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Famuwagun Idowu Babadele

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I. Introduction

Pepper (capsicum spp) of the genus capsicum belongs to the Family *Solanaceae* (Night shade). The Family contains about 90 genera and nearly 3000 species (Vidyarth and Tripatha 2002). Capsicum is a crop that is widely cultivated because of its spicy nature and nutritional value. *Capsicum annum* and *capsicum frutescens* are the most common species in Nigeria (Agele *et al.*, 2011).

The increase demand for high yield to meet consumers request has led the seed production companies to the era of using mainly F1 seeds as the most efficient means of facing food security challenges as well as retaining their names in the market. The increasing demand for pepper during the dry season in Nigeria for local consumption and export created opportunities for producers to increase their production. Declining soil moisture during this period has being the major hindrance to year round production of the crop hence the need for approaches to develop efficient soil water management strategies for sustainable production of the crop. More so, the circumstances of increasing challenges of producing more food to meet the ever increasing world population and to cope with the effects of changing climate also makes it imperative to improve on the understanding of moisture stress as it affects pepper production.

Crop yield completely depends on the available moisture to crops if climatic and agronomic conditions are normal. There are strong relationships between crop yield and water use. Under normal condition, when environmental conditions do not restrict crop production, crop yield is at maximum when the crop water requirement is met (Agele *et al.,* 2011). Certain growth stages of crops are more sensitive to water deficits than others. In fruit vegetable crops, the vegetative and flowering stages are very sensitive to water deficit (Dalla-Costa and Gianquinto, 2002). Crop water use depends mainly on the climate and the soil conditions of an area.

Large scale pepper production in Nigeria is mostly found in the northern part under irrigation system during dry season (September-March). The raining season crops (June-September) suffer serious pest and diseases damage, limiting the output during the season (FAO, 2003).

The amount and frequency of irrigations depends on soil type, bed type, plant size, humidity, wind, sunlight and prevailing temperatures (Njouajio *et al., 2007*). In the humid tropics pepper grown as a rain fed crop, with annual rainfall total of 650mm - 1250mm and relative humidity of 75% - 88% providing suitable growing condition. If the rainfall greater than this range is detrimental, as it leads to poor fruit set and rotting of fruits (Purseglove *et al*., 1981).

The objectives of this project are to determine the response of tested *Capsicumspecies* to different watering regime in terms of root shoot development and fruit yield

II. Materials and Methods

The experiments were carried out between November2017and April 2018 and October, 2018 to April, 2019 at the Teaching and Research Farm of the Federal University of Technology Akure (7° 16' N, 5° 12E) Nigeria. The treatment involves three irrigation regimes and three F1 pepper accessions. The irrigation regimes imposed were 2, 4, and 6 days intervals at 1litre

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of water per irrigation day/plant after transplanting while F1 accessions *Capsicum chinense*, Capsicum frutescens (cayenne pepper) and Capsicum annum (Bell pepper) varieties from East-West Seed Company. The experiments were 3x3 factorial experiment with three replications laid out in a randomized complete block design. The planting materials (seeds) were gotten from the Agro dealer of East-West Seed Company. The seeds were raised in the nursery for six (6) weeks using nursery trays before transplanting into the already prepared plots at one plant per stand on a 2 x 5 meter sub-plot at a spacing of 0.5 x 1.0 meter. The total plot size was 20m x 24m. Before transplanting, the plots were irrigated using gravity drip irrigation systems for four hours. Transplanting was conducted very early in the morning to reduce transplanting shock followed by 30minutes irrigation. Weeding was carried out as and when due during the period of the experiments. The watering regimes treatments were imposed beginning from one week after transplanting.

Data were measured on plant height, number of leaves and number of branches on a two weeks interval beginning from a week after transplanting. Tap root length, total length of lateral root, length of longest lateral root, fresh root weight and dry root weight were measured at termination of the experiments (36 weeks). Yield parameters which include numbers of days to flowering, total number of flower produced, number of fruits and the total fruit weight were also measured.

Analysis of variance was performed on the measured data using MINITAB and the mean were separated using Tukey test.

III. Results

The response of the selected pepper varieties to varying irrigation regimes were represented in table 1-6 below. Table 1 shows the response of pepper varieties to varying irrigation regimes on plant height development in 2017 and 2018 experiments. From the results, the growth patterns in the two experiments were similar (as seen in figure 2) but the height development of the three pepper varieties differs from each other. At transplanting, no significant difference in the seedlings height of the pepper varieties but beginning from the 8th week after transplanting *Capsicum chinense* had a significantly higher plant height compared to *Capsicum frutescens* and Bell pepper varieties. The variation in plant height continues till the termination of the experiment with *Capsicum chinense* having the highest significant plant height over the *Capsicum frutescens* and the bell pepper.

Figure 1, 2 and 3 represents the effects of varying irrigation regimes on height development of *Capsicum frutescens,* Capsicum chinense and the bell pepper respectively. From the results, no significant difference between 2 and 4 days irrigation interval on the plant height of *Capsicum chinense* but they were significantly higher in stem height compared to those under 6 days irrigation regimes, (Figure 1).Similar trends were also recorded under *Capsicum chinense* and bell pepper respectively.

Table 2 shows the response of three pepper varieties to varying irrigation regimes on number of leaves produced. It was clearly indicated that the morphological characteristic of the three pepper varieties in term of leaf production differs significantly from each other. The highest significant leaf numbers were produced by *Capsicum chinense* which was positively influenced by 2 days irrigation regimes over other irrigation intervals. No significant difference between Capsicum chinense under 4 day irrigation interval and those of *Capsicum frutescens* under 2 and 4 days irrigation regimes. Also, 6-days irrigation interval significantly lowered leaf development in the three pepper varieties as the plants increment in vigor which places more stress on the soil water which in turn leads to lower leaf area development across the three varieties.

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Table 1: Response of pepper varieties to varying irrigation regimes on plant height 2017 and 2018 experiments.

Pepper Variety	Irrigation regime	Plant Height in weeks after treatment application(cm) 2017						Plant Height in weeks after treatment application(cm) 2018					
		4	8	12	16	20	24	4	8	12	16	20	24
cayenne pe	2days	20.3a	26.7a	34.1	48.0a	57.8a	57.8b	21.6a	30.3a	35.4a	47.0a	57.8a	58.3a
	4days	19.4a	24.3b	29.1	36.8b	47.8b	47.8c	23.9a	29.3a	32.3b	42.7b	49.0b	51.3b
	6days	439.2a	23.4b	24.8	31.6c	37.4c	37.7d	22.7a	25.4b	28.7b	33.7c	36.6d	37.6d
Wrinkle	2days	21.3a	27.5a	36.8	45.6a	58.2a	72.0a	18.3c	26.6b	39.8a	50.2a	64.5a	66.0a
	4days	20.5a	24.8b	32.3	41.7a	52.8a	61.9a	17.3c	24.9b	31.3b	43.2b	49.8c	52.6b
	6days	18.3a	22.2b	28.3	30.3c	41.4b	47.1c	20.2b	24.2b	30.3b	36.6c	41.4c	44.6c
Bell	2days	18.0a	25.2a	31.7	41.1a	42.4b	42.8c	23.0a	30.2a	38.5a	49.1a	53.4b	54.8b
	4days	16.7b	24.8b	30.3	37.2b	46.3b	46.5c	18.1c	22.3c	27.6b	32.2c	47.5b	47.9c
	6days	15.4b	22.7b	2[illegible]	31.2c	37.2b	41.3c	19.7b	23.7c	30.0b	35.7c	38.1c	40.6d

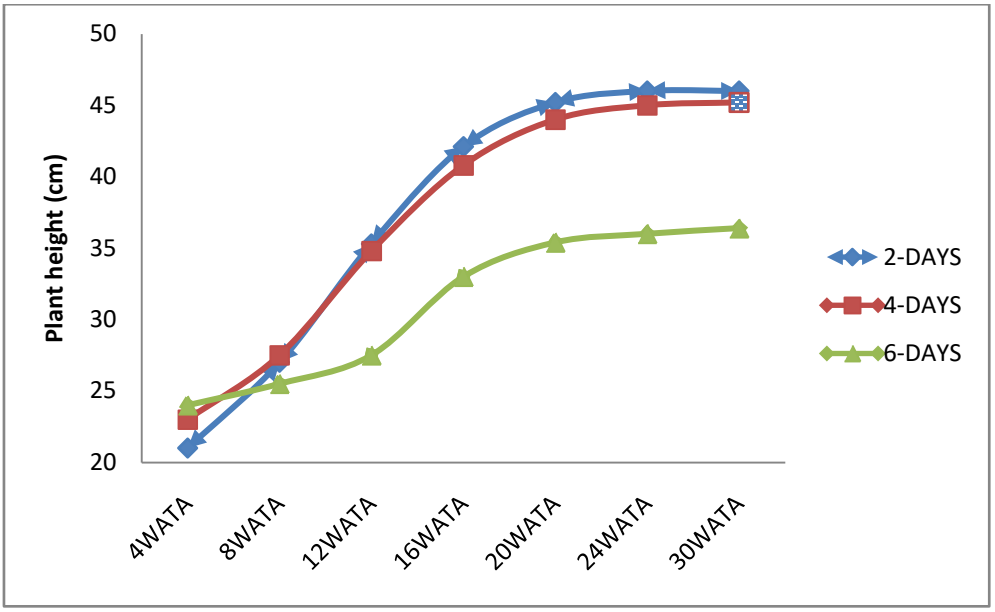


Figure 1: Effects of watering regimes on cayenne pepper plant height

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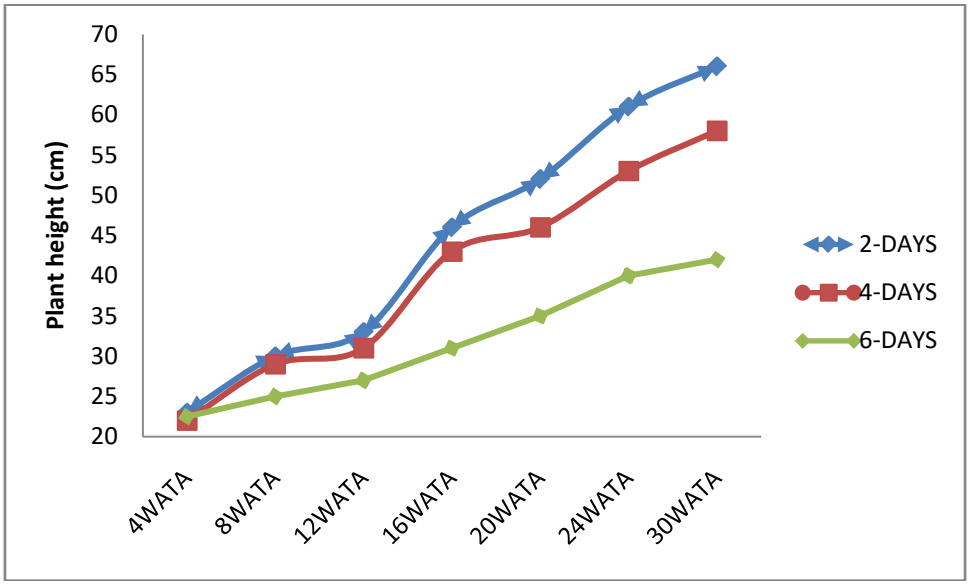


Figure 2: Response of Wrinkly pepper to watering regimes on plant height development

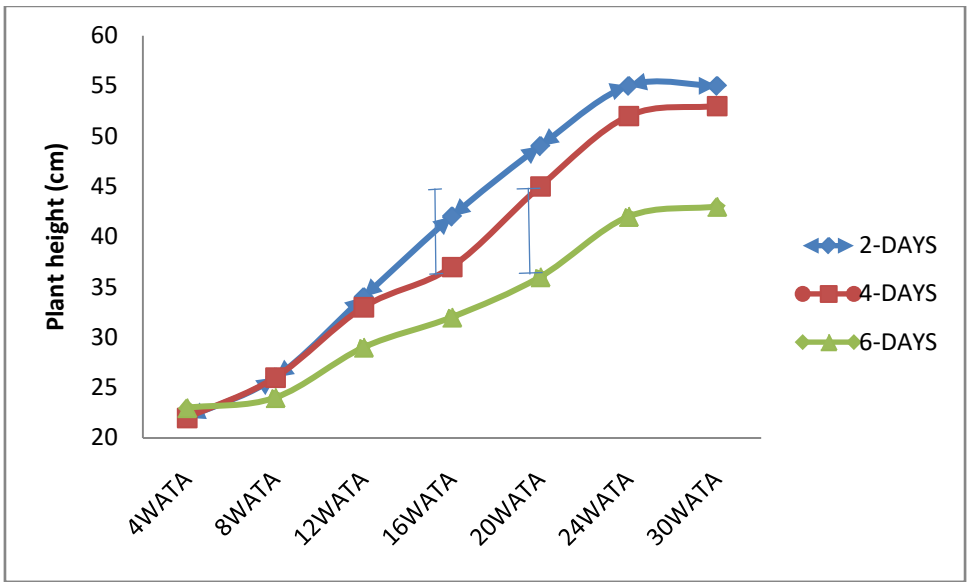


Figure 3: Response of Bell pepper to varying watering regimes on plant Height

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Table 2: Response of pepper varieties to varying irrigation regimes on number of leaves produced during 2017 and 2018 experiments

Crop Variety	Irrigation regime	Number of Leaves produced in weeks, 2017						Number of Leaves produced in weeks, 2018					
		4	8	12	16	20	24	4	8	12	16	20	24
Cayenne pepper	2days	10.11.5a	24.6a	37.4b	53.1b	76.4b	89.2b	13.4a	29.3a	47.4a	63.1a	86.4a	89.2b
	4days	12.1a	21.2a	35.2b	54.0b	78.9b	91.9b	12.1a	31.2a	45.2a	64.0a	72.9a	81.9b
	6days	12.1a	22.1a	29.9bc	36.6cd	45.7d	55.3d	11.1a	22.1b	34.9b	42.6b	53.7b	58.3c
Wrinkle pepper	2days	11.4a	23.9a	41.3a	69.4a	106.4a	118.4a	11.4a	23.9b	53.3a	63.5a	86.8a	98.6a
	4days	12.7a	23.8a	53.6a	76.1a	96.8a	102.6a	12.7a	25.8b	48.6a	60.1a	76.8a	92.1b
	6days	11.3a	19.9c	34.2b	44.9c	58.3c	77.3c	12.3a	20.2c	34.2b	44.2b	51.4bc	60.4c
Bell pepper	2days	12.2a	17.0b	33.8b	44.6c	49.3c	56.7d	11.4a	20.7c	28.7c	47.0b	63.9b	67.5c
	4days	12.3a	18.3b	28.3bc	42.5c	46.3d	52.5d	12.0a	25.3b	32.3b	40.4c	57.7b	60.3c
	6days	9.0a	16.2b	22.3c	28.9d	34.3e	36.7e	12.7a	15.3d	21.8c	29.7d	36.6d	40.6d

Table 3 represents the response of three pepper varieties to varying irrigation regimes on branch development. The results indicated that branching in wrinkle and Capsicum frutescens pepper were not significantly different from each other when combined with four and eight days irrigation interval but were significantly higher compared with branch development under twelve day irrigation regime. Branch development in bell pepper under the three irrigation regimes was significantly lower compared with those of Capsicum frutescens and Capsicum chinense under the same treatments.

Table 4 shows the root parameters of the three pepper varieties as influenced by varying irrigation regimes. The result indicated that root development among the three pepper varieties were positively influenced by the irrigation regimes. Four days irrigation intervals significantly favoured higher root development compared to those plants under two and six day irrigation intervals. Tap root development, total lateral root length and longest lateral root length were significantly higher in four days irrigation intervals over two and six day interval. The fresh root volume was also higher significantly under four days irrigation interval compared to other treatments. Dry root weight was higher significantly among four days irrigation intervals across the three pepper varieties. Capsicum frutescens pepper showed a significantly higher fresh and dry root weight over wrinkle and bell pepper. The root weight of bell pepper was significantly lower compare with that of Capsicum chinense.

Table 3: Response of pepper varieties to varying irrigation regimes on stem branch development for 2017 and 2018 experiments

Crop Variety	Irrigation regimes	Number of Branches produced in weeks, 2017						Number of Branches produced in weeks, 2018					
		4	8	12	16	20	24	4	8	12	16	20	24
Cayenne pepper	2days	2.2a	4.6a	7.4a	11.0a	11.5a	11.5a	2.2a	5.0a	10.4a	11.7a	11.6a	12.8a
	4days	2.0a	3.5a	5.0b	8.5b	8.6b	9.2ab	2.7a	6.4a	8.6a	8.5a	9.3a	11.3a
	6days	2.1a	2.5b	2.8c	3.0c	3.2c	3.2c	3.4a	4.8a	6.8b	7.0b	8.1b	8.1b
Wrinkle pepper	2days	1.7a	5.8a	7.9a	10.0a	12.4a	12.7a	1.5a	5.7a	9.1a	11.3a	12.4a	14.0a
	4days	1.5a	2.0b	3.4c	6.5b	8.0b	8.0b	2.4a	3.8b	8.0a	11.5a	12.7a	13.5a
	6days	1.8a	2.0b	3.2c	3.2c	3.5c	3.5c	3.3a	3.5b	5.1b	6.8a	7.5b	7.5b
Bell pepper	2days	2.1b	4.5a	5.2b	5.6c	6.0b	6.5b	2.5b	4.5b	6.2b	7.3b	7.5b	8.0b
	4days	2.0a	4.3a	4.5b	6.0b	6.0b	7.2b	2.1a	4.0b	5.0b	7.4a	7.5b	7.5b
	6days	1.8a	2.0b	3.5c	3.5c	4.2c	4.2c	1.00a	2.5c	2.5c	2.9c	5.4c	5.4c

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Table 4: Response of pepper varieties to varying irrigation regimes on roots parameters for 2017 and 2018 experiments

Plant Variety	Irrigation Regime	Tap root length (cm)		Total lateral root length (cm)		Longest lateral root length (cm)		Fresh root volume (cm^3)		Dry root weight (g)	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Cayenne pepper	2days	6.5b	7.2a	67.8b	58.6b	17.8c	19.1d	25.5a	26.0a	11.3a	10.8a
Wrinkle pepper	4days	5.3c	6.2b	62.4b	65.1a	18.9c	22.4c	22.7a	29.5a	10.6a	9.6a
	6days	7.5ab	7.8a	78.1a	68.4a	21.4b	23.2c	9.5c	13.0b	6.2b	5.2b
	2days	7.1ab	6.5b	58.6c	55.3b	22.3b	22.0c	26.5a	21.0ab	12.0a	11.3a
	4days	7.5a	7.0a	72.4a	53.8b	34.4a	29.5b	19.0b	27.5a	10.2a	7.4b
	6days	8.5a	8.6a	75.5a	68.1a	36.8a	35.8a	8.0c	15.0b	7.6b	5.4b
Bell pepper	2days	5.6c	5.2c	37.0d	45.7c	16.7d	77.5d	13.0c	12.0c	3.9c	3.2c
	4days	5.7b	4.5c	42.0d	48.5c	10.0c	7 19.4d	26.0c	11.0c	3.1c	3.0c
	6days	5.6c	4.8c	35.1d	46.8c	16.2b	24.6c	204.5d	6.5d	1.2d	1.5c

Table 5 shows the yield parameters of the three selected pepper varieties to varying irrigation regimes. The results show that flowering and fruiting in pepper is a factor of variety as the fruit yield data varied significantly with varieties. The highest significant flower and fruit yield was recorded from Capsicum chinense which was significantly higher than the values of both Capsicum frutescens and bell pepper. The lowest flower number and fruit number came from bell pepper which was significantly lower compared to the other two varieties. Interactions between irrigation regimes and varieties specifically influenced yield of the different pepper varieties. two and four days irrigation intervals induced flowering and fruit settings in wrinkle and cayenne pepper which led to high fruit yield. In bell pepper, increased frequency of irrigation (2 days interval) tends to promote flower abortion while irrigation at 4 days interval favours fruit setting and development.

The fruit weight(kg) were significantly enhanced in both wrinkle and Capsicum frutescens pepper by closer frequency of irrigation (2 days interval) which significantly differs from those of 4 and 6-days irrigation regimes. No significant difference was recorded between wrinkle and Capsicum frutescens pepper under 6days irrigation interval in term of fruit yield weight.

Table 5: Response of pepper varieties to varying irrigation regimes on yield parameters. 2017 and 2018 experiments

Plant Variety	Irrigation Regime	Total number of flowers/stand		Total Number of fruits/stand		Total Fruit weight (Kg)/stand	
		2017	2018	2017	2018	2017	2018
Cayenne pepper	2days	865.3b	980.5b	475.4b	398.9b	2.85a	2.94a
Wrinkle pepper	4days	662.8b	725.2b	380.2b	324.6b	1.54b	1.51b
	6days	325.2c	441.6c	197.8c	164.5d	0.82b	0.73c
	2days	1340.4a	1520.1a	580.1a	481.1a	2.64a	2.55a
	4days	1201.9a	1243.2a	420.9b	389.0b	1.35b	1.23b
	6days	732.0b	875.8b	230.5c	245.8c	0.91b	0.78c
Bell pepper	2days	135.4d	123.4d	19.2d	14.1e	0.13c	0.16d
	4days	93.7d	102.6d	16.4d	13.3e	0.12c	0.15d
	6days	61.3e	49.2e	4.7e	5.7e	0.04e	0.05e

IV. Discussion

The findings from this research shows that for sustainable and year round pepper production in the south western part of Nigeria, irrigation remains the only way out to meet the ever widening gap in between the production and consumption. Metin *et al.,* (2006) submitted that effective soil moisture managementis akey for sustainable pepper production. To meet the present world demand for pepper, a concerted effort is required in ensuring year round production through supplementary irrigation (Agele *et al*., 2011, Lodhi, *et al*., 2014).Considering the growth patterns of the selected pepper varieties that were similar across the two years

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of the experiment Agele *et al*., (2011) reported that growth, senescence and other physiological processes in pepper is actively controlled by moisture and nutrient availability in the soil. The physiological traits of the pepper varieties were influenced by moisture availability. The significantly higher stem height development recorded in Capsicum chinense was as a result of gene composition which dictates character expression in plant. Wrinkle and Capsicum frutescens pepper were known to grow taller in stem height compared to bell variety (Lodhi *et al*., 2013).

The similarity in the developmental pattern of Capsicum chinense with two and four day irrigation intervals may be due to sufficient moisture at the rooting zone which permit continuous moisture absorption and production of assimilates for growth and development. This was in line with the submission of Hsiao, (1993) that uninterrupted moisture availability within crop root zone during active growth stages enhances crop development. The significantly higher stem height development and leaves production recorded in the pepper varieties with two and four days irrigation intervals over those with six days irrigation intervals were justified by the findings of Agele *et al;* (2003) that maintaining soil moisture level at field capacity enhances shoot development in pepper.

The importance of soil moisture availability to plant growth and development was revealed as leaf production in the three pepper varieties were significantly influenced by irrigation regimes. This was in tandem with the findings of Agele *et al*, (2011) that closer irrigation intervals enhanced soil moisture retention which aids growth and development in pepper. The maximum average plant heights, number of leaves and leaf area index recorded in the three varieties showed that the plants responded differently to both nutrients and moisture availability. Although closer regimes of irrigation was applied across the varieties, this did not translated to corresponding uniformity in stem height, leaf number and leaf area across the varieties. This was as a result of variation in the water use efficiency of the pepper varieties, canopy and root system architectures. It is most probable that the amount of applied water per time may be too much for the crop use hence percolation losses without any appreciable compensation in term of shoot growth/development. These was in agreement with the findings of Njouajio *et al*.,2007.that though water is one major factor required for increasing pepper production, voids in soil structure were also needed to allow expansion of soil aggregates and roots during changes in soil temperature. This is also similar to the report of Bahmani *et al*. (2009) that constant saturation and over-saturation reduces crop growth and development especially for a crop like pepper that does not require too much water.

The significantly lower performance of crops under six days irrigation regimes was as a result of regular occurrence of soil moisture deficit through evapotranspiration, percolation and infiltration below field capacity even to wilting point during active vegetative and productive growth stages. This scenario continuously created a lacuna in the absorption and growth processes in the crop thereby leading to poor crop performance.

The significantly higher root parameters recorded in four and six days irrigation intervals was as a result of partitioning of higher percentage of produced assimilates for root development to enhance moisture absorption from the soil. This was supported by Famuwagun and Agele, 2010, Famuwagun, 2016 that plants adapt to moisture stress by partitioning more assimilates for root development as moisture in the soils diminished. The results were in line with that of Khan *et al.* (2005) who reported that plants under moisture stress tends to shortened their life span and try to complete their lifecycle in haste which causes earliness to flowering, fruiting and higher root volume development.

V. Conclusion

From the results, at the early stage of growth in pepper being a tap rooted plant, four- six day irrigation interval may be sufficient due to lesser transpiration rate, but as the canopy increases, a more frequent irrigation intervals is required to complement moisture requirement for growth and development and replace the lust moisture due to evapotranspiration for optimum growth, development and fruit yield..

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