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Impact of thermal performance of infrared lighting and water stress on growth and quality of cucumber

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ABSTRACT

Two field experiments were carried out at Experimental Station, Central Lab. for Agricultural climate, A.R.C, Dokki, during the two successive winter seasons in (2015/2016 and 2016/2017). This study was performed in four single type plastic houses to investigate the effect of infrared light and different water requirements (70, 85 and 100% of water requirements) and their interaction on climatic factors, vegetative growth, as well as fruit yield and quality of cucumber plants Parcoeda grown under clay soil condition. Obtained results revealed that infrared light increasing both minimum and maximum air temperature in general and especially at night. Infrared light and irrigated with any of used irrigation regimes (70, 85 and 100% of water requirements) enhanced all vegetative growth measurements (plant height, leaves number per plant, fresh and dry weight, whole plant) and increased all assayed chemical constituents of plant leaves i.e. chlorophyll, total nitrogen, phosphorus and potassium. Also it increased the total fruit yield and its components i.e., number of fruits per plant and fruit yield as well as total produced fruit yield. Economically, using infrared lamp with 100% water requirement was increasing the cucumber yield nearly 40%. While, using infrared with 85% water requirement was increasing yield nearly 25% and saving 15% of water irrigation. For the postharvest experiment, which aims to estimate the effect of all pre-harvest treatments on the quality of cucumber fruits during storage at 10°C and 85-90% relative humidity for 28 days, the results showed that infrared and irrigated with used irrigation regimes 100% of water requirements reduced weight loss% and decay score. Also maintained total soluble solids and color measurement (L*, a* and b* value) compared to other treatments.

Keywords: Cucumber - Infrared light -Water Requirement - Water stress - Protected Cultivation - Thermal performance - Post-harvest.

Introduction

Cucumber (*Cucumis sativus* L.) is one of the best vegetable crops of the world. It is also a major greenhouse vegetable not only in Egypt but also in the world. Moreover, cucumber is the fourth cultivated vegetable crop in the world after tomatoes, cabbage, and onions (Shetty and Wehner, 2002). Egypt ranked eighth in terms of production after (China, Iran, Turkey, Russia, USA, Ukraine and Spain) (FAO, 2017). Where production reaches 633,600 ton /year. Cucumber fruits contain (95% water& 3.6% carbohydrates and 0.65% protein), and also they are a good source of nutrients, Pantothenic acid (B_5) (0.026 mg kg^{-1}), vitamin C (0.28 mg kg^{-1}) Magnesium (1.3 mg kg^{-1}) (USDA, 2008). The cucumber fruit is use of fresh, some of which are absorbed into the skin, due to the increased water forgetfulness in the fruits. Cucumber plants are very sensitive to cold temperatures. There are differences between night and day temperatures in Egypt. In winter, the temperature reaches very low levels, which affects negatively on plants.

Temperature measurement is an important phenomenon in agricultural sectors. Several instruments and methods have been developed to measure the temperature of objects (Nott and Hall, 1999). Plant growth rate depends on the temperature (average, maximum and minimum) that informed by (Hatfield *et al.,* 2011) the region in the infrared band with wavelengths from 3 to 14 µm is called the thermal infrared region. This band is useful in imaging applications that use heat

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signatures (Gonzalez and Woods, 2002). Increase temperature of air work on increased soil temperature (Lamont, 1993). Several studies have shown that cold treatments work at low growth rates (Candolfi-Vasconcelos *et al.*, 1994), (Andreas *et al*., 2006). And thus vice versa. Greenhouses are designed to enhance crop productivity or to produce crops out of season by providing a favorable plant growth environment (Farag *et al.*, 2010). Increasing temperature to heat the greenhouse in cold seasons has a major effect on the cost of operation, as well as on plant growth and productivity (Seginer *et al*., 1994). The optimum day temperature were range between 22°C and 30°C (Grubben, 1997). On the other hand, (Papadopoulos *et al*., 2000) studied the effects of day and night air temperature (DT and NT) on growth of cucumber in the spring season. They found that plant development rates (leaves number) were linearly increased with increasing daily average air temperature. Also, they added that, the plant development rates increased with increasing air temperature regardless of DT or NT.

Water deficit is a major environmental factor restricting plant growth, development and productivity, particularly in arid regions more than any other single environmental factor. It seems the worldwide losses in crop yields from water deficit probably exceed the cumulative loss of all other stresses (Kramer, 1983). The water saving and conservation is essential to support agricultural activities (Abdrabbo *et al*., 2009). Cucumber plant is sensitive to water stress due to Levy root system is shallow (Kirnak and Demirtas, 2006; Hashem *et al*., 2011). In fact water irrigation is important for orchard man crops because water shortage in soil can cause flower and fruit drop in crops (Kaya *et al*., 2005). In cucumber, water stress has caused losses of yield and number of fruits/plant yield (Ayas and Demirtas, 2009; Wang *et al*., 2009; Zhang *et al*., 2011). In state of, excess water irrigation for cucumber lost lower fruit yields (Simsek *et al*., 2005; Hashem *et al*., 2011). Fruit effect by stress of water (Ayas and Demirtas, 2009; Wang *et al*., 2009; Zhang *et al*., 2011).

The changes in the quality of cucumber affected by temperature, relative humidity and light (Shin et al. 2007). The keeping quality in cucumber during postharvest handling are depend on mainly fruit general appearance due to loss of chlorophyll pigments, shriveling or wilting caused by loss of moisture which affects the firmness of the produce and physiological deterioration during storage (Manjunatha and Anurag, 2014).

Materials and Methods

First experiment (pre-harvest experiment):

Experiment was carried out during the two winter seasons (2015/2016 and 2016/2017) in Experimental Station, Central Laboratory for Agricultural climate, A.R.C, Dokki. This experiment was done under single type of a plastic greenhouse to investigate the growth and chemical composition of cucumber plants which grown under different infrared light and different water requirements.

Soil in the experimental site is clay soil in texture with pH of 7.5 and EC of 1.2 ds/m. Chemical analysis of soil and water show in Table (1).

Seeds of cucumber (*Cucumis sativus* L.) Parcoeda were sown on November 10th during two seasons (2015/2016 and 2016/2017) in multi-pot transplant trays were filled with mixture of peat-moss and vermiculite media (1:1 v/v). After sowing, trays were covered by black plastic mulching for four days, then moved to high tables and were followed by irrigation, fertilization and pest management in the nursery.

After 30 days from sowing, date transplants were set up into the plastic house on Dec 10th for the two seasons on the two sides of ridges 1m width and 15 m length. The distance between transplants was 30 cm within the row.

Table 1: Chemical analysis of soil and water.

	pH	EC (ds/m)	Anions (meq/L)				Cations (meq/L)			
			Cl^-	HCO_3^-	CO_3^{--}	SO_4^{--}	Na^+	K^+	Ca^{++}	Mg^{++}
Soil	7.5	1.2	2.2	2.1	-	35.8	9.1	1.0	20	10
Water	6.0	0.4	1.6	2.7	-	0.7	1.6	0.2	3	0.2

The experimental treatments

1-Infrared light treatment (IR):

a) Natural light (control).

b) Using infrared lamps (G2 1500/2000). These lamps were worked from 12 to 5 am. During this period, they turned on for 10 minutes then turned off for another 10 minutes and so on. The distance between plant and lamps was 1m height. Infrared is present between medium and long wave as shown in Fig.1.

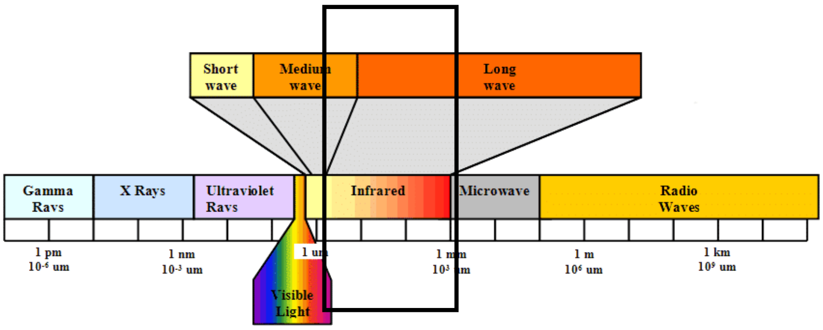

Fig.1 Analysis of light https://opranic.com/infrared-heating

2-Water requirement treatment (**W.R**):

a) 100% from water requirement (control).

b) 85% from water requirement.

c) 70% from water requirement.

Calculation of water regimes:

Data of class A pan (Epan) for Dokki experimental site expressed in mm/day were obtained from agro meteorological station located in the site.

$$Et_o = K_p \text{ X } E_{Pan} \quad (\text{mm / day})$$

Where:

Et_o = Potential evapotranspiration in mm / day.

K_p (Pan coefficient) = three stage (0.5, 0.75 and 1)

E_{Pan} = Pan evaporation in mm/day.

The second step was to obtain values of crop water consumptive use (Et_{crop}) as follows (FAO, 1977).

$$Et_{crop} = Et_o \text{ x } K_c \quad \text{mm / day}$$

Where:

Et_o = The rate of evapotranspiration from an excessive surface of green cover of uniform height (8 to 15 cm), actively growing, completely shading the ground and did not face shortage in water.

K_c = Crop coefficient "between"(0.3 to 1).

The third step is to calculate water requirements (WR) for each treatment as following:

$$WR = Et_{crop} \text{ x } L\% \text{ mm / day}$$

Where:

L % = Leaching requirement percentage in this saline water as follows.

L % = (E_{ciw} / E_{cdw}) x 100

Where:

E_{ciw} = Electrical conductivity of irrigation water dS/cm^{-1}.

E_{cdw} = Electrical conductivity of drainage water mMoh . cm^{-1}

L % was estimated to be 25%.

The fourth step was to calculate irrigation requirement (IR)

As: $$IR = WR \text{ x } R$$

Where:

WR= Water requirement
R = Reduction factor for drip irrigation only covers apart of land and leaves the rest dry.

Therefore, it was recommend by FAO (1977) to use R-value, which its estimated range between 0.25 and 0.9 for drip irrigation system.

Table 2: Water requirements (liter/plant/day) of cucumber under different level of irrigation water during two seasons.

Months	Et_o	Kc	Et_{crop}	L	W.R	R	IR W.R (100%)	85% W.R	70% W.R
Dec.	1.2	0.9	1.08	1.25	1.35	0.9	1.12	0.952	0.784
Jan.	1.4	1	1.4	1.25	1.75	0.9	1.58	1.343	1.106
Feb.	2	0.9	1.8	1.25	2.7	0.9	2.34	1.989	1.638

Water use efficiency (WUE):

Water use efficiency was calculated for the different water regimes treatments using the following equation (Srinivas *et al*., 1989).

WUE = Total water consumption (m^3 /fed.)/ Total yield (kg/ fed.).

Climatic conditions:

The micro climate is a major factor in this study, thus these following data were recorded:

Air temperature and relative humidity:

Average air temperatures and relative humidity at Dokki agro meteorological station show in (Table 3). The meteorological data of minimum and maximum air temperatures and relative humidity were recorded daily

Table 3: Monthly averages of maximum and minimum air temperature and relative humidity% during two growing seasons.

	2015/2016						2016/2017					
	Air temperature [°C]			Relative humidity [%]			Air temperature [°C]			Relative humidity [%]		
Months	Aver.	Min.	Max.	Aver.	min	max	Aver.	Min.	Max.	Aver.	Min.	Max.
Dec.	15.6	7	22.8	68.2	26.9	99.2	14.9	4	23.3	62.4	26.2	100
Jan.	13.6	1.6	22.3	62.6	24.7	100	13.9	2.2	24.5	59.1	13.9	100
Feb.	17.2	5.5	30.7	58.2	14.2	95.9	16.1	5.2	28.4	57.4	13.9	99.8

Experimental design:

The studied treatments were arranged using the split plot design. Light treatments were arranged in the main plots and water regimes treatments were arranged in the sub plots. All treatments were applied with three replicates. Randomize has been considered in the application of the studied treatments.

Cucumber growth, productivity and plant behavior were estimated by measuring vegetative growth parameters and yield as follow:

Vegetative growth:

Five plants were selected and labeled on each experimental plot and the following data were recorded.

- Plant height (cm) and number of leaves per plant were recorded at two times after 30 and 60 days from transplanting date.
- Leaf area (cm^2): The leaf area of the fifth leaf from the top was recorded two times after 30 and 60 days after transplanting by using a digital leaf area meter (LI-300 Portable Area Meter Produced by LI. COR, Lincoln, Nebraska, U.S.A).
- Total chlorophyll content: of the third positive leaf of the flowering stage was measured as SPAD units using Monitor Chlorophyll Meter (SPAD-501).

- A representative sample of three plants from each experimental unit were taken during the growth period, 180 days from transplanting to measure fresh (gm) and dry weight (gm).

Chemical properties:

Dry samples of plant foliage were ground and then 0.2 g of each sample was digested in sulphuric and percloric acid at ratio 2:1 by volume and then used for determining the chemical constituents.

- Nitrogen was determined in leaves by the distillation in a Macro-Kjeldahle apparatus ADAS/MAFF (1987).
- Phosphorus was colorimetrically determined in leaves in the acid digest using ascorbic acid and ammonium moly date as described by Watanabe and Olsen (1965).
- Potassium was determined by the flame- photo metrically as described by ADAS/MAFF (1987).

Yield components: data collected was number of fruits /plant and total yield (g/m^2).

Second experiment (storage experiments):

Cucumbers fruits were harvested at a optimum of developmental stages, and then transported to the laboratory of Post harvest and Handling of Vegetable Crops department at Giza governorate within 1.5 hours after harvesting. The fruits were carefully selected, free of visual damage or defects, washed initially with water, then air dried. Fruits were divided into three groups as the similar field treatments to study effect of these treatments and storage period on quality and storability of cucumbers fruits. After that fruits were packaged in bags each bag contain 500 gm and were placed in carton boxes.

The samples were taken at random in three replicates and arranged in a factorial complete randomized design and stored at 10˚C and 85-90% relative humidity for 28 days. The treatments were examined immediately after harvest and every seven days intervals for the following parameter.

Weight loss percentage: it was estimated according to the following equation: Weight loss% = [(Initial weight - weight of fruits at sampling date)/Initial weight of fruits] x 100.

Decay: it was determined as score system of 1= none, 2= slight, 3= moderate, 4= moderately severe, 5= severe. This depends on decay percentage on fruits.

Total soluble solids percentage (TSS): was determined as a composite juice sample by digital refractometer of model Abbe Leica according to A.O.A.C. (2000).

Color measurement: Color measurements (L*, a* and b* values) were performed using a Chroma meter CR-400 (Konica Minolta Inc. Osaka, Japan) with illuminant D65 with 8 mm aperture. The instrument was calibrated with a white reference tile (L*=97.52, a*=–5.06, b*=3.57) prior to measurements. The L* (0=black, 100=white), a* (+red, –green) and b* (+yellow, –blue) color coordinates were determined according to the CIELAB coordinate color space system.

Statistical analysis procedures:

Data were tested by analysis of variance according to Little and Hills (1975). Duncan's multiple range test was used to compare among treatments (Duncan, 1955).

Results and Discussion

First experiment (preharvest experiment):

Climatic Data:

Data in Figure (2), (3) and (4) shows maximum, minimum and average air temperature inside the greenhouse during two seasons as affected by using infrared lamps. The greatest value of maximum, minimum and average air temperature was detected by using IR lamps.

It may be conclude that to the best of any knowledge infrared radiation is thermal radiation is electromagnetic radiation. Energy is created the thermal motion of atoms, molecules and other particles of matter. Thermal radiation energy is energy moved by electromagnetic radiation obtained by thermal excitation motion of the particles of matter Dmitry (2015).

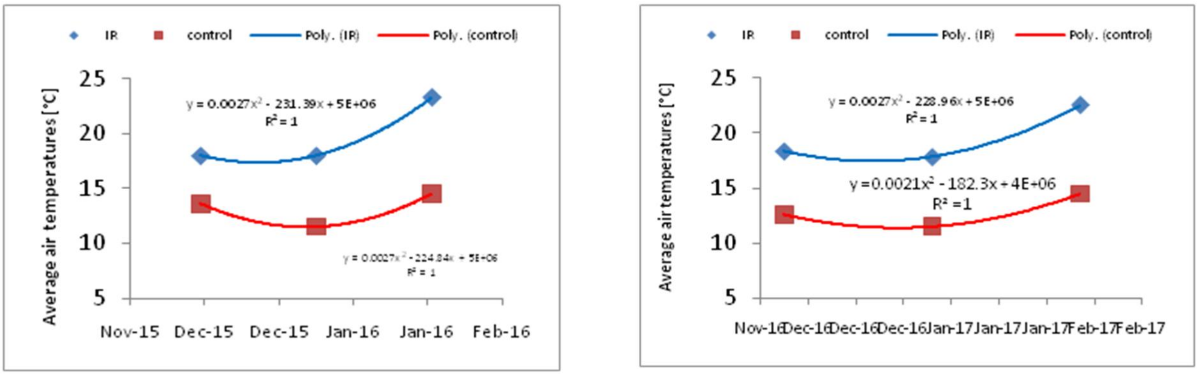

Fig. 2. Effect of inbreed lamp on average air temperature during (2015/2016) and (2016/2017)

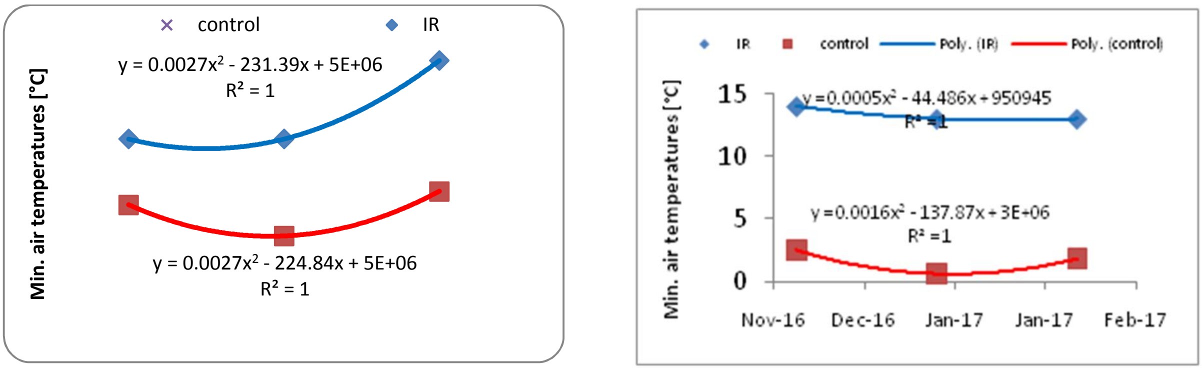

Fig. 3. Effect of inbreed lamp on minimum air temperature during (2015/2016) and (2016/2017)

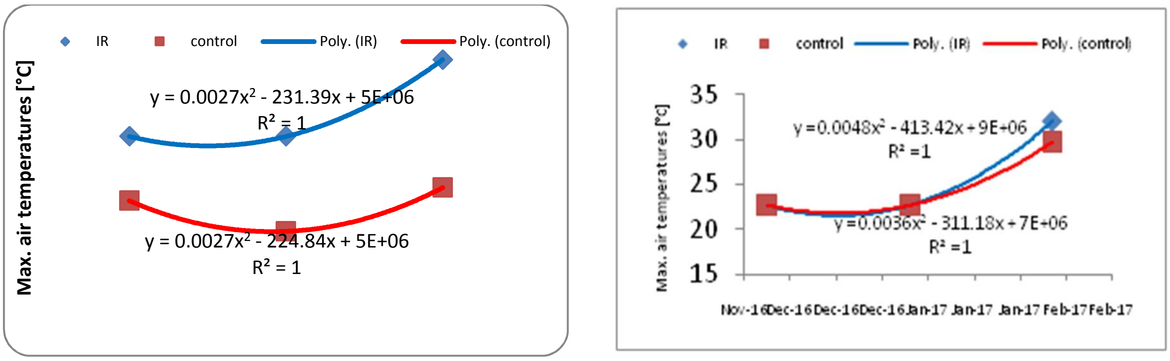

Fig. 4: Effect of inbreed lamp on maximum air temperature during (2015/2016) and (2016/2017)

Vegetative growth characteristics:

Data in Table (4 and 5) show that the effect of using infrared lamps and water stress on plant height, number of leaves and leaf area after 30 and 60 days of planting date.

Table 6 showed effect of using inferred lamb and water stress on total fresh weight, total dry weight and Total chlorophyll.

Effect of infrared lamps in plant height for both seasons was significant after 30 and 60 days. Using IR lamps presented the highest values compared with control treatment. Number of leaves was significant in both seasons except that in 30 day for the first season it was not significant. Leaf area was significant in both seasons. Infrared treatment given the highest values in fresh weight in both seasons was significant between all treatment 100% WR get highest values. In dry weight and total chlorophyll was no significant between 100% and 85% WR and significant with 70 %WR. These results due to increasing the air temperature around the plants during the night. This increase in air temperature may be resulted in increasing the photosynthesis. Increasing the values of vegetative growth under infrared treatments, that could be a result to increase the minimum temperature during

December, January and February (three months of the plant growth) were 2.5, 0.6 and 1.8°C, respectively. On the other hand, using infrared during these months presented increasing in the minimum temperature (13, 13 and 13.5°C, respectively). Similar results were obtained by Grafiadellis and Kyritsis (1981), Grafiadellis (1986), El-Doweny, *et al*. (1992) and Hatfield *et al*. (2011).

After 30 days, the differences between water treatments for plant height and leaf area in both seasons were not significant between 100% and 85% WR and significant with 70% WR after 30 days. While, after 60 days there was a significant effect between all treatment and the 100% WR treatment gave the highest value. That may be due the plant not exposed to water stress. Such results are in conformity Kirnak and Demirtas (2006), Hashem *et al.* (2011), Navarrete and Jeannequin (2000), Harmanto *et al.* (2005), Ibrahim (2005) and Sibomana *et al.* (2013).

Interaction between infrared and water requirement treatments for two seasons was significant. The best values for all parameter obtained by using infrared lamps with 100% WR after 30 or 60 days. And total fresh weight, total dry weight and Total chlorophyll.

That may be due to increasing temperature at night, which aid the plant to absorb the elements and water from the soil. These results show in Table (7).

Table 4: Effect of using infrared lamp and water stress on plant height (cm), number of leaves and leaf area (cm^2) after 30 day in two seasons.

Treatments	2015-2016			2016-2017		
	Plant height (cm)	**No. of leaves**	**Leaf area (cm^2)**	**Plant height (cm)**	**No. of leaves**	**Leaf area (cm^2)**
IR	63.6 A	14.0 A	2641.0 A	72.8 A	16.1 A	2676.4 A
Control	53.4 B	13.0 A	2235.0 B	65.9 B	14.0 B	2329.7 B
100% W.R	69.6 A	16.6 A	2587.6 A	76.8 A	16.5 A	2673.2 A
85% W.R.	61.1 A	12.4 A	2452.9 B	68.9 AB	15.0 A	2499.3 B
70% W.R.	44.9 B	11.6 B	2273.6 B	62.3 B	13.7 B	2336.6 B
100% W.R With IR	78.9 a	17.1 a	2829.6 a	81.5 a	17.7 a	2855.8 a
85% W.R With IR	66.6 a	14.7 b	2674.2 a	73.7 b	16.0 a	2705.0 a
70% W.R With IR	45.5 c	12.9 c	2419.2 b	63.3 c	14.7 b	2468.4 b
100% W.R Without IR	60.4 a	16.0 ab	2345.6 b	72.2 b	15.3 ab	2490.7 b
85% W.R Without IR	55.5 b	12.7 c	2231.6 bc	64.2 c	14.0 b	2293.7 bc
70% W.R Without IR	44.3 c	11.0 d	2127.9 c	61.3 c	12.7 c	2204.8 c

Table 5: Effect of using infrared lamp and water stress on plant height (cm), number of leaves and leaf area (cm^2) after 60 day in two seasons.

Treatments	2015-2016			2016-2017		
	Plant height (cm)	**No. of leaves**	**Leaf area (cm^2)**	**Plant height (cm)**	**No. of leaves**	**Leaf area (cm^2)**
IR	149.4 A	32.1 A	1031.3 A	167.0 A	36.8 A	1049.1 A
Control	134.2 B	26.2 B	887.4 B	143.1 B	31.7 B	898.8 B
100% W.R	163.3 A	33.4 A	1051.3 A	180.2 A	39.5 A	1072.4 A
85% W.R	143.5 B	29.4 A	944.4 B	153.2 B	33.8 B	964.9 B
70% W.R	118.6 C	24.8 B	882.2 C	131.8 C	29.3 B	884.4 C
100% W.R With IR	170.9 a	35.5 a	1158.9 a	190.8 a	42.0 a	1188.0 a
85% W.R With IR	155.0 b	32. ab	1003.4 ab	169.1 b	35.7 b	1023.4 b
70% W.R With IR	122.2 d	28.8 b	931.4 b	141.2 c	32.7 b	935.8 b
100% W.R Without IR	155.6 b	31.3 a	943.8 b	169.5 b	37.0 ab	956.8 b
85% W.R Without IR	132.1 c	26.6 b	885.4 bc	137.4 c	32.0 b	906.4 bc
70% W.R Without IR	115.0 d	20.8 c	833.0 c	122.4 d	26.0 c	833.1 c

Table 6: Effect of using infrared lamp and water stress on total fresh weight (gm), total dry weight (gm) and total chlorophyll (SPAD) in two seasons.

Treatments	2015-2016			2016-2017		
	Fresh weight (gm)	Dry weight (gm)	Total chlorophyll	Fresh weight (gm)	Dry weight (gm)	Total chlorophyll
IR	492.2 A	29.3 A	40.83 A	526.6 A	33.8 A	42.97 A
Control	414.8 B	23.5 B	33.07 B	439.6 B	26.6 B	34.51 B
100% W.R	557.6 A	28.7 A	40.15 A	593.7 A	30.5 A	41.56 A
85% W.R	466.7 B	25.5 A	36.70 B	494.6 B	32.8 A	39.13 A
70% W.R	336.2 C	24.9 B	34.00 B	361.0 C	27.3 A	35.53 B
100% W.R With IR	570.0 a	30.2 ab	45.8 a	634.4 a	31.7 b	46.9 a
85% W.R With IR	494.3 c	24.7 bc	40.2 b	542.1 b	37.4 a	43.6 a
70% W.R With IR	412.2 e	33.0 a	36.5 bc	403.3 c	32.3 b	38.4 b
100% W.R Without IR	545.1 b	27.3 b	34.5 cd	552.9 b	29.3 b	36.22 bc
85% W.R Without IR	439.1 d	26.3 c	33.2 cd	447.1 c	28.2 b	34.66 bc
70% W.R Without IR	260.1 f	16.9 d	31.5 d	318.7 d	22.3 c	32.66 c

Chemical characteristics:

Table (7) showed that the effect of using infrared lamp and water stress on Nitrogen %, Phosphor % and Potassium %. In two seasons, the effect of infrared treatments on nitrogen, phosphorus and potassium content were significant. Using infrared lamps gave the highest values for the three elements. That may be due to increase the air temperature or/and increase the number of leaves which cause increasing photosynthesis. also may be increasing observation the nutrient. Similar results were obtained by El-Doweny *et al*. (1992) and Hatfield *et al.* (2011).

Differences between water treatments in both seasons were significant for nitrogen and phosphorus content. The highest percentage was observed in 100% WR followed by 85%. The lowest percentage found under 70% W.R treatment. Effect between 85 and 70% WR was not significant. That may be due the plant not exposed to water stress. Such results are in conformity with Navarrete and Jeannequin (2000), Harmanto *et al.* (2005), Ibrahim (2005), Abdrabbo *et al.* (2009) and Sibomana *et al.* (2013).

Effect of interaction in both seasons was significant. The best values for the three elements were recorded by using infrared lamps with 100% W.R. That may be due to increasing temperature at night that increase water and elements absorb. These results were obtained by Hatfield *et al.* (2011).

Table 7: Effect of using infrared lamps and water stress on total Nitrogen, phosphor and potassium % in two seasons.

Treatments	2015-2016			2016-2017		
	N%	P%	K%	N%	P%	K%
IR	3.3 A	1.0 A	4.2 A	3.3 A	1.0 A	4.2 A
Control	2.8 B	0.8 B	3.4 B	2.8 B	0.9 B	3.4 B
100% W.R	3.5 A	1.0 A	4.4 A	3.4 A	1.0 A	4.4 A
85% W.R	3.0 B	0.9 B	3.9 B	3.0 B	0.9 B	4.0 B
70% W.R.	2.6 B	0.9 B	3.0 C	2.7 B	0.9 B	2.9 C
100% W.R With IR	3.9 a	1.0 a	4.7 a	3.6 a	1.0 a	4.7 a
85% W.R With IR	3.1 ab	1.0 a	4.3 b	3.2 ab	1.0 a	4.4 ab
70% W.R With IR	2.9 bc	0.9 b	3.5 c	2.9 b	0.9 b	3.4 c
100% W.R Without IR	3.2 ab	0.9 b	4.1 b	3.3 ab	0.9 b	4.2 b
85% W.R Without IR	2.8 bc	0.8 c	3.5 c	2.8 bc	0.9 b	3.5 c
70% W.R Without IR	2.3 c	0.8 c	2.4 d	2.4 c	0.8 c	2.4 d

Yield characteristics:

Table (8) showed that Effect of infrared lamps in both seasons was significant for number of fruits, yield and water use efficiency. Infrared lamps get the highest values in these parameters. This due to increasing air temperature and increasing vegetative growth due to increasing bio physiological operation in plant cell and chemical characteristics estimated to tables (4, 5 and 7). Plants which grown under infrared lamps were more healthy and stronger to get fruits and yield more than other plants.

Water requirement treatments had a significant effect on number of fruits, total yield and water use efficiency for the two seasons. The highest values were obtained by using 100% water requirement followed by 85%. On the other hand, using 70% water requirement presented the lowest values. This result may be rise because the plants not exposed to water stress. These results are in conformity with Navarrete and Jeannequin (2000), Harmanto *et al*., (2005), Ibrahim (2005), Ayas and Demirtas (2009), Wang *et al.* (2009), Abdrabbo *et al*., (2009), Zhang *et al.,* (2011) and Sibomana *et al.* (2013) also may be the observations of potassium it cased that.

Interaction between water requirement and infrared treatments was significant for the both seasons. The best values for all parameters were given by using infrared lamps with 100% water requirement. We can order the treatment to ((100%, 85% with IR), (100%, 85% without IR), 70% with IR and last one 70 without IR).

That may be due to increasing temperature at night that helped the plant to absorb the elements and water (Hatfield *et al.,* 2011).

Table 8: Effect of using infrared lamps and water stress on number of fruits/plant, total yield (g/m^2) and water use efficiency in two seasons.

Treatments	2015/2016			2016/2017		
	No. of fruits/plant	Total yield (g/m^2)	Water use efficiency	No. of fruits/plant	Total yield (g/m^2)	Water use efficiency
IR	39.3 A	11259.3 A	7.26 A	32.5 A	11763.9 A	7.68 A
Control	31.1 B	8437.0 B	5.44 B	27.8 B	9877.3 B	6.44 B
100% W.R	34.2 A	12075.6 A	6.66 A	40.1 A	11936.1 A	6.58 A
85% W.R	30.0 B	9753.3 B	6.32 A	37.1 B	11302.1 A	7.33 A
70% W.R.	26.2 C	7715.6 C	6.23 A	28.4 C	9223.6 B	7.26 A
100% W.R With IR	36.4 a	13728.9 a	7.57 a	43.3 a	12900.0 a	7.11 a
85% W.R With IR	33.0 b	11208.9 b	7.27 a	41.1 a	12333.3 a	8.00 a
70% W.R With IR	28.0 c	8840.0 d	6.96 b	33.4 c	10058.3 c	7.92 a
100% W.R Without IR	31.9 b	10422.2 c	5.74 bc	36.8 b	10972.2 b	6.05 b
85% W.R Without IR	27.0 c	8297.8 d	5.38 cd	33.1 c	10270.8 c	6.66 b
70% W.R Without IR	24.4 d	6591.1 e	5.19 d	23.4 d	8388.9 d	6.61 b

Second experiment (storage experiments):

Loss in weight percentage:

The results in Table (9) indicate that weight loss was significantly affected by pre-harvest treatments during storage period.

Fruits using IR lamb with using 100% water requirement during pre-harvest gave the lowest value of weight loss percent followed by fruits using IR lamb with using 85% water requirement during pre-harvest compared with control treatments for cucumbers fruits in both seasons. Similar results were reported by (Uchino *et al*., 2004).

Data also showed that weight loss percentage of cucumbers fruits was increased by the prolongation of the storage periods. This continuous loss in weight during storage results from the loss of water by transpiration and loss of dry matter due to respiration. These results are in harmony with results obtained by Kader *et al.* (1989).

Table 9: Effect of using inferred lamb and water stress on weight loss%, decay score and total soluble solids% of cucumber fruits during storage at 10ºC in two seasons.

Treatments	Days after storage	2015-2016						2016-2017					
		Weight loss %		Decay		Total soluble solids %		Weight loss %		Decay		Total soluble solids %	
100% W.R With IR	0			1.00	d	4.10	a			1.00	f	4.00	a
	7	0.31	o	1.00	d	4.07	ab	0.38	o	1.00	f	4.00	a
	14	0.53	n	1.00	d	4.03	abc	0.61	m	1.00	f	3.93	ab
	21	0.83	k	1.00	d	3.93	cdef	0.95	j	1.33	ef	3.90	abc
	28	1.20	hi	1.67	bcd	3.90	defg	1.35	g	1.67	def	3.80	cde
85% W.R With IR	0			1.00	d	4.10	a			1.00	f	4.00	a
	7	0.45	n	1.00	d	4.00	abcd	0.54	n	1.00	f	3.93	ab
	14	0.72	l	1.33	cd	3.97	bcde	0.81	k	1.00	f	3.87	bcd
	21	1.13	i	1.67	bcd	3.87	efg	1.21	h	2.00	cdef	3.80	cde
	28	1.44	f	2.00	abcd	3.80	gh	1.53	f	2.33	bcde	3.67	fgh
70% W.R With IR	0			1.00	d	4.10	a			1.00	f	4.00	a
	7	0.62	m	1.00	d	3.93	cdef	0.71	l	1.00	f	3.83	bcde
	14	0.95	j	1.33	cd	3.90	defg	1.08	i	2.00	cdef	3.73	efg
	21	1.46	f	2.00	abcd	3.73	hi	1.54	f	2.67	abcd	3.63	ghi
	28	1.75	d	2.67	ab	3.63	ij	1.84	d	3.00	abc	3.53	ijk
100% W.R Without IR	0			1.00	d	4.10	a			1.00	f	4.00	a
	7	0.52	n	1.00	d	4.00	abcd	0.59	mn	1.00	f	3.90	abc
	14	0.82	k	1.33	cd	3.93	cdef	0.94	j	1.67	def	3.80	cde
	21	1.34	g	2.00	abcd	3.80	gh	1.40	g	2.33	bcde	3.77	def
	28	1.61	e	2.33	abc	3.73	hi	1.72	e	2.67	abcd	3.60	hij
85% W.R Without IR	0			1.00	d	4.10	a			1.00	f	4.00	a
	7	0.73	l	1.33	cd	3.90	defg	0.86	k	1.33	ef	3.80	cde
	14	1.16	hi	1.67	bcd	3.83	fgh	1.26	h	2.33	bcde	3.67	fgh
	21	1.72	d	2.67	ab	3.63	ij	1.83	d	3.00	abc	3.57	hijk
	28	2.04	b	3.00	a	3.57	j	2.18	b	3.33	ab	3.47	kl
70% W.R Without IR	0			1.00	d	4.10	a			1.00	f	4.00	a
	7	0.79	kl	1.33	cd	3.90	defg	0.92	j	1.33	ef	3.80	cde
	14	1.21	h	2.00	abcd	3.80	gh	1.35	g	2.67	abcd	3.63	ghi
	21	1.93	c	2.33	abc	3.60	j	2.11	c	3.00	abc	3.50	jkl
	28	2.31	a	3.00	a	3.53	j	2.45	a	3.67	a	3.40	l
100% W.R With IR		0.72	F	1.13	C	4.01	A	0.82	F	1.20	E	3.93	A
85% W.R With IR		0.94	E	1.40	BC	3.95	B	1.02	E	1.47	DE	3.85	B
70% W.R With IR		1.20	C	1.60	AB	3.91	B	1.29	C	1.93	BC	3.81	C
100% W.R Without IR		1.07	D	1.53	B	3.86	C	1.16	D	1.73	CD	3.75	D
85% W.R Without IR		1.41	B	1.93	A	3.81	D	1.53	B	2.20	AB	3.70	E
70% W.R Without IR		1.56	A	1.93	A	3.79	D	1.71	A	2.33	A	3.67	E
	0			1.00	D	4.10	A			1.00	D	4.00	A
	7	0.57	D	1.11	D	3.97	B	0.67	D	1.11	D	3.88	B
	14	0.90	C	1.44	C	3.91	C	1.01	C	1.78	C	3.77	C
	21	1.40	B	1.94	B	3.76	D	1.51	B	2.39	B	3.69	D
	28	1.73	A	2.44	A	3.69	E	1.84	A	2.78	A	3.58	E

Decay:

As to the tested pre-harvest treatments during storage period, data in Table (9) indicate clearly that fruits using IR lamb with using 100% water requirement during pre-harvest gave the lowest score of decay followed by fruits using IR lamb with using 85% water requirement during pre-harvest then control treatments in both seasons, maybe increasing infrared radiation delay ripening (Hamanaka *et al.*, 2005, 2006, 2010). It is clear from data presented that the decay of fruits were significantly increased with prolongation of the storage period. The decay started slowly in all treatments and successively increased till the end of storage. This was a result of the changes which occurred in fruits during storage.

Total soluble solids percentage (TSS):

Data in Tables (9) revealed that, fruits using IR lamb with using 100% water requirement during pre-harvest or fruits using IR lamb with using 85% water requirement during pre-harvest had the highest value of TSS comparing with control treatments in both seasons. However, fruits using IR lamb with using 100% water requirement during pre-harvest was the most effective treatment in maintain this character (Uchino *et al*., 2004).

Data showed that TSS of the fruit decreased with the prolongation of storage period. This may be due to the higher rate of dry matter through respiration than that of moisture loss through transpiration (Wills *et al*., 1981).

Color measurement:

Data in Table (10) the color of cucumbers fruits was significant differences during storage period in both seasons. Fruits using IR lamb with using 100% water requirement during pre-harvest had lightest color (high L* value) compared with other treatments followed by Fruits using IR lamb with using 85% water requirement during pre-harvest.

In general, value for a* increased during storage for all treatments in both seasons. Concerning the treatments data indicated that fruits using IR lamb with using 100% water requirement during pre-harvest had lower a* value (means high green color) followed by using IR lamb with using 85% water requirement during pre-harvest compared to control treatments fruits (high a* value, means low green color).

For b* value data showed that fruits using IR lamb with using 100% water requirement during pre-harvest led to a slightly reduction in b * value in the end of storage (28 days) good green color followed by using IR lamb with using 85% water requirement during pre-harvest compared to control treatments Similar results by (Goncalves *et al*., 2016).

Conclusion

Economically, using infrared lamp with 100% water requirement increase the cucumber yield nearly 40%. While, using infrared with 85% water requirement increase yield nearly 25% and saving 15% of water irrigation. Using infrared lamp increasing growth and quality parameter. Using infrared lamp increasing water use efficiency.

Table 10: Effect of using inferred lamb and water stress on L*, a* and b* Value of cucumber fruits during storage at 10ºC in two seasons.

Treatments	Days after storage	2015-2016			2016-2017		
		L* Value	a* Value	b* Value	L* Value	a* Value	b* Value
100% W.R With IR	0	53.14 a	41.30 a	10.32 a	52.66 a	41.05 a	9.96 a
	7	53.01 b	41.21 a	9.80 hi	52.46 b	40.85 b	9.31 k
	14	52.80 c	40.92 cd	9.61 k	52.13 d	40.62 d	9.10 m
	21	52.51 g	40.44 fg	9.42 lm	51.81 fg	40.22 f	8.82 o
	28	52.12 j	40.22 hi	9.18 n	51.51 j	39.91 h	8.51 q
85% W.R With IR	0	53.14 a	41.30 a	10.32 a	52.66 a	41.05 a	9.96 a
	7	52.80 c	41.12 ab	9.94 f	52.31 c	40.70 c	9.47 hi
	14	52.65 e	40.82 de	9.75 ij	51.84 ef	40.31 e	9.25 l
	21	52.21 i	40.37 fgh	9.55 k	51.65 i	40.03 g	9.04 n
	28	51.72 m	39.91 kl	9.38 m	51.30 l	39.72 j	8.71 p
70% W.R With IR	0	53.14 a	41.30 a	10.32 a	52.66 a	41.05 a	9.96 a
	7	52.60 f	41.02 bc	10.14 c	51.90 e	40.34 e	9.67 de
	14	52.32 h	40.53 f	9.93 f	51.32 l	39.82 i	9.54 g
	21	51.81 l	40.02 jk	9.80 hi	51.31 l	39.52 k	9.31 k
	28	51.21 p	39.51 n	9.61 k	50.91 n	39.22 m	9.03 n
100% W.R Without IR	0	53.14 a	41.30 a	10.32 a	52.66 a	41.05 a	9.96 a
	7	52.73 d	41.02 bc	10.03 e	52.12 d	40.55 d	9.52 gh
	14	52.50 g	40.72 e	9.85 gh	51.51 j	40.05 g	9.40 j
	21	52.02 k	40.21 hi	9.71 j	51.41 k	39.71 j	9.21 l
	28	51.41 o	39.71 m	9.46 l	51.12 m	39.44 l	8.85 o
85% W.R Without IR	0	53.14 a	41.30 a	10.32 a	52.66 a	41.05 a	9.96 a
	7	52.52 g	40.91 cd	10.23 b	51.77 gh	40.18 f	9.77 c
	14	52.11 j	40.31 ghi	10.06 de	51.10 m	39.68 j	9.62 ef
	21	51.61 n	39.81 lm	9.89 fg	50.90 n	39.22 m	9.45 ij
	28	50.92 q	39.30 o	9.72 j	50.71 o	38.85 o	9.20 l
70% W.R Without IR	0	53.14 a	41.30 a	10.32 a	52.66 a	41.05 a	9.96 a
	7	52.50 g	40.83 de	10.26 ab	51.71 h	40.05 g	9.83 b
	14	51.80 l	40.17 ij	10.13 cd	50.94 n	39.45 kl	9.70 d
	21	51.41 o	39.64 mn	10.04 e	50.76 o	39.04 n	9.57 fg
	28	50.72 r	39.02 p	9.81 hi	50.54 p	38.66 p	9.32 k
100% W.R With IR		52.72 A	40.82 A	9.67 F	52.11 A	40.53 A	9.14 F
85% W.R With IR		52.50 B	40.70 B	9.79 E	51.95 B	40.36 B	9.29 E
70% W.R With IR		52.22 D	40.48 D	9.96 C	51.62 D	39.99 D	9.50 C
100% W.R Without IR		52.36 C	40.59 C	9.87 D	51.76 C	40.16 C	9.39 D
85% W.R Without IR		52.06 E	40.33 E	10.04 B	51.43 E	39.80 E	9.60 B
70% W.R Without IR		51.92 F	40.19 F	10.11 A	51.32 F	39.65 F	9.68 A
	0	53.14 A	41.30 A	10.32 A	52.66 A	41.05 A	9.96 A
	7	52.69 B	41.02 B	10.07 B	52.05 B	40.45 B	9.59 B
	14	52.36 C	40.58 C	9.89 C	51.47 C	39.99 C	9.44 C
	21	51.93 D	40.08 D	9.74 D	51.31 D	39.62 D	9.23 D
	28	51.35 E	39.61 E	9.52 E	51.02 E	39.30 E	8.94 E

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