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WATER REQUIREMENT, DEFICIT IRRIGATION AND CROP COEFFICIENT OF HOT PEPPER (*Capsicum frutescens*) USING IRRIGATION INTERVAL OF FOUR (4) DAYS

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ABSTRACT

This study was conducted to determine the seasonal water requirement of pepper, the crop coefficient under full water requirement as well as the effect of deficit irrigation on pepper growth and development under a rain shelter. The treatments imposed were T1, application of 100% crop water requirement, T2, was 80%, T3 60% and T4 40 % of crop water requirement. It was determined that pepper requires about 587.48mm of water over the growth season. The crop coefficient under full water supply was found to be: 0.47, 0.86, 1.42 and 0.91 for initial, development, mid-season and the late season stages, respectively. The study also revealed that reduction in 20% water need of hot pepper has no significant effect on growth, development and fruiting of the crop.

Keywords: pepper, water requirement, deficit irrigation, growth, crop coefficient.

INTRODUCTION

Deficit irrigation is a strategy that allows a crop to sustain some degree of water deficit in order to reduce costs and potentially increase income. It can lead to increase net income where water costs are high or where water supplies are limited (Kirda *et al.*, 2002).

Kang *et al.* (2001) conducted a hot pepper study applying water through alternate drip irrigation on partial roots (ADIP), fixed drip irrigation on partial roots (FDIP), and drip irrigation on whole roots (EDIP), and concluded that ADIP maintained high yield, with as much as 40% reduction in irrigation compared to EDIP and FDIP; moreover, the highest water-use efficiently occurred with ADIP. Costa and Gianquinto (2002) reported that continuous water stress significantly reduced total fresh weight of fruit and that the highest marketable yield was obtained with irrigation of 120% ET (Evapotranspiration), lowest at 40% ET and marketable yield was the same at 60%, 80% and 100% ET. Jamez *et al.* (2000) revealed that a water deficit during the period of flowering and fruit development reduced final fruit production.

Pepper is commonly grown in drought-prone areas of Ghana where climatic conditions are hot and water so scarce. In these circumstances, deficit irrigation will probably contribute to the economical use of water sources if significant reduction does not occur in crop yields. Many field studies of DI have been conducted. Such field studies are needed for economic analysis of DI and to increase net income and water-use efficiency (English *et al.*, 1990).

Pepper (*Capsicum and Capsicum frutescens)* is thought to originate from tropical America. Most of the peppers grown belong to *Capsicum frutescens*. Present world production is about 19 million tons fresh fruit from 1.5 million ha (FAOSTAT, 2001).

One of the major setback in vegetable production in Ghana, that is, pepper and leafy vegetables, is the inability of farmers to determine the correct amount of water required by the crop and adoption to the necessary irrigation practices during the growing season so as to maximize profit. This usually results in water stress which directly affects crop growth and yield. Deficit irrigation is a strategy that allows a crop to sustain some degree of water deficit in order to reduce costs and potentially increase income. It can lead to increase net income where water supplies are limited (English and Raja, 1996). The unavailability of rainfall to compensate for evapotranspiration losses by a crop necessitates the application of artificial irrigation if better yield is expected by the farmer. It is in the light of this that the study was conducted to delve into the determination of the water requirement for pepper plant and this will help reduced the problems encountered by commercial pepper farmers who face much challenges in the determination and application of correct amount of water require by the pepper plant.

MATERIALS AND METHOD

Study area

The study area was the School of Agriculture Teaching and Research Farm at the University of Cape Coast. Cape Coast Vegetation cover is made up of shrub. The soil type as classified by Asamoah (1973) is a sandy clayey loam of the Benya series, which is a member of the Edina Benya-Udu association. The study area experiences two rainy seasons namely the major season which starts from May and end in July and a minor season that starts around September and ends around mid November to give to the dry Harmattan season that runs through the end of March in the subsequent year. Mean annual temperature range for the day is 30^0C-34^0C and that of the night is 22^0C-24^0C with relative humidity between 75%-79%.

Experimental design and field layout

The Randomized Block Design was used, with four treatments (T1-T4) and three replications, (R1-R3). Forty-eight (48) poly-bags were filled with sandy loam soil from the experimental site weighed on a scale to a weight of six (6) kilograms each after which they were placed under rain shelter where the research took place and replicated (100%-T1, 80%-T2, 60%-T3, 40%-T4). Six (6) boxes each measuring 1.0m x 0.95m giving a total area of 5.7m^2 divided into three (3) replications with each containing twelve (12) nursery bags were used.

Planting

Seeds of the Legon 18 variety of hot pepper were nursed on 18th September, 2009 and transplanted on 8th October, 2009. A week before transplanting; water supply at the nursery was reduced in order to harden the seedlings to reduce transplanting shock. Before transplanting, both nursery and all forty-eight filled poly-bags were watered to enhance easy uprooting of seedlings and prevent root damage of the seedlings and also help quicken the recovery rate after transplanting. The transplants were subjected to equal amount of water application for seven (7) days to ensure uniform recovery of all transplants.

Growth stages

Four growth stages were considered. They were the initial stage, developmental stage, mid-season stage, and late season stage. The initial stage excluding seedlings at the nursery lasted for 15 days (October 15 - October 30, 2009). The developmental growth stage lasted for 30 days (October 30, 2009 - November 29, 2009). The mid-season growth stage (flowering and fruiting) stage lasted for 50 days (November 29, 2009 - January19, 2010) and the late season stage lasted for 26 days (January19, 2010 - February 14, 2010). This stage was later characterized by senescence and drying of leaves after the harvesting was over.

Irrigation regime

A four-day interval irrigation regime was adopted and the amount of water to be applied each four-day interval was derived from the computed loss in weight of each set up over the four days. The equivalent in volume basis was found and applied to the plants as the various treatments demanded. Irrigation days amounted to 60.5 days out of the 129days of the growing period.

Determination of crop coefficient (Kc) and water requirement (ETc) and reference evapotranspiration (ETo)

The crop water requirement (ETc) is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. This was calculated for the initial, mid-season and the late season growth stages for the various treatments.

ETc = ETo x Kc .... (1)

Kc = ETc/ Eto .... (2)

ETo = Epan x Kpan .... (3)

ETc (4days) = Loss in weight of poly bags

ETc for a growth stage = 4 days ETc x Growth period.

Where

ETc - Crop evapotranspiration or Crop water requirement (mm/day)

Kc - Crop factor

ETo - Reference crop evapotranspiration (mm/day)

K pan - Pan Coefficient (0.80)

Soil analysis

Soil samples were taken from nursery bags and were thoroughly mixed together. The samples were divided into four and two opposite quadrants were taken out. This was repeated and each time, another opposite quadrants was taken off until a substantial amount was obtained. The sample was then dried for four days after which it was grounded and then analyzed for the amount of nitrogen, phosphorous and potassium as well as moisture content and bulk density. This was done for the three growth stages considered.

Other data collected

a. **Plant height:** This was measured using a rule; three plants were selected from each treatment replication.
b. **Leaf area:** Five leaves from different parts of the plants were selected on each replication. The longest part along the petiole line of the leaf and the widest breath across the leaf were noted and measured as the length and breath of the leaf by using a 30 cm metre rule. The product was multiplied by a factor of 0.75 to get the leaf area.
c. **Mean number of fruits per treatment:** The number of fruits per treatment was determined by counting the number of harvested fruits. Mean fruit size: Mean fruit size per plant was determined by using a veneer calliper to transversely measure the breath.
d. **Mean fruit weight:** The number of fruits produced by each of the selected plants under each treatment was weighed by the use of an electronic analytical balance. Reference crop evapotranspiration rate and rainfall reading: Evaporation rate and amount of rainfall readings were obtained from the US Class A evaporation pan and a rain gauge respectively situated at the farm where the experiment was conducted. To obtain the reference crop evaporation. 0.8 was chosen as the pan factor because the experimental location had a moderate wind speed of 2-3 ms^{-1} and high humidity of 75-79%.

Statistical analysis

Data collected were subjected to analysis of variance and the means were separated by Duncan's Multiple Range Test at a probability level of 0.05.

RESULTS AND DISCUSSIONS

According to Iwena (2002), hot pepper requires 1000 to 1500mm of water during the growing season. According to FAO (1999) however, when the crop is grown extensively under rain fed conditions, high yields are obtained with rainfall of 600mm to 900mm, well distributed over the growing season. Huguez and Philippe (1998) also indicate that the total water requirements are 750mm to 900mm and up to 1250mm for long growing periods and several pickings. Agodzo *et al*. (2003) indicate that the crop water requirements range between 300mm - 700mm depending on the climatic condition and the season of the crop and the location. Grimes and Williams (1990) also asserted that water requirement for hot pepper per growing season ranges between 400 mm and 500 mm depending on the season of planting and the climatic conditions prevailing in the area.

The results obtained from this study shows that when the crop is given its full water requirement, 587.48 mm of water is required, but a Figure of 439.79mm is required when deficit irrigation of up to 40% of the crop water requirement is applied. Comparing these values to those obtained by other experimenters, it can be concluded that water requirement for pepper in the Cape Coast area compares well with results obtained Agodzo *et al*. (2003). This Figure is however lower than those obtained with the other researchers.

In terms of the crop coefficient, Freeira and Goncalves (2005) obtained 0.3, 1.22 and 0.65. According to FAO (1999) Kc is 0.4 following transplanting, 1.1 during full cover and 0.9 at time of harvest. The crop coefficient (Kc) is affected by a number of factors, which include: the type of crop, stage of growth of the crop and the cropping pattern (Allen and Smith, 1998). Doorenbos and Pruitt (2000) indicated that plant height and total growing season influence crop coefficient values. The higher the plant height and the longer the growing season the higher the crop coefficient values and vice versa.

In this study, Kc was 0.47, 0.86, 1.42 and 0.91 for initial, development, mid-season and the late season stages, respectively as indicated in Table-1. These values compare quite well with those obtained by FAO (1999) where the water requirement was 600 mm for the growing period of 120 days.

Table-1. Growth period, ETo, Kc and Etc for all the growth stages.

Growth stage	**Period** (days)	**ETc** (100%)	**ETc** (80%)	**ETc** (60%)	**ETc** (40%)	**ETo**	**Kc** (100%)	**Kc** (80%)	**Kc** (60%)	**Kc** (40%)
Initial	17	32.95	28.74	26.64	25.24	70.10	0.47	0.41	0.38	0.36
Dev.	32	115.84	84.86	105.07	96.98	134.70	0.86	0.63	0.78	0.72
Mid.	56	343.78	295.36	249.36	237.26	242.10	1.42	1.22	1.03	0.98
Late	24	94.91	87.61	84.84	80.31	104.30	0.91	0.84	0.81	0.77
Sum		**587.48**	**496.57**	**465.91**	**439.79**					

NPK levels

Soil NPK levels for the initial, mid-stage as well as the last stage are shown in Figures 1, 2 and 3. The uptake of nutrients such as nitrogen, phosphorus and potassium by plants are influenced by the amount of water available in the soil. Broeshart *et al.* (1965) found that flooding in a rice farm increased the uptake of potassium. Adequate amount of water in the soil tend to enhance aeration and this according to Cline and Erickson (1956), would improve potassium and nitrogen uptake. Shapiro *et al*. (1956) indicated that translocation of phosphorus increases when there is improvement in aeration. The results obtained from the study indicates that T4 utilised the most N, where as T2 and T1 the most P. With regards to K, utilisation was greatest under T4.

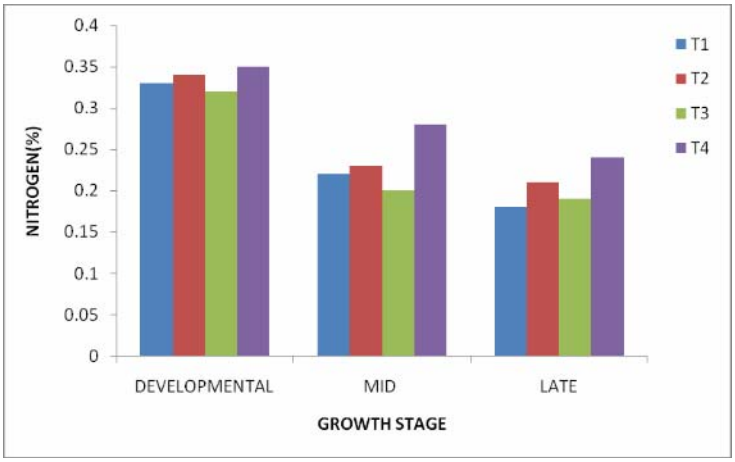

Figure-1. levels of Nitrogen in the soil for the entire growth period.

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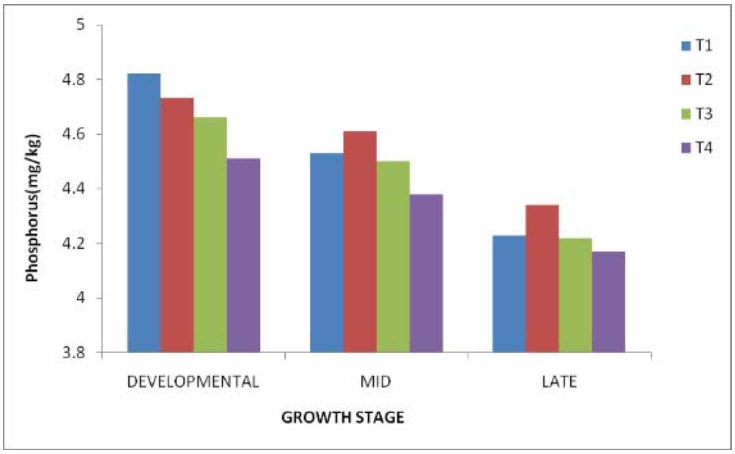

Figure-2. levels of phosphorus in the soil for the entire growth period.

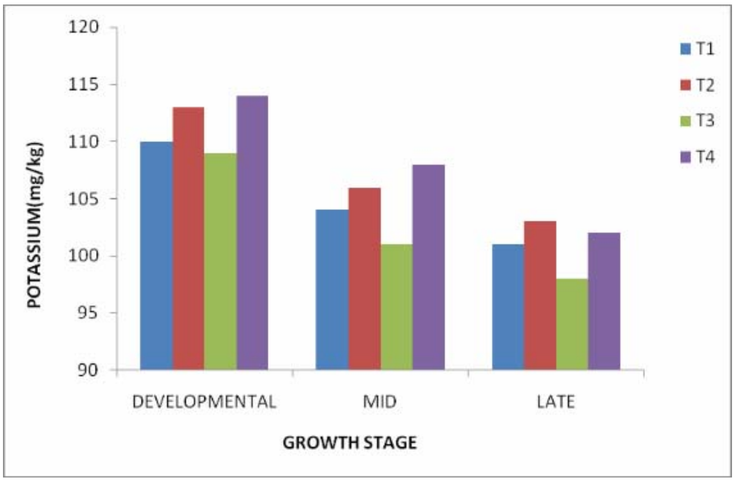

Figure-3. levels of potassium in the soil for the entire growth period.

Plant height and leaf area

At the end of the growth period, mean plant height was in the order T2>T1>T3>T4 and mean plant leaf area in the order T1>T2>T4>T3 (Table-2). Interestingly however, in both cases the results were not significantly different at the 5% probability level in spite of the large differences in amount of water applied.

Table-2. Mean plant height (MPH) and leaf area (LA) for the treatments at various stages of plant growth.

Treatments	Initial stage		Developmental		Mid-season		Late season	
	MPH (cm)	LA (cm^2)	MPH (cm)	LA (cm^2)	MPH (cm)	LA (cm^2)	MPH (cm)	LA (cm^2)
T1	7.85a	5.84a	21.56a	7.10a	31.96a	9.95a	33.73a	10.23a
T2	8.13a	6.46a	22.80a	7.12a	32.26a	9.61a	33.50a	10.11a
T3	7.04a	7.84a	20.76a	8.01a	31.66a	9.65a	32.62a	10.08a
T4	6.98a	6.93a	19.36a	7.01a	30.93a	9.04a	31.63a	9.56a
	Probability = 0.05		Probability = 0.05		Probability = 0.05		Probability = 0.05	

Pepper leaves photosynthesize more efficiently when water is abundant, resulting in a higher percentage of large, heavy, marketable fruits (Alvino *et al*., 1994). Under water stress, the products of photosynthesis are fewer; fruit growth and development are inhibited, and yield is decreased (Bray, 1997). Chlorophyll destruction is quickened by moisture stress (Alberte *et al*., 1997).

More severe and prolonged water stress may result in poor flower-cluster development and reduced pistil and pollen viability and subsequent fruit set (Falcetti *et al*., 1995). Following fruit set, severe water stress may cause flower abortion and cluster abscission, possibly associated with hormone changes (During, 1986). Uncorrected water stress during this stage of development may result in reduced canopy development and, consequently, insufficient leaf area to adequately support fruit development and maturation. Interestingly however, there were no significant differences in leaf area in spite of the water stress imposed.

Yield components

The relationships between crop yield and water use are complicated. Yield may depend on the timing of water application or on the amount applied. Information on optimal scheduling of limited amounts of water to maximize yields of high quality crops are essential if irrigation water is to be used most efficiently (Anaç *et al*., 1997). Timing, duration and the degree of water stress all affect crop yield.

Mean number of fruits

It can be seen from Table-3 that T1 produced the highest mean number of fruits (16.67) followed by T2 13.91 fruits, then T3, 9.52 fruits, and lastly T4 with 4.61 fruits. There was no significant difference between T1 and T2, but T1 differed significantly from T3 and T4. T2 was however not significantly different from T3.

According to Fisher *et al*. (1985) in an experiment conducted, highest yields were obtained from highest regulated irrigation regime and lowest yield was obtained from the lowest irrigation water applied. Reducing irrigation water application by 40% resulted in 30% decrease in marketable fruit yield. As long as soil moisture is maintained throughout the growing season the roots will be able to maintain an adequate flow of water to the leaves to maintain growth. At the mid-season and the late season stages, T1 utilized available nitrogen effectively (Figure-1) which may have influenced the highest number of fruits formed since nitrogen is a component of amino acids and proteins and so forms essential part of protoplasm, enzymes which are stored food for fruit development.

Factors that could be responsible for the low fruit numbers include blossom drop, a situation whereby all cells and tissues at the distal and blossoms end of the plants stems fail to receive enough moisture to maintain their body, grow and develop, and so leads to cell breakdown, flower abortion and its subsequent drop (Berrie *et al*., 1990). These were observed on some treatment levels at varying degrees, and were highest especially under T4 four where the drought stress coupled with the higher night temperatures favoured flower failure and this could be responsible for lowest number of fruits obtained.

The results of the study are in agreement with the results of the study by Pill and Lambeth (1980) who observed a reduction in the fruit number with decreasing soil water, explaining that lower soil moisture could result in pollen and stigma dehydration as well as unnecessary elongation of the flower’s style which could result in up to 50% reduction in fruit setting and final fruit yield.

Table-3. Mean values of yield components for the treatments.

Treatment	**Mean number of fruits**	**Mean fruit size** (mm)	**Mean fruit weight** (kg)	**Mean yield per total area** (tons/ha)
T1	16.67a	17.8a	0.145a	1.45a
T2	13.91ab	12.3ab	0.128a	1.28a
T3	9.52b	6.8bc	0.080bc	0.80 bc
T4	4.61c	3.5c	0.039c	0.39c
	Prob.= 0.05	Prob.= 0.05	Prob.=0.05	Prob.=0.05

Treatment means followed by the same letter are not significantly different at 5% probability level.

Fruit weight

T1 produced the heaviest fruits weighing 0.145 Kg. This was followed by T2 weighing 0.128kg while T3 recorded a mean weight of 0.080kg and the lowest mean fruit weight was recorded by T4 which was 0.039kg. T1 was not significantly different from T2 but was significantly different form T3 and T4. However, T3 and T4 were not significantly different from each other.

Plants can make virtually everything they need from water and air with a few nutrients that the roots absorb from the soil. The plant uses sunlight to split water into hydrogen and oxygen. It discards the oxygen as a waste product. The plant uses the hydrogen to make sugar from carbon dioxide in the air. Plants use oxygen in the air to burn sugar and make energy to live. The sole purpose of the leaves is to harvest light and make sugar (Longstroth, 1996) When the rate of photosynthesis is reduced as a result of reduced amount of water, the sensitive phytochrome pigments (chlorophyll pigmentation) that intercepts light for the process is affected then plants subjected to drought stress should be expected to have small and light fruits weights (Pill and Lambeth, 1980).

Mean fruit size

T1 produced the highest fruits size 17.8mm. This was followed by T2 (12.3mm) while T3 recorded a mean fruit size of 6.8mm and the lowest mean fruit size was recorded by T4 which was 3.5mm. The results also indicated that no significant difference exist in the mean fruit sizes of T1and T2 but was significantly different from that of T3 and T4. Pill and Lambeth (1980) investigated the effect of water on plants and concluded that water stress is capable of restricting plants to achieve their full genetic potential. As noted by Longstroth (1996) the early period of fruit growth is very important in determining final fruit size. For about a month after bloom the fruit grows by cell division. Later, the fruit grows by cell enlargement. So, two factors influence fruit size, cell number and cell size. Bigger fruits have more cells, so the final fruit size is determined in the month after bloom. Lack of water reduces the growth of new shoots and leaves. This means that there is less sugar to be used for fruit growth hence smaller sizes. Their work support the findings made in this study. Plants that were given full water application yielded the largest fruits while the opposite was true for treatment four which received the least amount of water applied.

CONCLUSIONS

The water requirement and crop coefficient of hot pepper were determined for the various growth stages using an irrigation interval of four days. At 100% water application (full irrigation), crop coefficient for hot pepper was determined to be 0.47, 0.86, 1.42 and 0.91 for initial, development, mid-season and the late season stages respectively and the total amount of water applied for the 129 days was 587.48mm. It is also important to note that reducing water application by 20% has no significant reduction on the yield of hot pepper but above this has adverse effect on the plant and yield as indicated by treatment four recording the lowest yield of 0.39. As a result, 20% reduction in water application could be recommended for deficit irrigation in hot pepper production.

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