SUCCESSIVE MANAGEMENT PROGRAMS FOR THE DEFICIT WATER RESOURCES IN HYDOPONICS AND SOILLESS GREEN FODDER PRODUCTION

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ABSTRACT

Maximization of water use efficiency (WUE) in green fodder production in the arid regions is considered critical issue for overcoming the limitation of water resources. Therefore, three experiments were executed using electric controller system to manage the deficit water resources inside hydroponics and soilless green fodder production system. Single, double, and triple programs for water management were applied in the first, second, and third experiments respectively. Irrigation intervals "4, 6, 8, 10, 12, and14h" and irrigation durations "30, 45, and 60sec." were used as main variables in these experiments. The consumed water, fresh weight of the produced green fodder, dry matter weight, dry matter percentage, water use efficiency and germination percentage were taken as main indicators. The statistical analysis of the results revealed that water use efficiency values for the best treatment in the first, second, and third exponent are 49.11, 79.92 and, 109.01 "gram of dry matter /liter of water" respectively. Therefore, applying triple successive programs "60 sec. per 6h in the initial period, "45 sec. per 10h in the intermediate period" and "30 sec. per 12h in the final period" is considered the best management of the deficit water resources inside hydroponics and soilless green fodder production systems.

Keywords: *successive programs - deficit water resources – water use efficiency - hydroponics and soilless – sprouted green fodder - production systems - water management program.*

INTRODUCTION

Fungi growth constitutes main problem affecting quantity and quality of the sprouted barley green fodder production. The applied irrigation programs are considered the main factor for fungi growth and its side effects on the hydroponics green fodder.

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Due to the hazard effects of fungi growth, a great part of green fodder production is excluded for keeping the animal health. As a result, the water use efficiency value is very small, **Abd-Rbo et al. 2016**. Therefore, the main objective of this research is searching on efficient irrigation programs for maximization of the water use efficiency value of the hydroponics sprouted green fodder production.

Limitation of water resources in the arid and semi-arid regions is considered main constraint for the agricultural development projects. Applying modern technologies and scheduling leads to more effective and rational use of the limited water resources. Using deficit irrigation techniques is considered effective solution for improving the irrigation management. Deficit irrigation could be defined as the application of water below full crop-water requirements (evapotranspiration). It is considered an important tool to achieve the goal of reducing irrigation water use, **Howell, 2001; Shangguan, et al., 2002; Kijne, et al., 2003; Ünlü et al., 2006; Fereres and Soriano, 2006; Fereres and Soriano, 2007; Geert et al., 2008; Geerts et al., 2008; Yenesew and Tilahun, 2009; Batisha 2011**.

The seasonal and annual changes in Nile River stream flow cause water shortage problems to people in the basin’s countries. The important source of the Nile River Water in Egypt comes from the Ethiopian Plateau, which supplies the country with nearly 80% of its needs. Reduction in the water share of downstream countries, especially in Egypt will be done due to the reservoir filling of Ethiopia dam. This leads to reduction of the agricultural lands and scattering millions of families, **Cabrera and Cobacho, 2002; Batisha, 2011; Elsanabary and Gan, 2013 and 2015; Abdelkader and Elsanabary, 2015.**

The regulated deficit irrigation, (RDI) and partial root drying, PRD are considered two different irrigation strategies for improving water resources management. Crop yield and water productivity are clearly affected with any change in the irrigation strategies, **Afzala et al., 2016.** Applying main strategies such as intensifying groundwater extraction, deficit irrigation, and reducing short-cycle crops are unsustainable in the mid-long term due to environmental and economic issues, **Martínez-Alvarez et al. 2014.** Climate change is expected to intensify the existing risks, particularly in regions where water scarcity is already a concern. Therefore adaptation strategies for agricultural water management under climate change is considered critical issue, **Iglesias and Garrote , 2015.** The effects of partial root drying (PRD) irrigation, planting method and different nitrogen application rates on yield, water and nitrogen use efficiencies of safflower at 46 kg N ha−1 are negligible compared with more than 46 kg N ha−1, **Shahrokhnia and Sepaskhah, 2016.** Water is now considered the most important resource in the Mediterranean region. Therefore irrigation and agronomic strategies are expanded fast to mitigate environmental stress and to guarantee stable yield and quality, **Costaa et al., 2016.**

Several cases of successful use of deficit irrigation on field crops, vegetables crops, and fruit trees for maximizing the water productivity rather than the yield. In addition to this advantage, deficit irrigation minimizes the risk of some diseases related to high humidity, minimizes nutrient loss by leaching of the root zone, and improves control over the sowing date and length of the growing period in comparison with full irrigation, **Ünlü et al., 2006; Fereres and Soriano, 2006;Geerts et al., 2008; Yenesew and Tilahun, 2009**.

Water use efficiency (WUE) expressed in kg/m³ “Equation No. 1” is an efficiency term, expressing the amount of marketable product (e.g. kilograms of grain) in relation to the amount of input needed to produce that output (cubic meters of water). The water used for crop production is referred to as crop evapotranspiration. This is a combination of water lost by evaporation from the soil surface and transpiration by the plant, occurring simultaneously, **Howell, 2001; Kijne et al., 2003; Yousefi and Mohammadi, 2011; Yousefi et al., 2011.**

$$\text{WUE (kg/ m}^3\text{)} = [(\text{Crop yield kg/ha}) / (\text{Water used m}^3\text{/ha})] \ldots\ldots\ldots\ldots (1)$$

Grain yield is considered the main production of the barley crop cultivated in the open field. Also, green fodder is considered the main production of the hydroponics and soilless green fodder production system. Therefore, the comparison process between the open field and the closed system is not fair. Alfalfa crop is considered competitive green fodder to the sprouted barley green fodder, and approximately similar in the chemical composition. Therefore, the comparison process is approximately fair.

Total cumulative ET for alfalfa ranges from less than 200 mm in arid conditions to over 1000 mm in well watered conditions. The average $WP_T/_{ET}$ for alfalfa is typically around 1.0–2.6 kg/m3, but has been reported as high as 2.9 kg/m^3. The diversity of climate and soil types used to grow alfalfa means reported yields range from less than 1 ton DM/ha in rainfed systems, on soils of low water holding capacity combined with low annual rainfall (<300mm/year) to over 26 ton DM per year at well watered deep silt loam soil in New Zeeland. A similar maximum yield has been reported in Africa, with yields of 10 to 20 ton DM/ha commonly produced in Europe, China and North America under irrigated conditions, **Steduto et al., 2012**.

Sprouting is a group of process to encourage the dry seeds/grains on germination until completing the first leaf. Briefly, germination begins when the seed/grains absorbs water and ends with the appearance of the radicle. Germination of barley has three stages as follows: (1) Water absorption stage starts when the dry grain begins to absorb water to reach a moisture content reaches around 35% to 45% of its dry weight to begin germination. (2) Activation stage begins when the seed moisture content of around 35% to 45%, the embryo produces hormones that stimulate enzyme activity to break down starch and protein stored in the seed to sugars and amino acids, providing energy to the growing embryo. (3) Visible germination stage when the embryo starts to visibly grow. The radicle emerges, followed soon after by other primary roots and the coleoptile. The enzymes produced in stage no. (2) mobilize sugars and amino acids stored in the grain and enable their transfer to the growing embryo, **Edwards 2010**. Therefore, applying unique program for irrigation management through the germination growth life does not cope with the germination stages. Searching on successive and variable irrigation programs could be suitable for improving the water use efficiency.

Oxygen, dormancy, moisture, and temperature are essential factors affecting on the germination rate. Grains absorb oxygen rapidly during germination and will die without sufficient oxygen. Barley grains need a very short period of dormancy to begin germination process. Germination is rapid if the soil is moist, and slow if the soil is dry to near the wilting point. The ideal temperature for barley germination is between 12°C and 25°C, **Edwards 2010**. Therefore, irrigation management programs are considered urgent technique for executing the needed stability between the air as a source of oxygen and the water as a source of moisture around the barley grains for maximizing the germination rate. In the hydroponic systems, the vegetation growth depends upon the composition of nutrient solution, water quantity and quality, pH and EC of water, light intensity and CO2, and air temperature and humidity. Therefore, using the automated systems in the hydroponic systems is considered critical issue, **Dominguesa et al., 2012, Hak-JinKim et al., 2013, and Netoa et al., 2014.**

MATERIALS AND METHODOS

Sprouted green fodder production unit was locally designed and fabricated with dimensions of 4, 6 and 3 meter for width, length and height respectively. This unit contains three stands each of them divided into nine rows. Each row is designed to receive 16 trays with dimensions of 30, 90 and 3 cm. As a result, the total production capacity of this unit is 432 tray per cycle. Automated irrigation system was designed and fabricated using high quality materials, equipment, and tools purchased from the local market. The utilized irrigation system consist of two main parts, the first is the indoor water distribution unit, and the second is the outdoor automatic controller unit. The indoor water distribution unit consists of polypropylene tube with diameter of 1inch as a water main-line, polyethylene tubes with diameter of 16 mm “as laterals” were horizontally fixed in top of each raw as a source of irrigation water. Four foggers were installed using cross manifold fixed in the PE tube on distance of 60 cm between the cross foggers, Figs. (1) and (2). The standard flow rate of the cross foggers is 42 l/h at 4 bars. Poly Ethylene sheets were used to separate among the different treatments inside the chamber. Each group of two trays are served with one cross foggers. Therefore, each tray is receiving 0.35 liter/minute. The outdoor controller unit consists of electric controller system, electric motor, water pump, water tanks, pressure regulators, water meter, water filter, and solenoid valves, Fig. (3). The irrigation control system consists of electric switches, control magnetic relays, contactors, timing relays, pressure switches and regulators, water pump with electric motor and solenoid valves, **Herman 2010. Petruzella 2010, Moeller 2011, Giri 2013.** Consumed water CW “l/tray per cycle”, fresh weight of green fodder FW “kg/tray”, dry matter “kg/tray”, dry matter percentage DMP , water use efficiency WUE ”gram of dry matter /liter of water”, germination percentage GP, Ash percentage, crude fiber Cf, crude protein Cp, ether extract EE, and nitrogen free ether NFE were measured and calculated.

Three types of experiments were statistically designed as factorial experiments in complete randomize design to determine the best program for management of the deficit water resources in the hydroponics sprouted barley grains production. Duration of irrigation (sec.), irrigation interval (hour), and irrigation schedule (day/program) are considered the core area of the program for management of the deficit ware resources. Three times of irrigation “30, 45, and 60 sec”, three times of irrigation interval (4, 6, and 8 hours), and single program for irrigation schedule (9 day/program) were applied in the first experiment, table (1). Three times of irrigation “30, 45, and 60 sec”, three times of irrigation interval (8, 10, and 12 hours), and two variable programs for irrigation schedule (3days/program$_1$ and 6days/program$_2$) were applied in the second experiment. The first was applied through the first three days and fixed on the best treatment in the first experiment. The second was applied through the remainder six days and operated to cover nine treatments, table (2). Three times of irrigation “30, 45, and 60 sec”, three times of irrigation interval (10, 12, and 14 hours), and three programs for irrigation schedule (3 days/program$_{1,}$ 3 days/program$_2$ and 3 days/program$_3$) were applied in the third experiment. The first and second programs were fixed on the best treatments in the first and second experiments respectively. The third was applied through the remainder three days and operated to cover nine treatments, table (3). Consumed water (CW) "l/tray per cycle", fresh weight of green fodder (FW) "kg/tray", dry matter weight (DM) "kg/tray", dry matter DMP "%",water use efficiency (WUE) "gram of dry matter /liter of water", and germination (GP) "%", Ash percentage, crude fiber Cf, crude protein Cp, ether extract EE, nitrogen free ether NFE, and Infection Inf. were studied and analyzed as main variables "factors" in each one of the three experiments mentioned above. Also, DMP, GP, Ash, Cp, Cf, EE, NFE, and Inf. were statistically analyzed as Arc SIN data.

Germination percentage was used as main criteria in to select the best treatment in the first experiment. The remainder factors were used as sub-criteria for this selection. Germination percentage, water use efficiency, and crude protein percentage were used as main criteria in to select the best treatment in the second experiment. Germination percentage, water use efficiency, crude protein percentage, and infection rate were used as main criteria in to select the best treatment in the third experiment. In addition to minimum ratios of infection rate, Ash, crude fiber, ether extract, and nitrogen free ether.

The environmental conditions inside the green fodder production unit were fixed at 20^{o}C for air temperature, 75-85 % for air relative humidity, and 1500LUX for light intensity. Copper nutrient solution was utilized for fertilization at 1000 ppm through four days only using the installed irrigation system. These experiments were statistically designed and analyzed as factorial experiments in complete randomized blocks. Life cycle duration "9 days" of the sprouted green fodder "Barley with variety of Giza 126" was divided into three equal periods.

The consumed water for the sprouted green fodder production could was calculated as follows:

$$TCW = SCWW + SW + IW \qquad (2)$$

where**:** TCW is total consumed water (Liter), SCWW is system cleaning and grain/seeds washing (Liter), soaking water for grain/seeds, and IW irrigation water for sprouted green fodder production (Liter).

Infection of the green fodder production by fungi growth was remarked by the naked eyes as light fiber around the sprouts. Fungi color was changed from white, to brown or black at the end of the life cycle. The sprouts infection ratios were calculated as follows:

$$SIR = (IT/TT) * 100$$

where: SIR is sprouts infection rate, IT is number of infected trays, and TT number of total trays of sprouts.

According to the chamber design, three treatments were executed in the same time through one production cycle. In addition to one or two weeks is needed for sampling and analyzing. Therefore, each experiment takes a period from 45 to 60 days in average. The green fodder samples were analyzed according to **A.O.A.C. 2000, Van Soest et al. 1991.**

RESULTS AND DISCUSSION:

Table (4) shows the mean values of the consumed water (CW) “l/tray per cycle”, the fresh weight of green fodder (FW) “kg/tray”, the dry matter (DM) “kg/tray”, the dry matter percentage (DMP) “%”, the water use efficiency (WUE) “gram of dry matter /liter of water”, and germination (GP) “%” through the first experiment “one irrigation program in one production cycle”. Statistically, the differences between values of the means in all treatments and their values in the control T_1 «30 second duration every 4 hours» are significant at ($P<0.05$). Numerically, the values of the all means “T_3 and T_8” are considered the best two treatments in the first experiment. Technically, T_3 “30 second duration every 8 hours” and T_8 «60 second duration every 6 hours» are not considered good results in comparison with the found results by, **Fazaeli et. al. 2012**.

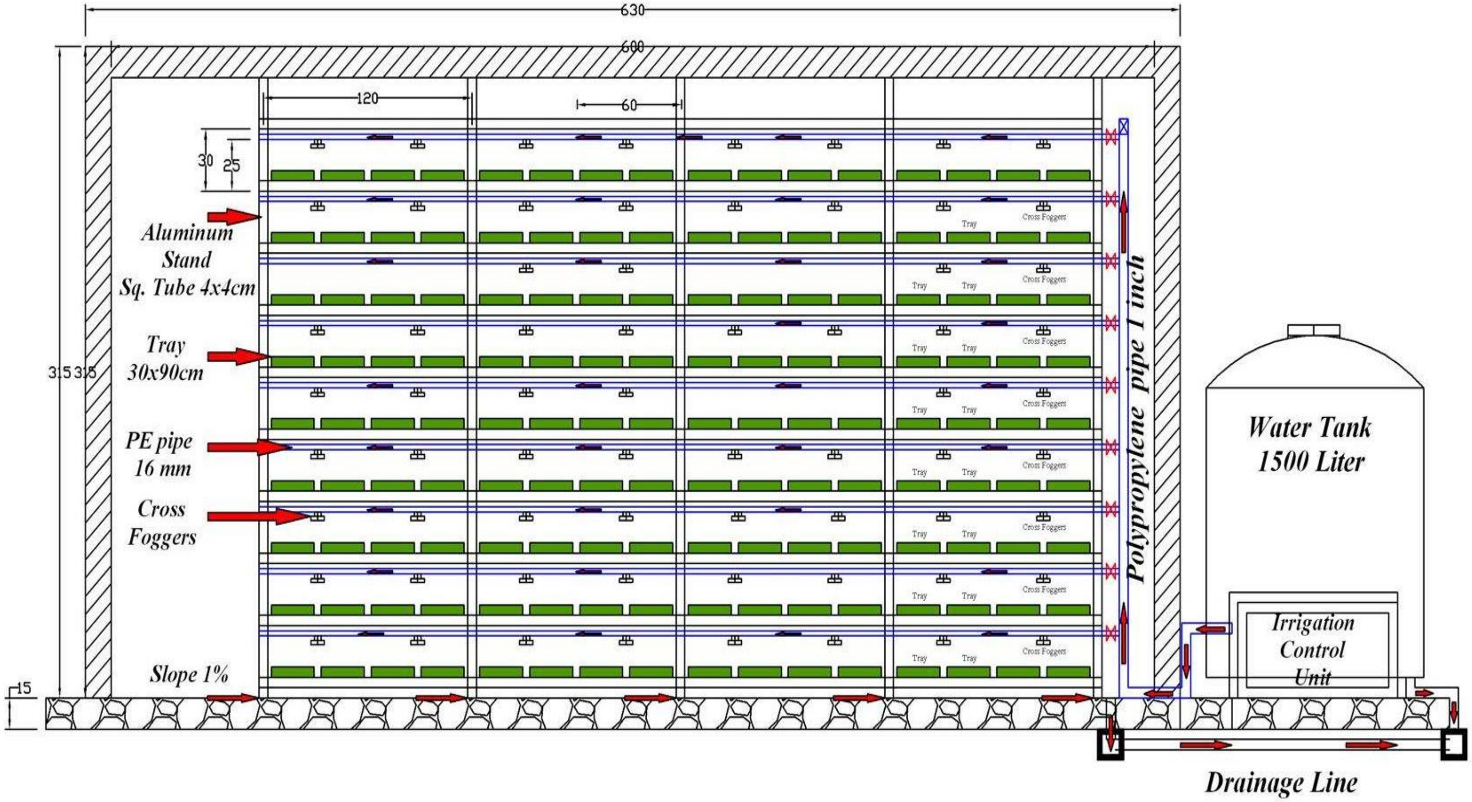

Fig. (1): Indoor water distribution unit through side view of the sprouting greed fodder production system.

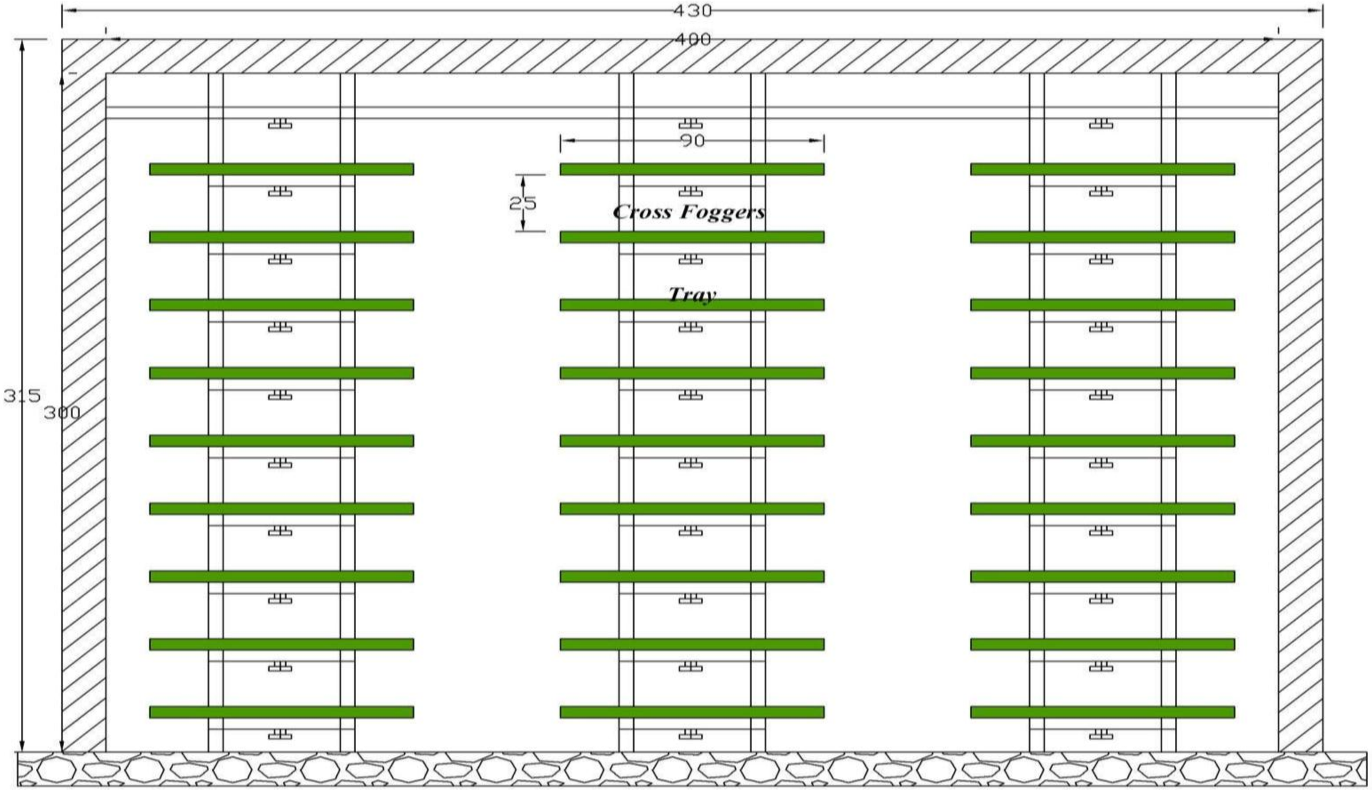

Fig. (2): The indoor water distribution unit through elevation of the sprouting greed fodder production chamber.

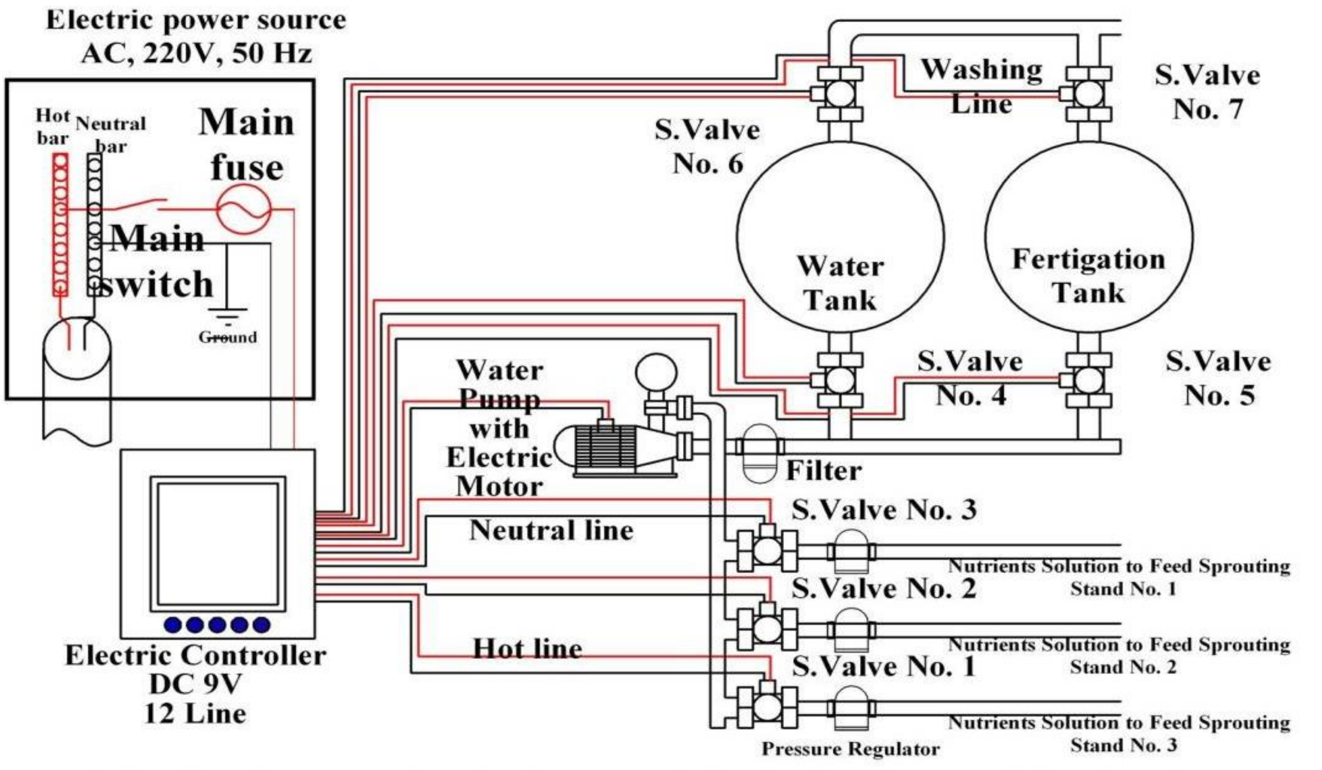

Fig. (3): Design and technical details of the outdoor water controlling unit fabricated outside the sprouting green fodder production chamber.

Table (1): Statistical design of the first experiment "One irrigation program in one production cycle (9days)".

Duration (Second)	Irrigation interval (hour)		
	4 h (One program)	6 h (One program)	8 h (One program)
30	T_1	T_2	T_3
45	T_4	T_5	T_6
60	T_7	T_8	T_9

Where: T_1 through T_9 are treatments; T_1 is control for comparing process.

Table (2): Statistical design of the second experiment "Two irrigation programs in one production cycle (3, 6 days)".

Duration (Second)	Irrigation interval (hour)					
	(Two programs)		(Two programs)		(Two programs)	
	x h (3days)	8 h (6days)	x h (3days)	10 h (6days)	x h (3days)	12 h (6days)
30	T_x	T_{10}	T_x	T_{11}	T_x	T_{12}
45	T_x	T_{13}	T_x	T_{14}	T_x	T_{15}
60	T_x	T_{16}	T_x	T_{17}	T_x	T_{18}

Where: T_x will be executed through the first three days as was done in the best treatment of the first experiment. T_{10} through T_{18} are new treatments. (T_x + T_{10}) is control for comparing process.

Regarding with T_3, due to the drought environment around the grains the mean value of the germination (GP) "%"is very small (62.4^{f}). Therefore, the cost of the consumed barley grains will be very high and the economic efficiency will be under to the level. Regarding the T_8, the abundant water around the grains the mean value of the germination (GP) "%"is very high (94.3^{a}). The mean value of the water use efficiency (WUE) in T_8 is very small (49.11^{de}). Scientifically, improving process of the germination percentage under drought is very difficult. But, improving process of the water use efficiency (WUE) under the high value of the germination percentage is not impossible. As a result, development process of the T_8 is considered more positive than the $T_{3.}$ Biologically, the application of single program for irrigation management through the three stages of germination is not in agreement with, **Edwards, 2010**.

Table (3): Statistical design of the third experiment "Application of three irrigation programs in one production cycle (3, 3 and 3 days)".

Duration (Second)	Irrigation interval (hour)								
	(Three programs)			(Three programs)			(Three programs)		
	x h **(3days)**	**y h** **(3days)**	**10 h** **(3days)**	**x h** **(3days)**	**y h** **(3days)**	**12 h** **(3days)**	**x h** **(3dyes)**	**y h** **(3dyes)**	**14 h** **(3days)**
30	T_x	T_y	T_{19}	T_x	T_y	T_{20}	T_x	T_y	T_{21}
45	T_x	T_y	T_{22}	T_x	T_y	T_{23}	T_x	T_y	T_{24}
60	T_x	T_y	T_{25}	T_x	T_y	T_{26}	T_x	T_y	T_{27}

Where: T_x will be executed through the first three days as was done in the best treatment of the first experiment; T_y will be executed through the second three days as was done in the best treatment of the second experiment; T_{19} through T_{27} are new treatments. ($T_x + T_y + T_{19}$) is control for comparing process.

Since, the germination stage needs more water for increasing the grains moisture content from 10 to 45 percent. The second stage needs less water than the first for keeping the grains moisture content around 45%. As a result, giving more water at the second stage leads to scarcity of oxygen, decreased germination rate and increased fungi growth rate. Therefore, division of the life growth in to three stage “three days per stage” is considered the best way for improving the germination rate and decreasing the fungi growth rate. Therefore, the T_8 «60 second duration every 6 hours through the first three days» was used as first program for the treatments in the second experiment. This table shows that, at the end of this experiment the remarked infection rate by fungi is found between 59 and 93%. Fig. (4) shows that the remarked infection rate is increasing due to the increasing in the applied water. Also, the relationship between the two variables is strong. Since, the values of determination coefficient (R^2) correlation coefficient (r) are 0.59 and 0.76 respectively. Scientifically, this result is referred to the high rates of moisture around the sprouts. Since the high rates of moisture are considered suitable environment to fungi growth. This results is in agreement with that was mentioned by **Popovskis and Celar 2012, Suleiman et al. 2013, Pratiwi et al. 2015, Poonam 2015, and Clerck et al. 2016.** Therefore, using double program with the replacement of the single program to minimize the infection rate is considered critical issue.

Table (5) shows the mean values of the technical criteria through the second experiment “using two irrigation programs in one production cycle”. Statistically, the differences between values of the means in all treatments and their values in control T_8+T_{10} are significant at ($P<0.05$). Numerically, according to values of the dry matter (DM), the water use efficiency (WUE), and the germination percentage (GP), the (T_8+T_{13}) “60 second duration every 6 hours through the first three days and 45 second duration every 8 hours through the second three days” is considered the best treatment in this experiment. The fresh weight, the dray matter, the dry matter percentage, the water use efficiency, and the germination rate is improved. The results in this experiment are better than that the first experiment. This improvement could be referred to growing primary roots constituting a sponge thin layer below the sprouted grains keeping a part of irrigation water available for grains absorption. Although this improvement (T_8 + T_{13}) the dry matter DMP "%", is less than other treatments such as T_8+T_{12}. Therefore, the treatment (T_8+T_{13}) is good, but not ideal for managing the deficit water resources in the hydroponics sprouted barley grains production. Fig. (5) shows that the remarked infection rate is increasing due to the increasing in the applied water. Also, the relationship between the two variables is strong. Since, the values of determination coefficient (R^2) correlation coefficient (r) are 0.72 and 0.85 respectively. Therefore, triple irrigation program experiment using treatment (T_8+T_{13}) as base through the first six days is needed. This result is in agreement with our assumption dealing with using triple irrigation program production cycle. Also, the triple program is in argument with the three stages of the sprouting, **Edwards, 2010.** This table shows that, at the end of this experiment the remarked infection rate by fungi is found between 30 and 45%. This decreasing in the remarked infection rate is referred to the same reasons mentioned above.

Table (6) shows the mean values of the technical criteria through the third experiment using three irrigation programs in one production cycle. Statistically, the differences between values of the means in all treatments and their values in control (T_8+T_{13}+T_{19}) are significant at ($P<0.05$). Numerically, depending on the values of the consumed water (CW) "l/tray per cycle", the dry matter (DM) "kg/tray", the dry matter percentage DMP "%", the water use efficiency (WUE) "gram of dry matter /liter of water", and germination (GP) "%", the treatment (T_8+T_{13}+T_{20}) "60 second duration every 6 hours through the first three days, 45 second duration every 8 hours through the second three days and 30 second duration every 12 hours through the second three days" is considered the best one in this experiment. This improvement is due to growing the primary and secondary roots constituting layer of fabric with thickness of 2-3cm and growing the first leaf constituting layer of grass with long 15-20 cm keeping irrigation water for a period of time. Therefore, minimizing the irrigation water is considered type of controlling on the Fungi growth rate. Numerically, Table (6) shows the mean value of the dray matter percentage in the treatment (T_8+T_{13}+T_{20})

is 17.01%. This result is higher than that found by **Fazaeli et al. 2012,** since the chemical analysis shows the highest value of the dray matter percentage was 14.3%. The increasing rate in the DMP is due to the great management of irrigation and its reflection on the growth rate. This table shows that, at the end of this experiment the remarked infection rate by fungi is found between 1 and 7%. Fig. (6) shows that the remarked infection rate is increasing due to the increasing in the applied water. Also, the relationship between the two variables is strong. Since, the values of determination coefficient (R^2) correlation coefficient (r) are 0.82 and 0.91 respectively. This decreasing in the remarked infection rate is considered a clear confirmation on that were mentioned above.

This table shows the mean value of the fresh weight “arranged from 5.0 to 7.8 kg per tray with dimension of “30x90” cm. This weight is equivalent of 641 kg fresh matter/m^3 of water with 17.01% dry matter including the consumed water in washing and soacking. Therefore, the research result is higher than that found by **Ghazi, Al-Karaki and Al-Hashimi, 2012.** Since **Ghazi, Al-Karaki and Al-Hashimi, 2012** mentioned that, the mean value of barely crop produce was “654 kg fresh matter/m^3 water with 17% dry matter at 8 day” excluding the consumed water in washing and socking. Also, this table shows the mean value of the water use efficiency (WUE) is 109.01**”**kg of dry matter /m^3 of water” including the consumed water in washing and soaking. Therefore, the research result is higher than that found by **Ghazi, Al-Karaki and Al-Hashimi, 2012.** Since **Ghazi, Al-Karaki and Al-Hashimi, 2012** mentioned that the mean value of barely crop was **110**”kg of dry matter /m^3 of water excluding the consumed water in washing and soaking. Briefly, according to the reported data in the available literature reviews, our research results are located at the top comparing with the research.

Depending on the manifested data in Table (6), the annual value of the sprouted yields is [(0.85*16*9*3)(366/8)(10000/24)(1/1000)] = 6999.75 tons DM/ha, The maximum yield has been reported in Africa, with yields of 10 to 20 tons DM/ha commonly produced in Europe, China and North America under irrigated conditions, **Steduto, et. al., 2012**.

Table (4): Effects of using one irrigation program per cycle on the production quality.

Treatments	**Variables Means and Its Ranks**											
	CW	**FW**	**DM**	**DMP (%)**	**WUE (g/l)**	**GP (%)**	**Ash (%)**	**Cp (%)**	**Cf (%)**	**EE (%)**	**NFE (%)**	**Inf. (%)**
T_1	9.42^{e}	3.00^{de}	0.42^{cd}	14.00^{cde}	44.62^{e}	74.5^{d}	3.7	11.6^{c}	14.7^{b}	4.8^{a}	65.2^{c}	93^{a}
T_2	6.60^{b}	2.72^{ef}	0.40^{cd}	14.87^{bc}	61.26^{b}	70.5^{e}	2.9	12.5^{b}	13.9^{c}	4.7^{a}	66.0^{b}	74^{b}
T_3	**5.30^{a}**	2.35^{g}	0.38^{d}	**16.36^{a}**	**72.38^{a}**	62.4^{f}	3.2	11.7^{c}	14.1^{b}	3.4^{b}	67.6^{a}	55^{cd}
T_4	13.66^{g}	3.27^{cd}	0.43^{cd}	13.23^{e}	31.63^{f}	84.5^{b}	3.1	12.5^{b}	15.2^{a}	4.1^{a}	65.1^{c}	95^{a}
T_5	9.46^{e}	3.01^{de}	0.42^{cd}	13.93^{de}	44.39^{e}	74.3^{d}	3.6	12.1^{b}	13.4^{c}	3.5^{b}	67.4^{a}	76^{b}
T_6	7.40^{c}	2.60^{fg}	0.39^{cd}	15.10^{b}	52.74^{cd}	70.3^{e}	3.5	13.3^{a}	14.2^{b}	4.1^{a}	64.9^{d}	56^{c}
T_7	**17.82^{h}**	3.80^{b}	0.44^{c}	11.50^{f}	24.57^{g}	82.7^{b}	3.7	12.5^{b}	12.2^{d}	3.7^{b}	67.9^{a}	97^{a}
T_8 √	12.25^{f}	**4.30^{a}**	**0.60^{a}**	14.02^{cde}	49.11^{de}	**94.3^{a}**	3.3	13.8^{a}	13.3^{c}	3.9^{a}	65.7^{c}	78^{b}
T_9	9.17^{d}	3.50^{c}	0.51^{b}	14.50^{bcd}	55.41^{c}	79.6^{c}	3.5	13.2^{a}	14.3^{b}	4.1^{a}	64.9^{d}	59^{bc}
±SE	0.06	0.10	0.02	0.24	1.86	0.69	0.60	0.85	1.22	1.67	0.37	5.41

Where: a, b, c, d, e, f, g, and h: Means in the same column with different superscripts are significant different ($P<0.05$). Also, **±SE** is standard error in average for each mean in the same column. CW is consumed water "l/tray per cycle", FW is fresh of green fodder "kg/tray", DM is dry matter "kg/tray", DMP is dry matter percentage, WUE is water use efficiency "gram of dry matter /liter of water", GP is germination percentage CP, crude protein, EE: ether extract, CF: crude fiber, NFE: nitrogen free extract.

Table (5): Effects of using two irrigation programs per cycle on the production quality.

Treatments	Variables Means and Its Ranks											
	CW	**FW**	**DM**	**DMP (%)**	**WUE (g/l)**	**GP (%)**	**Ash (%)**	**Cp (%)**	**Cf (%)**	**EE (%)**	**NFE (%)**	**Inf. (%)**
T_8+T_{10}	7.55^{c}	3.50^{e}	0.56^{c}	16.01^{bc}	74.24^{abc}	94.6^{a}	2.9^{b}	13.1^{b}	13.2^{b}	3.6^{ab}	67.2^{a}	45^{ab}
T_8+T_{11}	7.02^{b}	2.90^{f}	0.50^{d}	17.02^{ab}	70.78^{bcd}	93.7^{a}	3.1^{b}	13.3^{b}	13.5^{b}	4.2^{a}	65.9^{a}	33^{b}
T_8+T_{12}	**6.72^{a}**	2.42^{h}	0.43^{d}	**17.88^{a}**	64.44^{d}	94.6^{a}	3.5^{a}	13.5^{b}	13.1^{b}	3.7^{a}	66.2^{a}	27^{cde}
T_8+T_{13} √	9.01^{f}	4.77^{b}	**0.72^{a}**	15.07^{cd}	**79.92^{a}**	**95.0^{a}**	3.3^{b}	**14.7^{a}**	**14.6^{a}**	**4.3^{a}**	63.1^{c}	46^{ab}
T_8+T_{14}	8.21^{d}	3.90^{d}	0.63^{bc}	16.06^{bc}	76.19^{ab}	93.9^{a}	3.8^{a}	14.3^{a}	13.7^{b}	3.9^{a}	64.3^{c}	34^{b}
T_8+T_{15}	7.54^{c}	3.60^{e}	0.61^{b}	17.01^{ab}	80.96^{a}	94.4^{a}	4.2^{a}	14.4^{a}	14.5^{a}	4.3^{a}	62.6^{c}	29^{cd}
T_8+T_{16}	10.63^{h}	**5.00^{a}**	0.65^{bc}	13.12^{e}	63.07^{d}	93.6^{a}	3.8^{a}	13.5^{b}	14.3^{a}	3.9^{a}	64.5^{b}	48^{a}
T_x+T_{17}	9.32^{g}	4.40^{c}	0.62^{bc}	14.01^{de}	66.38^{cd}	94.9^{a}	3.5^{b}	14.1^{a}	13.8^{b}	4.2^{a}	64.4^{b}	35^{b}
T_8+T_{18}	8.48^{e}	4.20^{c}	0.63^{b}	15.01^{cd}	74.40^{abc}	94.7^{a}	4.0^{a}	14.3^{a}	14.5^{a}	3.1^{b}	64.1^{b}	30^{cd}
±SE	0.06	0.08	0.02	0.38	2.65	0.64	0.89	0.76	1.45	1.95	1.27	1.24

Where: a, b, c, d, e, f, g, and h: Means in the same column with different superscripts are significant different ($P<0.05$). Also, **±SE** is standard error in average for each mean in the same column. CW is consumed water “l/tray per cycle”, FW is fresh of green fodder “kg/tray”, DM is dry matter “kg/tray”, DMP is dry matter percentage, WUE is water use efficiency ”gram of dry matter /liter of water”, GP is germination percentage CP, crude protein, EE: ether extract, CF: crude fiber, NFE: nitrogen free extract,.

Table (6): Effects of using three irrigation programs per cycle on the production quality.

Treatments	Variables Means and Its Ranks											
	CW	**FW**	**DM**	**DMP (%)**	**WUE (g/l)**	**GP (%)**	**Ash (%)**	**Cp (%)**	**Cf (%)**	**EE (%)**	**NFE (%)**	**Inf. (%)**
$T_8+T_{13}+T_{19}$	8.03^{b}	5.20^{bc}	0.78^{abc}	15.04^{cde}	97.28^{b}	94.6^{ab}	3.2	14.5^{c}	14.4^{a}	4.1^{a}	63.8^{b}	5^{c}
$T_8+T_{13}+T_{20}$ √	**7.80^{a}**	5.00^{cd}	**0.85^{a}**	**17.01^{ab}**	**109.01^{a}**	**95.2^{a}**	3.1^{b}	**16.3^{a}**	13.6^{b}	**3.6^{ab}**	63.4^{b}	2^{cd}
$T_8+T_{13}+T_{21}$	**7.65^{a}**	4.31^{e}	0.76^{bc}	17.51^{a}	98.76^{b}	94.2^{ab}	3.4^{b}	15.7$^{a b}$	13.4^{b}	3.2^{b}	64.3^{a}	1^{cde}
$T_8+T_{13}+T_{22}$	8.49^{c}	5.49^{b}	0.77^{abc}	14.01^{e}	90.88^{b}	94.5^{ab}	3.9^{ab}	14.9^{c}	14.3^{a}	4.3^{a}	62.6^{c}	7^{b}
$T_8+T_{13}+T_{23}$	8.37^{c}	5.20^{bc}	0.75^{bc}	15.86^{de}	90.01^{b}	93.6^{b}	4.2^{a}	15.1$^{a b}$	13.5^{b}	3.5^{ab}	63.7^{b}	4$^{b c}$
$T_8+T_{13}+T_{24}$	8.06^{b}	4.50^{e}	0.71^{c}	14.01^{bcd}	88.64^{b}	93.8^{ab}	3.3^{b}	16.1^{a}	14.0^{a}	3.9^{a}	62.7^{c}	3^{cd}
$T_8+T_{13}+T_{25}$	9.09^{e}	**5.80^{a}**	0.81^{ab}	15.01^{e}	89.68^{b}	94.0^{ab}	3.9^{ab}	15.9$^{a b}$	14.2^{a}	3.4^{b}	62.6^{c}	9^{a}
$T_8+T_{13}+T_{26}$	8.69^{d}	5.50^{b}	0.83^{ab}	15.01^{cde}	95.22^{b}	94.4^{ab}	4.1^{a}	14.3^{c}	13.1^{b}	3.8^{ab}	64.7^{a}	6^{b}
$T_8+T_{13}+T_{27}$	8.44^{c}	4.80^{d}	0.77^{abc}	15.97^{bc}	90.98^{b}	94.6^{ab}	3.3^{b}	15.1$^{a b}$	14.5^{a}	4.2^{a}	62.9^{c}	4$^{b c}$
±SE	0.06	0.09	0.03	0.36	3.61	0.58	0.45	0.66	1.54	1.54	0.77	0.03

Where: a, b, c, d, e, f, g, and h: Means in the same column with different superscripts are significant different ($P<0.05$). Also, **±SE** is standard error in average for each mean in the same column. CW is consumed water “l/tray per cycle”, FW is fresh of green fodder “kg/tray”, DM is dry matter “kg/tray”, DMP is dry matter percentage, WUE is water use efficiency ”gram of dry matter /liter of water”, GP is germination percentage CP, crude protein, EE: ether extract, CF: crude fiber, NFE: nitrogen free extract.

Table (7): The differences among the selected treatments of the single, duple, and triple programs.

Treatments	Variables Means and Its Ranks											
	CW	**FW**	**DM**	**DMP (%)**	**WUE (g/l)**	**GP (%)**	**Ash (%)**	**Cp (%)**	**Cf (%)**	**EE (%)**	**NFE (%)**	**Inf. (%)**
Single program *	12.25^{a}	4.30^{c}	0.60^{c}	14.02^{c}	49.11^{c}	94.3^{b}	3.3^{a}	13.8^{c}	13.3^{c}	3.9^{b}	65.7^{a}	78^{a}
Double program **	9.01^{b}	4.77^{b}	0.72^{b}	15.07^{b}	79.92^{b}	95.0^{a}	3.3^{b}	14.7^{b}	14.6^{a}	4.3^{a}	63.1^{b}	46^{b}
Triple program ***	7.80^{c}	5.00^{a}	0.85^{a}	17.01^{a}	109.01^{a}	95.2^{a}	3.1^{c}	16.3^{a}	13.6^{b}	3.6^{c}	63.4^{b}	2^{c}
±SE	0.13	0.11	0.025	0.27	2.28	0.57	0.55	0.75	1.54	1.54	0.77	0.03

Where: a, b, c, d, e, f, g, and h: Means in the same column with different superscripts are significant different ($P<0.05$). Also, **±SE** is standard error in average for each mean in the same column. CW is consumed water "l/tray per cycle", FW is fresh of green fodder "kg/tray", DM is dry matter "kg/tray", DMP is dry matter percentage, WUE is water use efficiency "gram of dry matter /liter of water", GP is germination percentage CP, crude protein, EE: ether extract, CF: crude fiber, NFE: nitrogen free extract,.

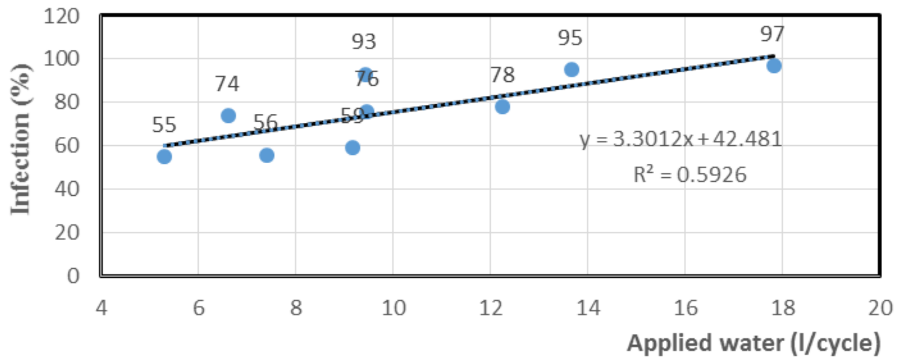

Fig. (4):Using one program per cycle

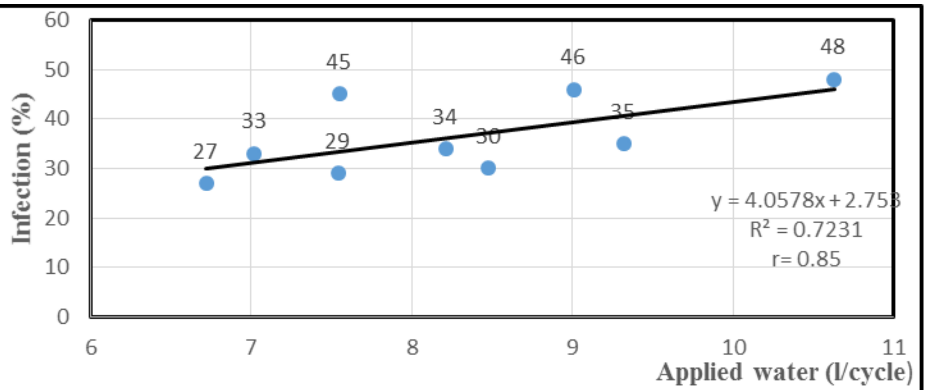

Fig. (5): Using two programs percycle

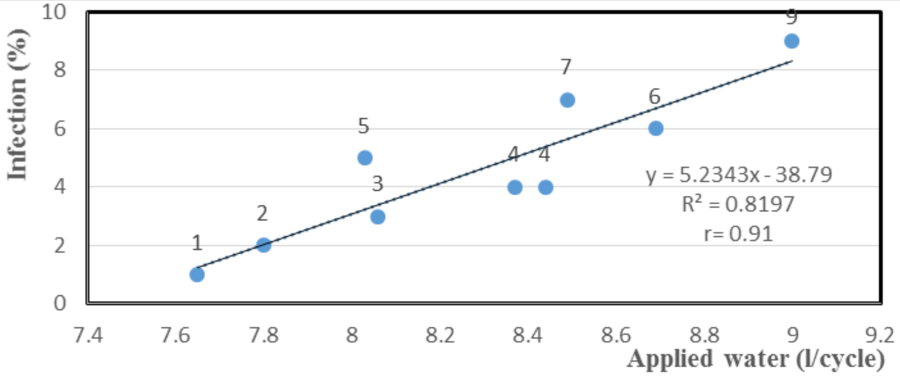

Fig. (6): Using three programs percycle

This result means that the productivity of one hectare of the sprouted green fodder is approximately equal to 350-700 hectare of the open field. Since, water consumption, water productivity in the open field are

{(10000/4200)(20*270))= 12875 m^3 per year, and 1.55 kg/ m^3 of dry matter /m^3 of water per year respectively. Also, the mean value of the water use efficiency (WUE) in the sprouting system is 109.01”kg of dry matter /m^3 of water”. Therefore, the ratio between value of the water use efficiency (WUE) in the open field and the sprouting system is equal 1: 70.

Table (7) shows the differences among the selected treatments of the single, duple, and triple programs. The high values of fresh weight of green fodder FW “kg/tray”, dry matter “kg/tray”, dry matter percentage DMP , water use efficiency WUE ”gram of dry matter /liter of water”, crude protein Cp, and germination percentage GP are considered positive indicator on the green fodder quality. The small values of consumed water CW “l/tray per cycle”, Ash percentage, crude fiber Cf,, ether extract EE, nitrogen free ether NFE, infection rates are considered positive indicator on the green fodder quality. Statistically, (a) is more significant than (b), and (b) is more significant than (c). Therefore, there are significant differences among the treatments in the triple programs in comparing with the single and double programs.

CONCLUSION

From the above analysis, and results, the research conclusion could be summarized as follows:

1. There is strong correlation between the applied water in irrigation and the infection rate with Fungi growth. Therefore, using one irrigation program in one production cycle is considered technical mistake, since the excessive use of irrigation water leads to Fungi growth. Also, deficient use of irrigation water leads to lack of production.
2. There are significant differences among the treatments of the single, duple, and triple programs. Therefore, operating the irrigation system on three programs (the first is 60 second every 6 hours for the first three days”, the second is 45 second every 8 hour for the second three days”, and the third is 30 second every 12 hours for the remainder days) for the best engineering management for the deficit water resources in the hydroponics sprouted barley grains production.

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الملخص العربى

برامج إدارة متتالية للموارد المائية الشحيحة فى إنتاج الأعلاف الخضراء مائيا بدون تربة

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المشكلة: تعتبرغرف الإستنبات بيئة مناسبة لنمو الفطريات بأنواعها المختلفة. كما يؤدى نمو الفطريات على الأعلاف المستنبتة مائيا الى تقليل كمية الإنتاج مع إنخفاض الجودة. ويعتبر برنامج إدارة منظومة الرى من العوامل الرئيسية فى إرتفاع معدل نمو الفطريات على الأعلاف المستنبتة مائيا.

***قسم الهندسة الزراعية - كلية الزراعة – جامعة القاهرة**

حيت يؤدى إنخفاض معدلات الرى الى إنخفاض نسبة الإنبات وصغر حجم النباتات. كما أن إرتفاع معدلات الرى يؤدى الى إرتفاع معدل نمو الفطريات على الأعلاف المستنبتة مائيا. ونظرا للتأثير السام للفطريات تستبعد الأعلاف المصابة من عمليات تغذية الحيوانات لخطورة وإنتقال المواد السامة التى تنتجها الفطريات الى الإنسان عند التغذية على اللحم أواللبن. وهذا يعتبر إهدار لإصول الإنتاج والموارد المائية المحدودة وإضرار بالصحة العامة.

الهدف: يهدف هذا البحث الى تصميم وتنفيذ وتقييم برنامج لإدارة الموارد المائية يحقق أعلى نسبة إنبات وأكبر مجموع خصرى خالى من الفطريات وأعلى مواصفات لجودة الأعلاف دون إستخدام أى نوعية من المبيدات الفطرية.

المنهج العلمى: ولتحقيق هذا الهدف تم إتباع تصميم وإجراء وتحليل إحصائى لثلاث تجارب عاملية كاملة القطاعات العشوائية. التجربة الأولى تعتمد على برنامج رى واحد خلال دورة الإنتاج. وتحتوى على عدد تسعة من المعملات، ثلاث أزمنة للرى وهما ٦٠ ،٤٥، ٣٠ ثانية، وثلاث فترات بين الريات وهما ٤، ٦، ٨ ساعات. التجربة الثانية تعتمد على عدد إثنين من برنامج الرى خلال دورة الإنتاج الواحدة. يكون البرنامج الأول مطابقا لأفضل معاملة بالتجربة الأولى ولمدة ثلاثة أيام الأولى من التجربة. بينما يطبق البرنامج الثانى طوال الستة أيام التالية. وتحتوى على عدد تسعة من المعملات، ثلاث أزمنة للرى وهما ٦٠ ،٤٥، ٣٠ ثانية، وثلاث فترات بين الريات وهما ٨، ١٠، ١٢ ساعة. التجربة الثالثة تعتمد على عدد ثلاث من برنامج الرى خلال دورة الإنتاج الواحدة. يكون البرنامج الأول مطابقا لأفضل معاملة بالتجربة الأولى ولمدة ثلاثة أيام الأولى من التجربة، ويكون البرنامج الثانى مطابقا لأفضل معاملة بالتجربة الثانية ولمدة ثلاثة أيام التالية من التجربة. بينما يطبق البرنامج الثالث طوال الستة أيام الأخيرة. وتحتوى على عدد تسعة من المعملات، ثلاث أزمنة للرى وهما ٦٠ ،٤٥، ٣٠ ثانية، وثلاث فترات بين الريات وهما ١٠، ١٢، ١٤ ساعة. وتم قياس كمية الماء المستهلك لتر/ صينية، ووزن الأعلاف الخضراء كجم/ صينية، ووزن المادة الجافة كجم/صينية، ونسبة المادة الجافة، وكفائة إستخدام المياه جم مادة جافة/لترماء، ونسبة الإنبات. كما تم حساب عدد صوانى الإنتاج المصابة بالفطريات و عدد الصوانى الخالية من الفطريات بجميع التجارب العملية.

النتائج: وقد أضحت نتائج التحليل الإحصائى للبيانات أن برنامج إدارة الرى الثلاثى المتتالى المراحل "والذى يتم فيه إدارة نظام الرى لمدة ٦٠ ثنانية كل ٦ ساعات خلال الثلاث أيام الأولى، لمدة ٤٥ ثنانية كل ٨ ساعات خلال الثلاث أيام لثانية، لمدة ٣٠ ثنانية كل ١٢ ساعة خلال الثلاث أيام الأخيرة" هو أفضل البرامج. وذلك من حيث كمية الإنتاج من الأعلاف الخضراء وكذك جودة الأعلاف الناتجة من حيث إحتوائها على العناصر الغذائية وخلوها من الفطريات. كماأوضحت النتائج أن إرتفاع التلوث بالفطريات يرجع أساسا الى سوء إدارة المباه المضافة للرى أكثر من انها إضافة مياه للرى. وقد أكد ت نتائج التحليل انه يوجد ارتباط قوى بين كمية المياه المضافة للرى وبين نسبة الإصابة بالفطريات.