A SIMPLE HYDROPONIC SYSTEM FOR PEPPER PRODUCTION IN UPPER EGYPT

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ABSTRACT

The aim of this research is to design and test an appropriate hydroponic system for pepper production in Upper Egypt to overcome the problems associated with expensive models that used high technology. The designed system has the following advantages: simple, available to all people in the upper Egypt to set up, fabricated from commercial available materials in the local market and easy to operate and maintain. The system was installed and tested on the roof (area 10 m²:5 m length x 2 m height, covered with 20 m² theran sheet to reduce hazard of sun radiation and high temperature on healthy plant growth and production) building of Agricultural Engineering Department, Al Azhar University, Assiut branch through two seasons 2008-2009 and 2009-2010, for high quantity and quality pepper crop production with two irrigation cycles number 5 and 10 (cycle time of 15 min.), Flow rates (1.5, 2 and 2.5 L/min), and EC (electrical conductivity 2 and 3 mmhos/cm) with pH range of 5.5 - 6.0. The main results showed that the optimum conditions for pepper crop "Bigmami" production by using the designed HYDROPONIC system were: flow rate of 2 L/min, electrical conductivity "EC" of 3 mmhos/cm and irrigation cycle number of 10 /day. The results obtained in optimum conditions were: Average root length per plant = 18.6 cm, Average total leaves area = 8290.4 cm², average total fruits yield = 6.0 kg / plant, Maximum consumptive water use = 18 L / plant/season, Average water use efficiency = 333 g / L , and the cost of produce 1 kg of pepper fruits was 1.27 L.E..

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INTRDODUCTION

Pepper is one of the important crops grown under protected cultivation in Egypt. It presents about 25% of the cultivation under plastic houses, **Anonimous (2003).**

Abou-Hadid et al., (1995) tested different growing media for producing cucumber under Egyptian condition . The tested growing media were peat moss: sand : vermiculite (1: 1 :1 v / v / v), peat moss :vermiculite (1 / 1   v / v), peat moss : sand (1 : 1 v / v) and rock wool in comparison with the traditional cultivation in soil . They found that the peat –based mixture gave higher number of leaves than the other growing media .

El- Behariy et al., (2001 a) indicated that plants grown in NFT system gave higher total leaf area than substrate system (sponge**).**

  The advantages of simplified HYDROPONIC (SH) were summarized in the following points, **Caldeyro (2003)**:

• It is a low cost and easy-to-learn technique.

• It allows the production of vegetables "without soil" in containers with water or in low-cost natural substrates (sand, rice skulls, pumice stone, etc.). It allows to grow a wide variety of vegetables, such as lettuce, tomatoes, carrots, garlic, watercress, aborigines, beans, parsley, radish, leek, strawberries, melons, flowers, aromatic and medicinal plants, etc.

• It allows the use of recycled materials to build the containers, thus making low-cost materials such as wood and disposable containers, useful.

• It is ideal for food production in Urban Agriculture. It offers the advantage of using places that have not previously been thought appropriate for food production (courtyards, small gardens, walls, balconies, rooftops).

• High efficiency of the use of water, but requires uncontaminated water availability.

• Generation of direct income for family or community micro enterprises.

• It allows the production of high quality, harmless food. The fruits and vegetables have a very high biological and nutritional value. Since they are grown by the family, they are harvested immediately before their use, thus, the products are fresh and they keep their nutritional and medicinal qualities intact. Another advantage for the settlements is that it allows cultivation out of the ground, harmless and uncontaminated. In order to assure the harmlessness of the final product, it is essential to use drinking water and / or clean rainwater.

Hydroponic systems are classified in either open or closed. In the open system, which is an intermittent system, the nutrient solution either flows through cultivation tubes or is deposited onto the cultivation substrates, and the exceeding amounts return to the catchment tank. In the closed system, which is a static-intermittent system, the nutrient solution is injected only once per irrigation cycle and the remaining solution is not returned to the catchment tank **(Resh 1997 and Jensen 1999)**.

Haddad and Boukhris (2003) demonstrated that both very early and early marketable yields of tomato were not affected by substrate type but total yield was higher in sand grown plants compared perlite grown plants.

HYDROPONIC is a technology for growing plants in nutrient solution (water containing fertilizer) with or without use of an artificial medium (sand, gravel, vermiculite, rock wool, polite, peat moss, coir, or sawdust) to provide mechanical support. Liquid HYDROPONIC systems have no other supporting medium for the plant roots

HYDROPONIC is the production of plants in a soilless medium whereby all of the nutrients supplied to the crop are dissolved in water. Liquid hydroponic systems employ the nutrient film technique (NFT), floating rafts, and no circulating water culture. Aggregate hydroponic systems employ inert, organic, and mixed media contained in bag, trough, trench, pipe, or bench setups.

Aggregate media used in these systems include perlite, vermiculite, gravel, sand, expanded clay, peat, and sawdust. Normally, hydroponic plants are fertile (soluble fertilizers injected into irrigation water) on a

periodical cycle to maintain moist roots and provide a constant supply of nutrients. These hydroponic nutrients are usually derived from synthetic commercial fertilizers, such as calcium nitrate, that are highly soluble in water. Hydroponic recipes are based on chemical formulations that deliver precise concentrations of mineral elements. The controlled delivery of nutrients, water, and environmental modifications under greenhouse conditions is a major reason why HYDROPONIC is so successful.

Jensen and Collins (1985) published a complete review of HYDROPONIC highlighting many new cultural systems developed in Europe and the United States.

Merle Jensen (1997) mentioned that the European glass structures that today are commonly being built for vegetable production in the southwestern part of the United States are very different from the polyethylene/fiberglass houses used in HYDROPONIC production between 1965 and 1990

EL- Beltage et al. (1992) reported that cucumber plant grown in peat moss + sand + vermiculite (1 :1 : 1) substrate yielded higher vigorous plant than those grown in other in tested mixed media.

Ahmed (2003) indicated that the highest total leaf area was obtained by using sand: peat moss: perlite ``3: 1: 1   v / v / v `` substrate then A-shape NFT system, while the lowest value was obtained by the aeroponic system.

Bohme (1994) demonstrated that highest total yields were recorded from the plants grown in compound organic substrates, compared with rock wool mats, perlite and urea foam.

Marle and Jensen (1997) concluded that the general recommendations outlined in "Application of fertilizer and water." Target 5 % over drain early in the cycle and increase over drain up 30 % in summer. Increase the amount of water in accordance with the demands of the plant.

Tuzel et al. (2001) reported that there were an interaction between substrate volume and substrate type and irrigation times, where the highest yield of tomato plant was recorded for plants irrigated four times a day and substrate volume 8 liter per plant.

MATERIALS AND METHODS

- Materials:

- The designed HYDROPONIC system:

The designed HYDROPONIC system consists of the following parts as shown in fig. 1a and b:

(a) Nutrient solution tank.

A nutrient solution plastic-tank has 80 cm diameter and 90 cm height (volume of 450 liter).

(b) Nutrient solution.

The composition of the nutrients solution **(Hogland)** that used in experiment were maintained ranged from 2 to 3 m.mhos/cm for EC and pH of 5.8 to 6.0 by using digital EC and pH meter during the experiments.
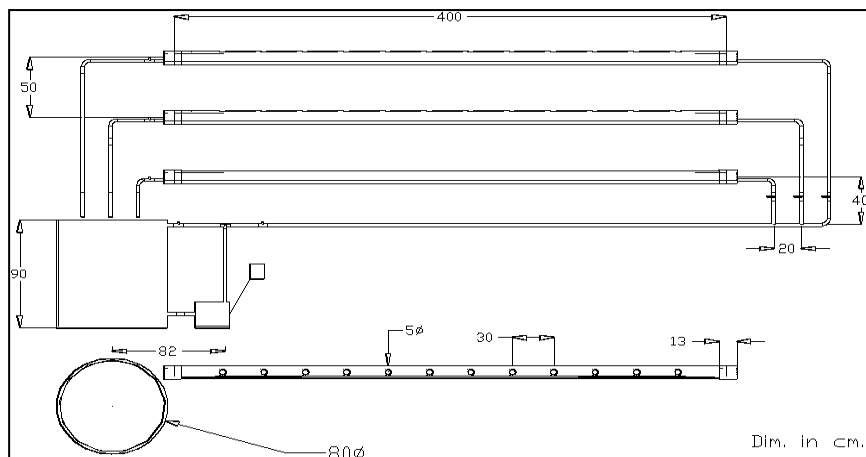
(c) Pump and Timer.

Centrifugal pump of 0.38 kw was used in this experiment to circulate the nutrient solution between nutrient solution tank and pipes. In addition to timer was used to control irrigation cycle time with increment of 15 min.

The pumping of the nutrient solution from the tank was performed automatically during nursery and growing stages, starting on irrigation cycles times for (at 7:00 a.m., maintaining an intermittent nutrient flow, working for 15 min, during the production phase, until 12.00 p.m.. At night).
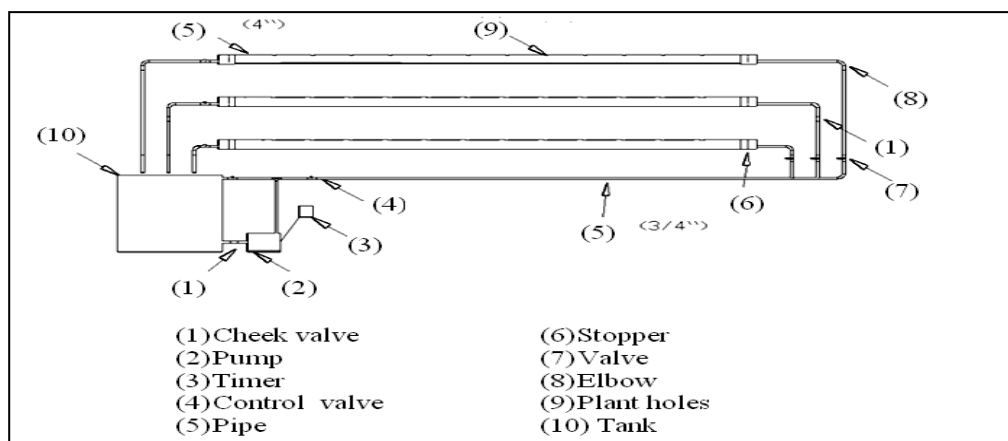
(c)   P.V.C pipe.

 Three 4" PVC pipes (4 m length) with 12 hole (diameter of 75 mm) fixed horizontally on the roof wall in zero level with 50 cm spacing were used to support the plants in pipe hole using polyethylene bag, with diameter of 75 mm. and in order to control and maintain the flow rate in pipes within desired limit (solution height 52.5 mm of inside pipe diameter), two 1" valves used on each pipe inlet and outlet.

-Tested crop. Pepper crop "Bigmami" variety was cultivated in this study.

(A)

(1) Cheek valve   (6) Stopper
(2) Pump   (7) Valve
(3) Timer   (8) Elbow
(4) Control valve   (9) Plant holes
(5) Pipe   (10) Tank

(B)

Figure 1:(A) The developed hydroponic system with dimensions.

(B) The Schematic diagram of developed hydroponic system

-Instrumentations:

- pH meter range 0-14 with accuracy of 0.1.
- EC meter range 1-3 mmhos/cm and accuracy of 0.001 mmhos/cm.
- Thermometer glasses with range of $0 – 200$ C° was used.
- Total surface leaves area was determined using L1-300 portable area-meter.
- Relative humidity was determined using RH meter (RH 200).

-Methods:

- Studied factors:

1- **Irrigation cycle:** Timer adjusted to give 5,10 irrigation circulation time (15 min) with Start times at 7,9,11 am and 1,4 pm in the first season (2008-2009) and in the second season (2009-2010) start times were 3,7,9,11 am. and 1,3,5,7,10.12 pm.

2- **Flow rate:** Included of three discharge (1.5, 2 and 2.5 L/min) were adjusted using control valves, graduated cylinder and stop watch.

3- **Electrical Conductivity** (EC) **:** were adjusted at 2 and 3 mmhos/cm using Hogland solution and EC meter.

Measurements:

-**Microclimate factor:** light intensity (foot-candles), average temperature (C°) and Relative humidity (%).

-**Solution measurements:** electrical conductivity (EC) and humidity (pH).

-**Plant growth parameters:** Root length, total leaves area, and total yield**,** consumptive water use using Blaney-Criddle equation **(Ponce 1989).**:

$$ETo = p \cdot (0.46 \cdot Tmean + 8)$$

Where:.

ETo: is the reference evapotranspiration [mm day−1] (monthly)

Tmean: is the mean daily temperature [°C]

p :is the mean daily percentage of annual daytime hours.[1]

- **Water use efficiency** and Consumptive water use.

-**cost detail.**

RESULT AND DISCUSSION

-Effect of the flow rate on plant characteristics:

1- Root length.

Fig. 1 shows that the maximum average root length of 18.6 cm on 10th irrigation cycles number by using a solution with EC 3 mmhos/cm with flow rate 2 L/min through season (2009-2010) . And, the minimum average root length 8.7 cm on 5th irrigation cycles number by using a

solution with EC 2 mmhos/cm with flow rate 1.5 L/min through season (2008-2009) .

The increasing average root length with increasing of flow rate agrees with (Fahem 1989) results.

2- Total leaves-area.

Fig. 1 shows that the maximum average total leaves-area 7345.5 cm^2 and 8290.4 cm^2 on 10th irrigation cycles number by using a solution were EC 2 and 3 mmhos/cm were flow rate 2 L/min respectively at two seasons (2008-2009 and 2009-2010) respectively. Meanwhile, the minimum average total leaves-areas of 4605.6 cm^2 and 5624.8 cm^2 on 5th irrigation cycles number by using a solution were EC 2 and 3 mmhos/cm for flow rate 1.5 L/min at two seasons(2008-2009 and 2009-2010) respectively. The increasing total leaves-area may be due to increased of temperatures and Light intensity (foot-candles) recorded through season that agree with (Fahem 1989) results.
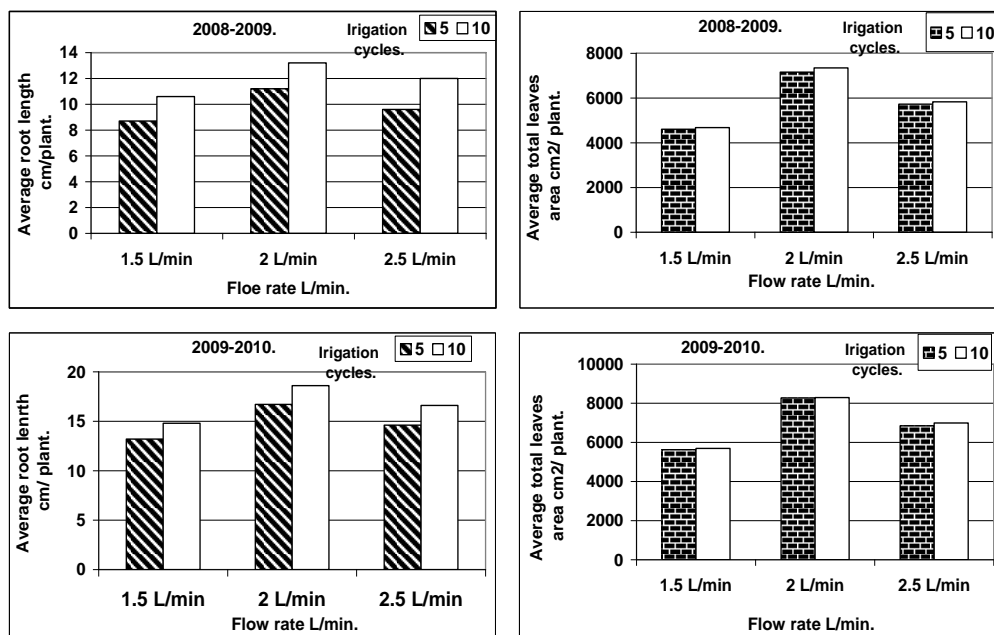

Fig.1: Effect of flow rate on average root length and total leaves area by using two irrigation-cycles number (5 and 10 / day) at two seasons.

- Effect of flow rate on total fruits-yield.

Fig. 2 shows that the maximum average total fruits – yield of   6 kg / plant /season on 10th irrigation cycles number by using a solution with EC 3 mmhos/cm for flow rate 2 L/min through season (2009-2010).
Meanwhile, the minimum average total fruits yield 3 kg /plant /season on 5th irrigation cycles number by using a solution with EC 2 mmhos/cm for flow rate 1.5 L/min through season (2008-2009).
The increasing total fruits - yield may be due to increasing of flow rate and irrigation cycles number.
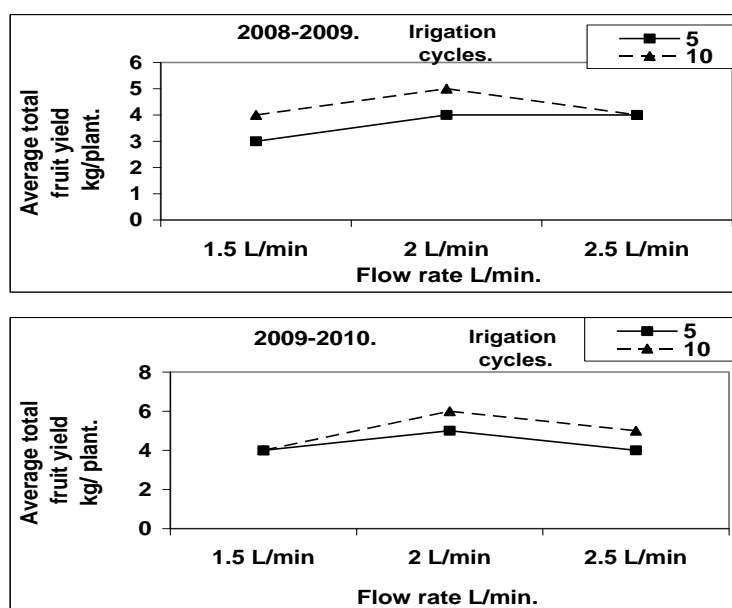

Fig. 2: Effect of flow rate on average total fruit yield by using two irrigation-cycles number (5 and 10 / day) at two seasons.

-Consumptive water use.

Average consumptive water use measured increased from 15 to 18 L/ Plant/season through   two seasons   (2008-2009 and 2009-2010) respectively., Meanwhile calculated average consumptive water use using Blaney-Criddle equation (Ponce 1989) was 45 and 47 L/ Plant/season through   two seasons   (2008-2009 and 2009-2010) respectively.

-Effect of flow rate on water use efficiency.

Fig. 3 shows that maximum water use efficiency of 333 g/L was obtained with flow rate of 2 L/min, irrigation cycle number of 10/ day and "EC" of 3 mmhos/cm through seasons (2009-2010)**.** Meanwhile, the minimum water use Efficiency of 200 g/L was obtained with flow rate of 2.5 L/min, irrigation cycle number of 5/ day and "EC" of 2 mmhos/cm through seasons (2008-2009)**.**
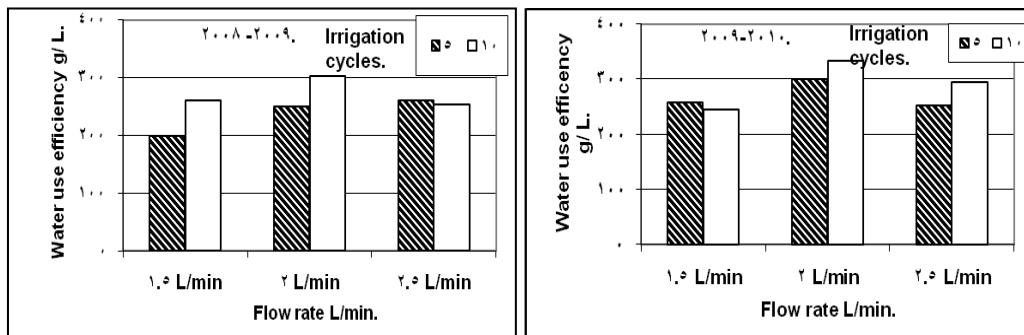

Fig. 3: Effect of flow rate on water use efficiency by using two irrigation-cycles number (5 and 10 / day) at different seasons.

-Effect of system cover (theran) on weather data :

Table 1 shows that using system cover encourage healthy plants growth and reduce hazard of high temperature on pepper plant by reducing average temperature, light intensity and relative humidity from (32 C°, 190.3 foot- candle , 75.3%) to (28.9 C° ,186 foot- candle , 72.5%) through season 2008 -2009 and from (33.2 C° , 195.6 foot- candle , 77.8%) to (30.8 C° , 191 foot- candle , 75.1%) through season 2009 -2010 respectively.

Table 1: Average measured weather data inside and outside system cover and through two seasons (2008-2009 and 2009/2010).

Season	Average of Weather data					
	Outside system cover			Inside system cover		
	T avg. (C°)	Li	RH (%) avg.	T avg. (C°)	Li	RH (%) avg.
(2008/2009)	32.0	190.3	75.3	28.9	186	72.5
(2009/2010)	33.2	195.6	77.8	30.8	191	75.1

-Cost analysis:

Table.2 Shows that total pepper plant productivity were 270 and 324 kg/season for seasons (2008-2009 and 2009-2010) respectively. And also the average productivity per season was about 30   kg/m^2. Meanwhile the production cost of produce 1 kg pepper crop was about 1.27 L.E under the experimental conditions through two seasons (2008-2009 and 2009-2010) .

Table 2: The designed hydroponic system cost details.

ACTUAl COST AND PRODUCTIVITY DATA			
Cost items	**Actual season cost , L.E.**		
	(2008-2009)	**(2009-2010).**	
Seedlings	30	30	
Nutrient solution tank	15	15	
Nutrient solution	50	50	
Pump	50	50	**Total**
Timer	30	30	
P.V.C pipes	35	35	
fitting	30	30	
Valves	8	8	
Theran sheet	40	40	
Electricity	40	40	
Maintenance	50	50	
Total cost ; L.E.	**378**	**378**	**756**
*Actual plant productivity kg/season (8 month).	**5**	**6**	**11**
** Total Productivity; kg/season .	**270**	**324**	**594**
***Productivity kg /m2	**27**	**32.4**	**59.4**
****Production cost of one kg L.E./m^2			**1.27**

*Actual plant productivity; kg/season. From the experment results(Fig .2).
**Total productivity , kg/season = (Plant Productivity   / season)* Number of pepper plants   (54).
***Productivity , kg /m2 =Total productivity / * System area (10 m^2).
****Production cost of one kg , L.E./m2=Total cost /Total productivity *System area (10 m^2).

CONCLUSION

The optimum conditions for Pepper crop "Bigmami" production by using the designed HYDROPONIC system were: flow rate of 2 L/min, nutrient solution electrical conductivity "EC" of 3 mmhos/cm and irrigation cycle

number of 10 /day. The results obtained in optimum conditions were: Average season root length per plant = 18.6 cm, Average season total leaves area per plant = 8290.4 cm^2, Average total fruits yield per season = 6.0 kg / plant, Average consumptive water use per season = 18 L / plant/season, maximum water use efficiency = 333 g /L, and the cost of produce 1 kg of pepper fruits was1.27 L.E. by using the designed HYDROPONIC system.

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<u>المخلص العربى</u>

نظام بسيط للزراعة المائية لإنتاج الفلفل بالصعيد

عبد القادر على النقيب[1]، حسن عبد الرازق عبد المولى[2]، أحمد ماهر الليثى[3]، صبري حجاب[4]، ياسر السيد عبد الفتاح[5]

تهدف الدراسة إلى تصميم واختبار نموذج زراعة مائية لإنتاج الفلفل بصعيد مصر لتحسين إنتاجية وجودة محصول الفلفل بالمزارع المائية والتغلب على المشاكل المتعلقة بالتكلفة العالية للانظمة المستوردة وذات التكنولوجيا العالية التي تحتاج إلى عمالة ماهرة ومدربة على تلك الأنظمة، فتم تصميم نظام بسيط التركيب بتكاليف مناسبة لايحتاج إلى مهارة عالية في تشغيله ليناسب الايدى العاملة والظروف المناخية في صعيد مصر. ويستخدم مؤقت زمنى تلقائي لسهولة التحكم فى فترات وازمنة التشغيل مما ييسر عملية التشغيل والإدارة للنظام.

تم إجراء تجارب اختبار النظام على سطح مبنى كلية الزراعة – جامعة الأزهر فرع أسيوط لمدة موسمان متتالين (٢٠٠٨/٢٠٠٩) و(٢٠٠٩/٢٠١٠) وأخذ من السطح مساحة (١٠م٢ ،(٥ م طول × ٢م ارتفاع)) وتم تغطية هذه المساحة بغطاء (من الثيران أبعاده ٥ × ٤ م) لحماية النباتات من درجات الحرارة العالية في بداية النمو و استخدام الفلفل من صنف (Bigmami).

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تم دراسة تأثير فترات الرى ومعدل التصرف ودرجة التوصيل الكهربى على الانتاجية والصفات النباتية خلال موسمين ٢٠٠٨ ـ٢٠٠٩ و٢٠٠٩ ـ ٢٠١٠ كالتالي:

١. فترات الري: يشمل فترتين هما ٥ أوقات ري /يوم في الموسم الأول و ١٠ أوقات ري /يوم للموسم الثاني كل ريه مدتها ١٥ دقيقة.

٢. معدل التصرف: تم اختبار ثلاث تصرفات على الترتيب هم (١.٥ ، ٢ ، ٢.٥ لتر/دقيقة).

٣. درجة التوصيل الكهربية : تم اختبار درجتين من الملوحة (٢و٣ ملليموز/سم).

النتائج المتحصل عليها:

وجد أن أنسب ظروف للحصول على اعلى انتاجية وافضل صفات نباتية كانت كالتالي: معدل تصرف ٢ لتر/ دقيقة، معدل توصيل كهربائي لمحلول التغذية ٣ مليموز/سم ، وعدد فترات الري ١٠ مرات في اليوم وطول فترة الري الواحدة ١٥ دقيقة، وكانت النتائج في نهاية موسم ٢٠٠٩-٢٠١٠ هي كالتالي : متوسط طول الجذر = ١٨.٦ سم، المساحة الكلية للأوراق = ٨٢٩٠.٤ سم² ،متوسط الإنتاجية = ٦ كيلوجرام/ نبات في الموسم، استهلاك المائى = ١٨لتر/نبات فى الموسم، واعلى كفاءة لاستخدام المياه ٣٣٣ جم/لتر ومتوسط تكلفة إنتاج كيلوجرام فلفل = ١.٢٧ جنيه.