NFT CONTROLLED – ENVIRONMENT FACTORS AFFECTING PRODUCTION OF GREEN FODDER

M. A. MOSALLAM [1], **M. E. SHETAWY** [2],
R. R. EL-BESSOUMY [3] and **T. ABDEL - FATTAH** [4]

ABSTRACT

*A Nutrient-Film Technique "NFT" and A semi- Environmental control chamber were used to detect the effect of slope and environmental parameters affecting the NFT. The environmental parameters are : concentration of the nutrient solution "NS" , lighting type and light exposure and air change per hour. Four slopes were tested; from: 5 to 25%. Three concentrations were tested: from: 0.5 to 1.5% in addition to tap water as control. Three types of lighting were tested: light- emitting diodes (LED$_S$) , fluorescent lamps and compact fluorescent lamps (CFL$_S$) in addition a natural light as control. Four lighting times were tested: from: 6 to 24 h/day. Four airing rates were tested: from 30 to 60 times per hour. The optimal parameters for transplanting fodder are : the slope of NS channel of 5%, the feed pump discharge of 4.66 L/min under cultivating density of 1.6 kg/m^2 and the discharge corresponds to an empirical depth and an empirical speed of the NS(measured from a previous study of NFT unit without cultivation, **Mosallam et al.,2015**) this depth and this speed are 3mm 0.1m/s , respectively, concentrations of the nutrient solution 1 % , lighting type :light-emitting diodes (LED$_S$) , lighting exposure: 12h/day and air change rate of 40 times/h.*

Keywords: nutrient-film technique, semi- environmental control chamber, LED light source, nutrient solution, air change rate.

INTRODUCTION

Egypt, like other developing countries of the arid and semi- arid regions, faces four major problems, namely: high rate of population increase; limited natural sources of good quality water; existence of salt-affected land ;shortage of food and feed. Therefore, studies should be oriented towards solving these problems, **Ashour *et al.* 1997.**

(1) Prof., (2) Assoc – prof., (3) Lec.;(4) Teachg. Assist. All in the Fac. Ag. Eng., AL- Azhar univ., Cairo.

Nutrient film technique (NFT) is the system which makes efficient use of water, fertilizers, non-arable land for optimized productivity, **Resh 1991 and Al-Karaki** *et al,.* **2012.**

This research aims to study design and environmental parameters affecting the NFT to maximize green fodder production under this system.

REVIEW OF LITERATURE

Cooper 1996, reported that: the design key requirements in achieving NFT unit are : suitable slope of the channel of the nutrient solution , the inlet flow rate must not be so rapid that a considerable depth of water flows down the gradient, the width of the channels in which the roots are confined must be adequate to avoid any damming up of the nutrient by the root mat and ensure that the depth of the nutrient solution is only a few millimeter at the most. **Spensley** *et al.,* **1978**, **Lynette 1999** and **Carly 2011** found that slope of the channel of the nutrient solution must not be less than 1%. **Jenner** *et al***.,(1980)** mentioned that: the discharge of the feeding pump should not be less than 2 L/min and this discharge depends on the size of the plant and intensity of cultivation. **Graves (1983)** reported that the flow of nutrient solution into each channel should be 2-3 liters per minute. **Maher (1977)** mentioned that low solution flow rates (2L/min) also can result in dramatically falling oxygen concentration in NFT system. **Graves and Hurd 1983** mentioned that depth of the nutrient solution is 1 – 3 mm.

Ikeda *et al.***, 2011** in recent years, with the development of agricultural science, system science and computer technology, the study on crop growth environment system has gradually become a new area of research. Temperature, humidity, light, carbon dioxide (CO_2) concentration, air movement and nutrient are the main environmental regulatory factors affecting crop growth. The crop growth environment simulation system is an automated or semi-automated control system in greenhouse or growth chamber by simulating the natural environment of crop growth with environment control technologies, **Liguo** *et al,.* **2014.**

Liguo *et al.,* **2014** also added that nutrition is one of the primary indispensable factors in crop growth. Different crops and different stages of crop life cycle have different needs for nutrients. **Massantini and Magnani 1980 and El-Deeba** *et al.***, 2009** reported a positive response to added nutrient solution, which is temperature related. Light is one of the most important environmental factors which acts on plants as one source of energy. **Jane** *et al.***, 2011**found that the plant responds to light quantity and quality and duration. **Bourget 2008 and Morrow** *et al.***, 2005** Compared to those conventional light sources, gallium–aluminum and light-emitting diode (LED).The light-emitting diode has several unique advantages, including the ability to control the spectral composition, a small mass and volume, long operating lifetimes, relatively cool emitting surfaces, minimum heating. **El-Deeba** *et al.,* **2009** fond that lighting time 12-16h/day is optimal for production of barley green fodder. Ventilation in agricultural facilities helps regulate temperature , humidity and exhaust of harmful gases**, Stout** *et al.***, 1984. Aldrich** *et al.,* **1994** reported that ventilation systems in agricultural buildings can be classified into three classes: negative pressure, positive pressure and neutral pressure. **Gordon ,2008** recommended an ideal environment of at least 30 air changes per hour.

MATERRIALS AND METHODS

This study aims to investigate the slope and environmental parameters affecting the NFT. These parameters are:

The environmental parameters : concentration of the nutrient solution , lighting type and light exposure and air change per hour.

To study the previously mentioned parameters , an "NFT" and a semi-environmental control chamber were constructed. Fodder seeds and nutrient solution were used.

The "NFT" : Fig.(1) shows the unit. The unit consists of a channel for the nutrient solution, made from acrylic of thickness 4mm and dimensions 67×28×4 cm. At the head of the channel, a hole for entrance of the nutrient solution was made. The hole diameter is 15mm. At the end of channel, 7 holes for drainage the nutrient solution were made. Each of hole diameter was 7 mm and these 7 was distributed through the width of the channel.
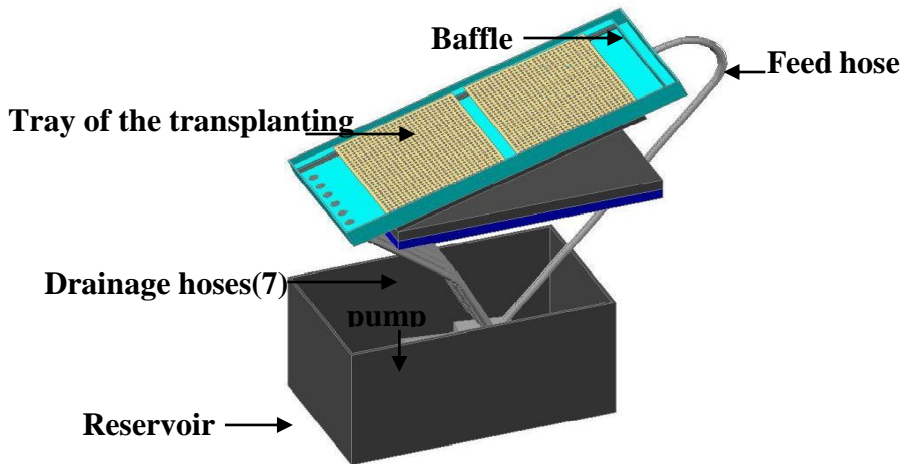
Fig.(1):The (NFT) unit.

Experimented transplanted seeds were cultivated over   tray. Each tray was of dimensions of 24×26 cm and each tray was made from acrylic of thickness 4 mm. The tray had pierced openings, to allow the roots to contact with the nutrient solution. The opening diameter was 3mm. A reservoir of the nutrient solution capacity is of 20 liter was used. Feeding pump (RS-3001) was used to force the nutrient solution into the channel of a closed recirculating system.
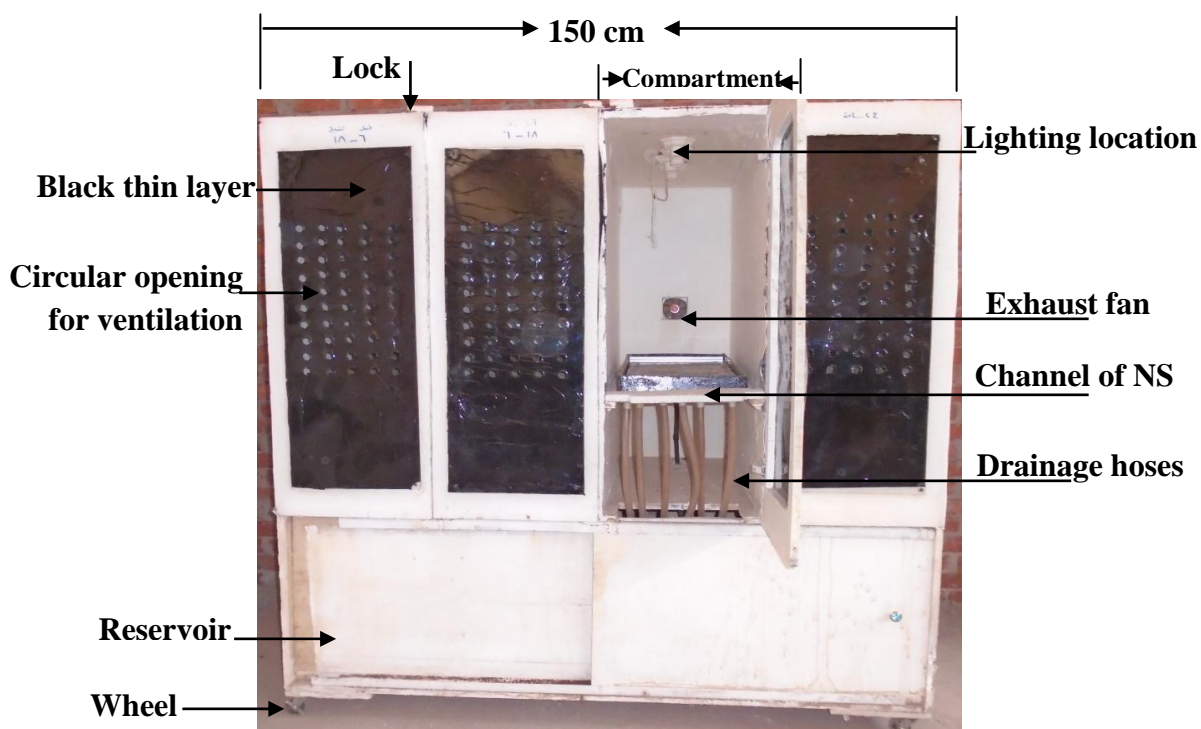
The semi- environmental control chamber: plate (2) shows the semi-environmental   control   chamber.   Its   dimensions   were: 100×150×150cm.The chamber was constructed from wood of thickness 1.8 cm. The chamber was divided into four compartments ,each of dimensions of 37.5×100×100 cm. Each compartment had a separate door for allowing a separate experiment from other compartments. To allow following – up the experiments without opening the compartment door, a transparent sheet of the poly- acrylic of thickness 1.5mm was installed at the door of the compartment. On the rear side of the compartment, an exhaust fan was installed. For allowing an appropriate ventilation rate, circular openings (each 1.8 cm diameter) were made on the transparent poly- acrylic sheet. A shelf was installed inside the compartment, the

shelf slope was determined according to slope experiments. The inner side of the roof has been designed to allow installing different lighting systems. The inside walls of the compartment were painted white.

Cultivated seeds: Two types of green fodder seeds were used in this study: barley (Giza 168 جيزة) seed and pearl millet(Shandawel1شندويلى). The season of cultivation determined the type of fodder.

Nutrient solution(NS): The NS solution developed by **El-Behairy 1994** was used. It nutrient solution consists of:

Nutrient	Mo	Zn	Cu	B	Mn	Fe	S	Mg	Ca	K	P	N
Amount ppm	0.1	0.1	0.1	0.3	1	5	221	50	160.2	300	35	295.6

The depth of chamber is 100cm

Plate (2): The semi – environmental control chamber.

To investigate the effect of channel slope on growth of pearl milt , four slopes were tested. These slopes were: 5, 10, 15, 20 and 25%. under feed - pump discharge of 4.6 L/min. The optimal slope under corresponding

discharge obtained through the experiment will be related to each depth and the NS before transplanting according to **Mosallam *et al.,* 2015**.

To investigate the effect of concentration of the NS on growth of barley, three concentrations were tested :0.5,1 ,1.5% in addition to tap water as a control.

To investigate the effect of lighting type on growth of barley, three types of lighting were tested. These types were: light- emitting diodes (LEDs) , fluorescent lamps   and compact fluorescent lamps (CFLs) in addition to natural light as control.

To investigate the effect of light time exposure on growth of barley, four lighting durations were tested: These times were: 6,12,18 and 24 h/day.

To investigate the effect of air change rate on growth of barley, four rates were tested: 30 , 40 , 50 and 60 times per hour.

The slope experiments were carried out on pearl millet, then the environmental experiments were carried out on barley. This was according to the ambient temperature.

Number of replicates of each experiment was two.

RESULTS AND DISCUSSION

1- <u>Effect of the slope of the channel of the nutrient solution on the growth of pearl millet:</u>

Figure (4) shows the relationship between time of pearl - millet growth and the fresh mass under the four tested slopes(5,10.20 and 25%).
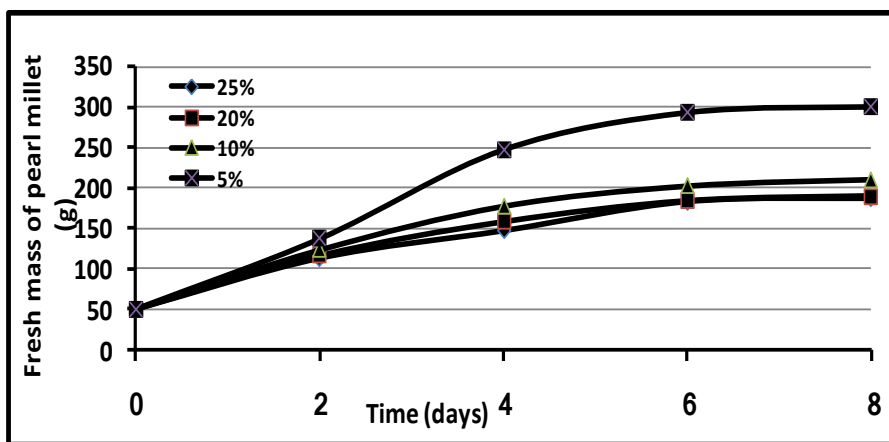

Fig.(4): Pearl millet growth and fresh mass
under four slopes of the NS channel.

Generally, for the four slopes, there was a gradual increase in fresh mass with time of growth. The curves that represent the relation between production and slopes 10,20 and 25% approache each other. This means that the three previously mentioned slopes are simillar in their effect of the production. A significant increase in the production of pearl millet occurred at 5% slope. This suggests that still less slope can be used,5% slope with 4.6 L/min feed pump discharge , 3mm empirical (revise **Mosallam** *et al.,* **2015)** depth and 0.1m/s empirical speed of the NS can be found from the graphs, without cultivation as shown in figs. (2)and (3), in accordance to; **Mosallam** *et al,.* **2015**. Each empirical depth and empirical speed of the NS may guide of the depth and the speed of the NS when transplanting.
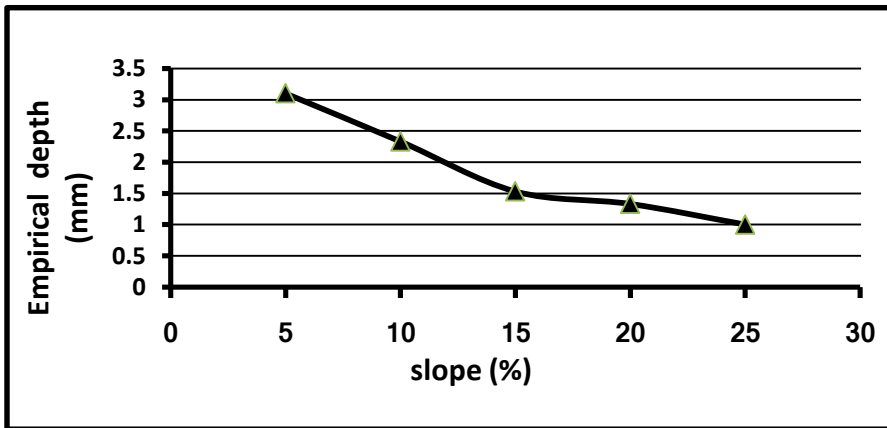

Fig. (2): Slope of the NS channel and the empirical depth under 4.66L/min feed - pump discharge,(Mosallam *et al.*, 2015)
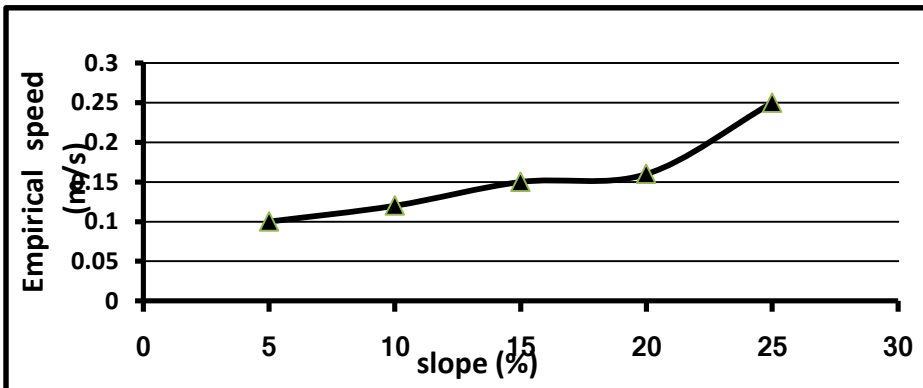

Fig. (3): Slope of the NS channel and the empirical speed under 4.66L/min feed - pump discharge,(Mosallam *et al.*, 2015).

2- The relation between the price of the NS and the production of barley:

Figure (5) shows the relationships between the price of the nutrient solution and the production of barley under the three concentrations of the nutrient solution (0.5,1,1.5%) in addition to tap water control.
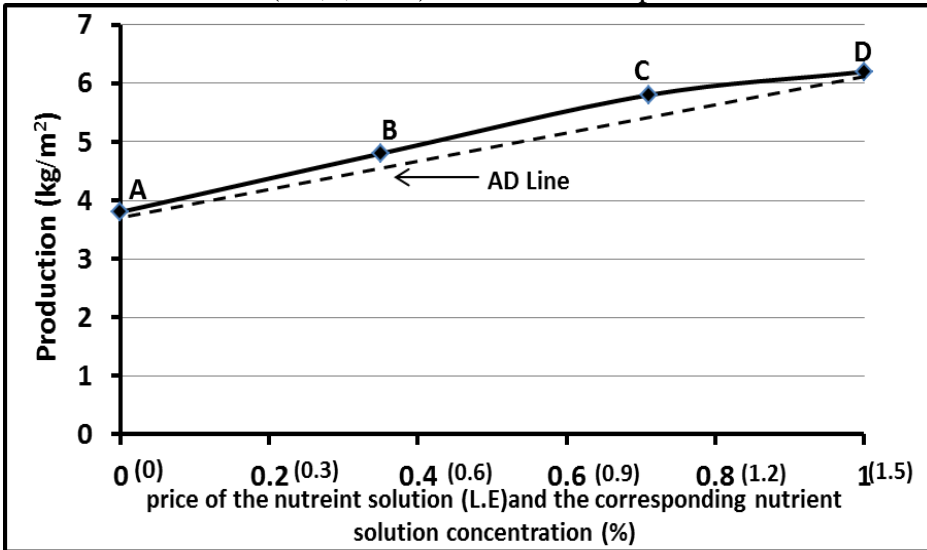

Fig.(5):The relationship between the price of the nutrient solution and the production of barley.

The points (A,B,C) belong to a definite straight line while the point (D) does not belongs to this line. The slope (money rate) of the ABC line (the continuous line) is calculated to be 2 $Kg/m^2.L.E$ and this slope is found to be greater than the slope of the AD line (the dashed line) which is 1.6 $Kg/m^2.L.E$ .This means that the production due to addition of one unit of money price of the nutrient solution is better in the case of ABC line (nutrient solution concentration 0.5-1%) than that of AD line than. The previous discussion indicates that , from point of view of price of NS, concentration range of 0.5-1% corresponding to price of the used quantities of NS (0.33-0.66 L.E) is more economic than concentration of 1.5%.

3- Effect of the lighting type on the growth of barley:

Figure (6) shows the relationships between time of the barley growth and fresh mass under four tested lighting types: natural light, light emitting diode(LED) 10W, fluorescent lamps 20W, and compact fluorescent lamps(CFL) 30W.
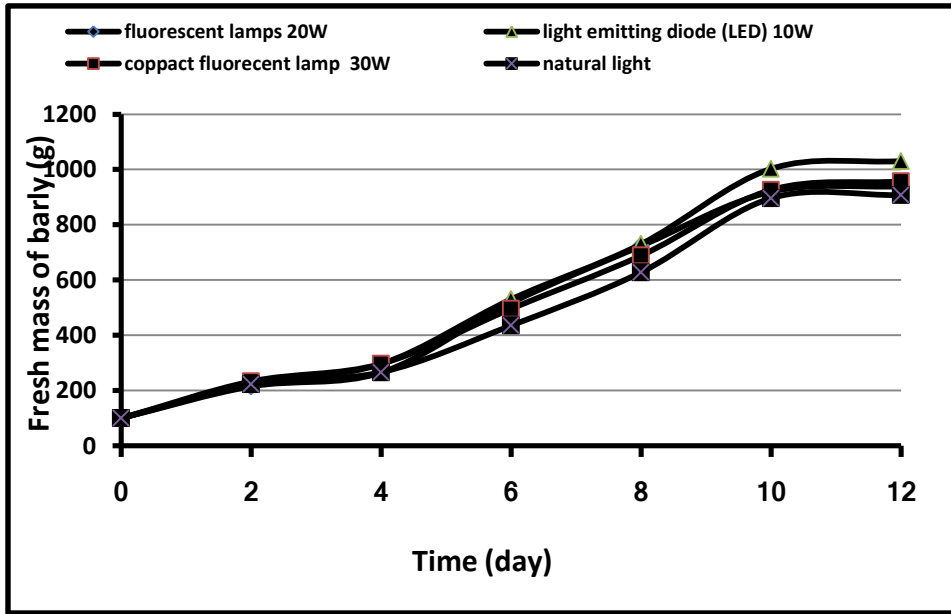
Fig.(6): Time of the barley growth and the fresh mass.

Under the four lighting types, the relation between time of barley growth and fresh mass is increasing from 1:10 day. There is a slight difference between the results for the four lighting types. however, increase seams to diminish after ten days.

To reduce the consumption of energy for growing fodder, the effect of the lighting type on growth of the pearly was studied. Figure (7) shows the relationships between the lighting and the quantity of electricity consumed (kW. h) through the experiment period. The lowest electricity consumption is obtained under (LED).
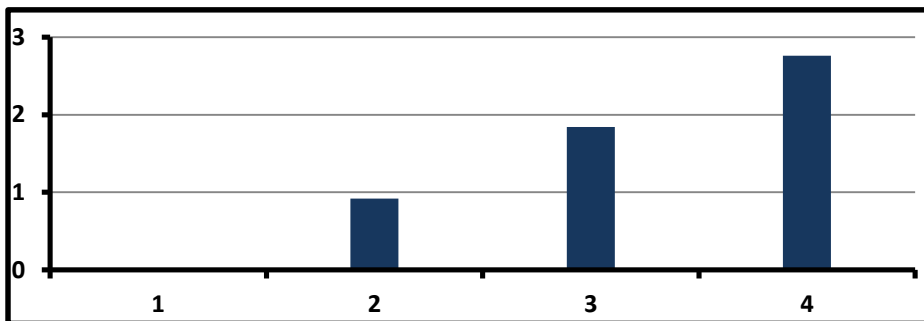

Fig.(7):The relationship between the light types: (1) natural light,(2) light emitting diode (LED),(3) fluorescent lamps,(4) compact fluorescent lamps and electricity consumed(kW. h).

Effect of lighting time on growth of barley:

Figure (8) shows the relationships between time of the barley growth and fresh weight under the four lighting times tested: (6,12,18 and 24 h/day).
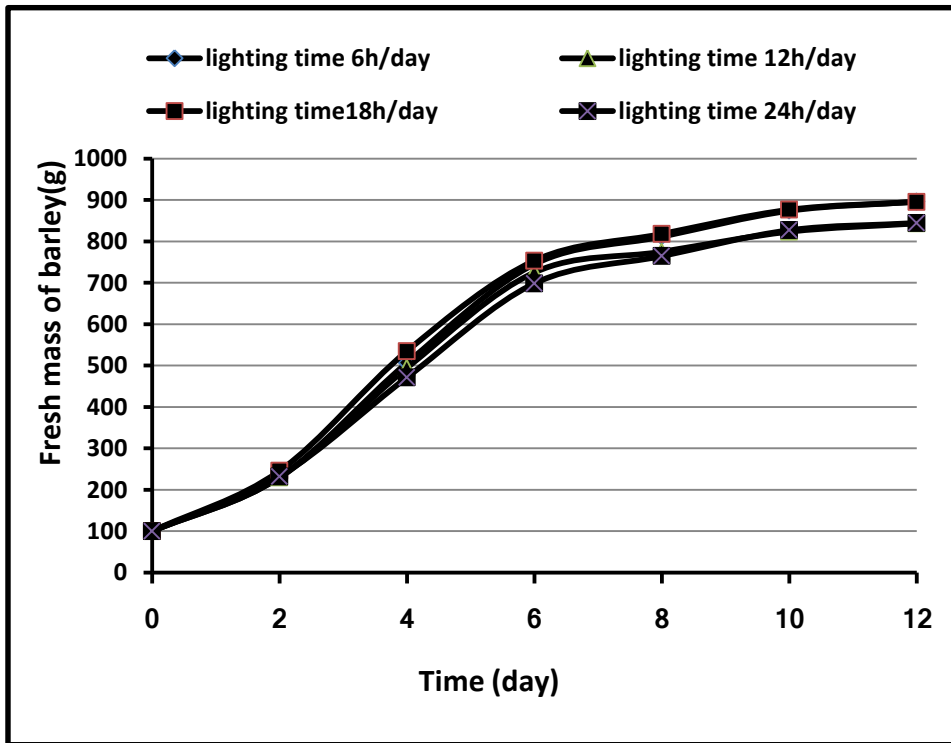

Fig.(8): Time of barley growth and fresh mass.

Generally, under the four lighting times tested, the relation between time and fresh mass is an increasing from 1:10 day. However , the mass increase diminish after six days.

Under lighting time 6h/day, the barley appeared yellow(weak) and the root mat was so thick. The lowest fresh mass was obtained with lighting time of 24h/day, where the barley appeared weak. The two carves for 12 and 18h/day gave an intact fresh mass with two close.

The fresh mass obtained with lighting time of 12 h/day coincides with that obtaind by; **El-Deeba et al. 2009.** It can be concluded that; amongst the four tested lighting times , 12 h/day is chosen for energy saving.

4- <u>Effect of the air changes per hour on growth of barley:</u>

Figure (9) shows the relationships between time of the barley growth and fresh weight under the four air changes tested: (30,40,50and 60 times per hour).
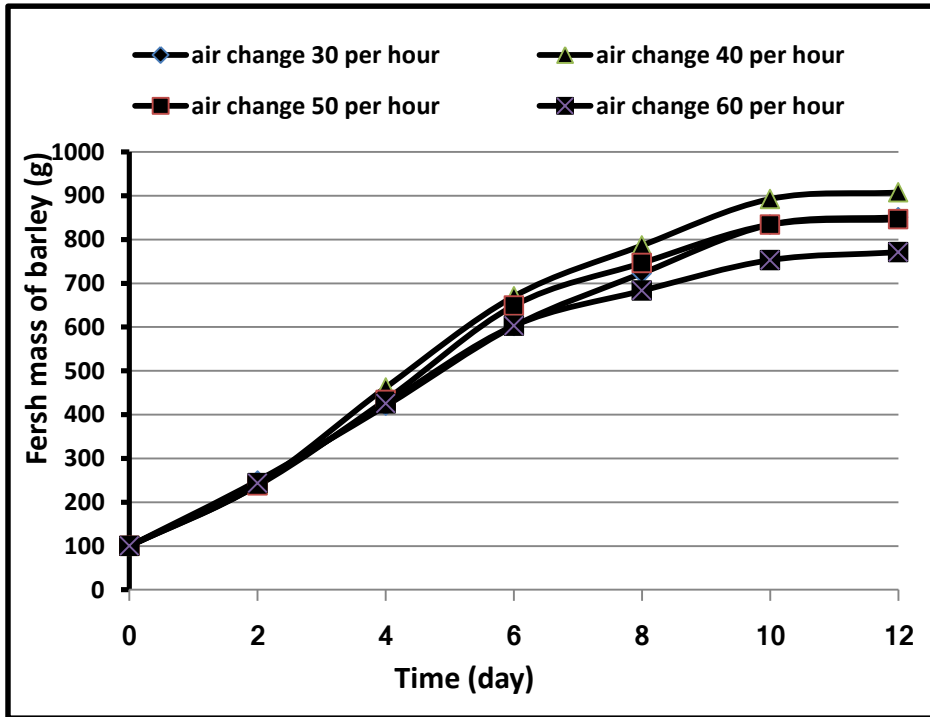

Fig.(9):Time of barley growth and fresh mass.

There was a slight difference in fresh weight between air change rate of 50 and 30 time per hour. The lowest fresh weight obtained with air changes 60 time per hour and the highest fresh mass was obtained with air change rate of 40 times per hour.

SUMMARY

This study aims to investigate slope parameter and environmental parameters affecting the "NFT" by using a small unit and a semi-environmental control - chamber.
The studied parameters are:

The slope of the NS channel . Four slopes were tested: 5,10, 20 and 25%
Environmental parameters :

- Concentration of the NS are : 0.5,1,1.5% were tested in addition to tap water as control.

- Lighting type: three types of lighting were tested: light- emitting diodes (LED$_S$) , fluorescent lamps ,compact fluorescent lamps (CFL$_S$) in addition a natural light as control.

- Lighting time : four lighting times were tested: 6,12,18 and 24 h/day.

- Air change per hour: four air changes rates were tested: 30 , 40 , 50 and 60 times per hour.

CONCLUSIONS

Under the tested slope range (5-25%), the slope of 5% under feed pump discharge of 4.66 L/min is optimal for the production of the green fodder. This slope corresponds to depth of NS and speed before transplanting of 3mm and 0.1m/s respect to, **Mosallam *et al.,* 2015**.

Under the tested concentrations of the nutrient solution, the concentration of 1% is optimal for the production of barley green - fodder.

When studying the effect of lighting type on the plant growth, the results showed that there is a slight difference between the results for the four lighting types tested. So, it is preferable to produce the green fodder under light-emitting diodes (LED$_S$) to save the energy consumption.

The results showed that the lighting time of 12h/day is optimal for the production of green fodder to save the energy consumed in lighting.

Under lighting time 6h/day, the barley appeared yellow(weak) and the root mat became so thick. Under lighting time of 24/day the barley appeared yellow.

When studying the effect of air change rates on the plant growth ,the results showed that the 40 times per hour is optimal for the production of green fodder.

REFERANCES

Aldrich R. A., and J. W. Bartok (1994). Greenhouse engineering. 3rd rev., NRAES (USA). Greenhouse series. no. 33.

Al-Karaki G. N., and N. Al-Momani (2012). Evaluation of some barley cultivars for green fodder production and water use efficiency under hydroponic conditions. Jordan Journal of Agricultural Sciences, 7(3):448-454.

Ashour N. I., M. S. Serag , A. A. El-Haleem and B. B. Mekki (1997). Forage production from three grass species under saline irrigation in Egypt. Journal of arid environments, 37(2):299-307.

Bourget M.C. (2008). An introduction to light emitting diodes. Hortscience ,43:1944–1946.

Carly M. (2011). Leafy asian vegetables and their nutrition in hydroponics. Industry & Investment NSW., ISBN 978174256 0779,(24):7-8.

Cooper A.(1996). The ABC of NFT. 2ed. Grower Books, London, UK,: 20.

El-Behairy U. A. A. (1994). The effect of levels of phosphorus and zinc in the nutrient solution on macro and micro nutrients uptake and translocation in cucumber ('Cucumis Sativus' L.) grown in nutrient film technique (NFT) (Doctoral dissertation, University of London ,:56.

El-Deeba M. M. , M. N. El-Awady, M. M. Hegazi , F. A. Abdel-Azeem and M. M. El-Bourdiny (2009). Engineering factors affecting hydroponics grass- fodder production. The 16th. Annual Conference of the Misr Society of Ag. Eng., 25 July: 1647-1666.

Folta K., L. Koss , R. M. Morrow , H. Kim , J.D. Kenitz, R.Wheeler and J. Sager (2005). Design and fabrication of adjustable red-

green-blue LED light arrays for plant research. BMC Plant Bioi., 5: 17.

Gordon A.(2008). Home hydroponics, http://www.geocities.com./cache/hydroponics.html:1-7

Graves C.J. (1983). The nutrient film technique. Horticutural Review. 5: 1-44.

Graves C.J. and R.G. Hurd (1983) .intermittent solution circulation in the nutrient film technique Acta hortic.,133:47-52.

Ikeda and Hideo (2011). Plant factory trans action son sensor sound micro machines, 131(6):200-205.

Jane B. and A. Neil (2011). Campbell. Biology: 9th Edition. California: Pearson Education.

Jenner G. and N. Starkey(1980). Nutrient film technique: Practicalities of cadmium. Plant Soil, 49: 333-342.

Liguo T. , M. Qinghao, W. Liping and D. Jianghui(2014). A Study on crop growth environment control system. International Journal of Control and Automation ,7(9):357-374.

Lynette M.(1999). Nutrient Film Technique (NFT) Production of Lettuce. Source. Available from: URL [http:www.cropking.com/NFT lettuce 1 .shtm1],:1-3.

Maher M. J. (1977). The use of hydroponics for the production of greenhouse tomatoes in Ireland. In 4th International Congress on Soilless Culture, Las Palmas (Spain),:161-169.

Massantini F. and G. Magnani (1980). Hydroponic fodder [cereals] growing: use of cleaner-separated seed. In 5th. soilless culture. Wageningen (Netherlands).

Mosallam M.A., M. E. Shetawy, R. R. EL-Bessoumy and T. A. Fattah (2015). Empericl graphs relating the main factors affecting a nutrient-film system. Misr Soc.of Ag.Eng.,32(4):1709-1716.

Resh H. M.(1991). Hydroponic food production. Woodbridge Prespup. California,: 462.

Spensley K., G. W. Winsor and A. J. Cooper (1978). Nutrient film technique-crop culture in flowing nutrient solution [Tomatoes], (No. 79-415860. CIMMYT.),9:299:305.

Stout B. A. (1984). Energy use and management in agriculture. belmont, CA: Breton Publishers.

<div dir="rtl">

الملخص العربى

عوامل التحكم البيئية المؤثرة على إنتاج العلف الأخضر بتقانة الغشاء المغذى NFT

محمود أحمد مسلم(¹)، محمد السيد شتيوى(²)، رزق ربيع البسومى(³) و طه عبد الفتاح محمد(⁴)

يهدف هذا البحث الى دراسة عامل تصميمى وعوامل بيئية للزراعة بنظام الغشاء المغذى A وغرفة شبة تحكمNFT وذلك باستخدام وحدة "NFT" Nutrient-Film Technique semi- environmental Control Chamber.

العوامل التى دُرست هى:

- عامل تصميمي: ميل قناة سريان المحلول المغذى وقد تمت دراسة اربعة ميول هى : ٥، ١٠، ٢٠و٢٥٪ .

- العوامل البيئية:

- تركيز المحلول المغذى: ٥,٠،١٠,٥٪ وماء الصنبور.

- نوع الاضاءة : ضوء طبيعى، مصابيح فلورسنت ٣٠ سم ، LEDₛ مصابيح موفرة و مصابيح.

- فترة الاضاءة : ٦،١٢،١٨،٢٤ ساعه/يوم.

- عدد مرات تغير الهواء فى الساعة: ٣٠،٤٠،٥٠ و ٦٠مرة /ساعة.

</div>

<div dir="rtl">

(١) أستاذ – ، (٢) أستاذ مساعد – ، (٣) مدرس – و (٤) معيد. الجميع فى ك. الهندسة الزراعية ، ج. الأزهر

</div>

بينت هذه الدراسة الاتى:

تحت مدى الميول المختبرة لقناة الزراعة بنظام الغشاء المغذى (٥-٢٥٪) كان الميل ٥٪ عند التصرف ٤٫٦٦لتر/دقيقة هو الأفضل لإنتاج العلف الأخضر. يناظر هذا الميل عند عدم الزراعة عمق٣ مم وسرعة ٠٫١متر/ثانية للمحلول المغذى.

تحت مدى تركيزات المحلول المغذى المختبرة كان التركيز ١٪ هو الأفضل لإنتاج علف أخضر من نبات الشعير.

أظهرت النتائج انه ليس هناك فروق جوهرية بين أنواع الاضاءة الأربعة المستخدمة على انتاج العلف الأخضر ، ولكن يفضل استخدام (LED_S) لخفض الطاقة المستهلكة فى الاضاءة.

أظهرت النتائج أن فترة الاضاءة ١٢ ساعه/يوم مفضلة وذلك لتقليل الطاقة وأن فترة الاضاءة ٦ ساعة/يوم تعطى نباتاً اصفر(ضعيفا) ذُو مجموع جذرى سميك وأن فترة الاضاءة ٢٤ ساعة /يوم تسبب احتراق أطراف اوراق النبات .

عند دراسة اثر عدد مرات تغير الهواء ، أظهرت النتائج ان تغير الهواء ٤٠ مرة /ساعة يعطى أفضل انتاج للعلف الأخضر.