fruit yield and water use efficiency to variable water depth application.

Treatments	Sombo (capsicum frutescens)					Atarodo (Capsicum annum)				
	Fruit length (cm)	Fruit width (cm)	Fruit weight (gm)	Fruit Yield (t/ha)	WUE (kg/ha/ mm)	Fruit length (cm)	Fruit width (cm)	Fruit weight (gm)	Fruit Yield (t/ha)	WUE (kg/ha/ mm)

A	9.6a	1.8b	12.04a	21.20a	32.87a	3.2b	2.1a	9.58b	19.75a	30.62a
B	10.1a	2.2a	14.89a	15.15b	31.32a	3.6a	2.2a	11.75a	14.35b	29.66a
C	8.6b	1.7b	9.26b	8.90c	27.60b	2.9bc	1.8b	8.01bc	8.35c	25.89b
D	7.7b	1.0c	6.06c	3.85d	23.88c	2.7c	1.7b	7.12bc	3.10d	19.22c

Mean in the same column followed by the same letter(s) are not significantly different at 0.05 probability, using Turkey Test.

In the Sombo (Capsicum frutescens) variety, the water application that provided the highest yield value (0.424 kg plant $^{-1}$; 21.20 t ha^{-1}) was 645.0 mm (100% ETc) and the least (0.077 kg plant $^{-1}$; 4.85 t ha^{-1}) was 161.25 mm equivalent to 25 % of ETc. Likewise, in the Atarodo (capsicum annum) variety, the water application that provided the highest yield value (0.395 kg plant $^{-1}$; 19.75 t ha^{-1}) was 645.0 mm (100% ETc) and the least (0.062 kg plant $^{-1}$; 3.10 t ha^{-1}) was 161.25 mm equivalent to 25 % of ETc as shown in Table 4.

Conclusion

The results indicated that there was a significant difference between the WUE, yields and growth parameters under different levels of irrigation in the two pepper varieties. The results showed that water use efficiency, yields and other agronomic parameters such as plant height, number of leaves and fruit length and weight were higher during the study periods for both pepper varieties under treatments A and B compared with treatments C and D respectively. However, there was no significant difference in WUE of treatments A and B. Statistical analysis among the agronomic parameters showed a significant difference ($p<0.05$) in all the treatments. It was concluded that irrigating at 75% ET in the study area will result in water saving and maximum sustainable production of these pepper varieties.

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