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Research article

Investigating the performance of hydroponic green fodder and simplified heat transfer model of nanofarm for agricultural engineering application

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Abstract

In this study, root length and number of roots in forage production were investigated by hydroponic nanofarm chamber. For this purpose, specific amount of corn was planted in a special metal nanofarm culture room in two floors equipped with automatic control system. After 6 and 7 days of growth of corn from treated and non-treated sample were randomly selected. The amount of performance of the nanofarm was considered as humidity, temperature, and light parameters. In this research, an experimental observation on nanofarm device was done to check the grow and cultivate corn fodder with and without 202020 fertilizers. Also, the evaluated Nutrient Film Technique (NFT) system was used for prediction and simulation of hydroponic nanofarm. According to our study, there are more than 900 different agricultural products used to make animal feed in which green fodder has the most important response in the agriculture field. The efficiency of seed to fodder in this system is about 1 Kg to 7 Kg of seed (barley), an average of 7 Kg of barley fresh fodder hydroponic can be obtained. This system can have less waste product and higher efficiency. One of the main goals of the control system in nanofarms is to control the temperature of the internal environment of nanofarm. A simplified model for heat transfer in nanofarm is studied. In the discussion of nanoform heat transfer, various methods of heat transfer, including conduction, displacement, and radiation are of interest.

Keywords: Nanofarm, Hydroponics, Forage cultivation, Simulator, Heat transfer model

1- Introduction

Ruminants excrete a few percent of the food they eat without digestion, which in turn leads to a loss of seed consumption that can reduce by feeding forage [1-4]. Since the consumed seeds are not disinfected in most cases, the consumption of seeds keeps the farmer away from organic meat production [5-8]. Because animal waste is used directly in agriculture, consumption of forage produced with disinfected seeds has significantly reduced

the transmission of disease from animal waste to agricultural lands, which in the long run reduces the use of pesticides and approaches production which enables the organic product [9-12]. It even reduces the transfer and growth of weeds. Now, one kilogram of seeds produces 7 Kg of fodder by hydroponic method in nanofarm chamber. In a performed laboratory experiment, the balance of dry matter (DM) obtained from fresh grass to dry matter consumption (seed) during 6-day growth periods with an appropriate result compared to other studies [13-18]. Lack of green forage in livestock rations causes nutrition and complications. In addition, the absorption of substances in green fodder is easier for livestock than dry fodder [19-25]. The production of hydroponic forage for animal feed is important because it is applicable throughout the year and consecutively. In this method, the seeds are massively spread on shallow plastic trays that have a sheet of damp paper [26-33]. The seeds are sprayed with water in the first few days. After the seeds germinate, the trays are sprayed with a nutrient solution every few days to allow the seed to grow rapidly [31-33]. These trays can be placed on shelves inside or outside the greenhouse. When the forage reaches a height of 15-17 cm and forms a dense vegetation, it is fed to livestock. It takes 6 to 8 days to turn a seedling into a full plant. One kilogram of seeds may give 6 to 8 Kg of green fodder, depending on the type of crop and seeds [34-39].

Usually in this type of forage production system, plants such as barley, oats, corn and wheat are grown which have a high nutritional value for animal feed. Green forage is preferable to direct consumption of seeds as feed, which is at best 30% digestible, because it is 95% digestible [40-47]. The occurrence of drought in the many countries has made it difficult to supply forage needed by livestock. In such circumstances, hydroponic forage production is a solution that can reduce the limitation of water resources in forage production and also due to time-consuming conditions with high cost of forage production. This method can be used well in agricultural land, although all aspects should be considered before using this method extensively [32-47]. One of the main issues in the agricultural field of the country is the limitation of resources, water, energy and soil [48-52]. Currently, this limitation is the bottleneck of crop production, including the production of fodder for animal feed. Eliminates the problem of forage production due to the mentioned restrictions, while helping the country's meat production industry, one of the main and most fundamental concerns of livestock units can be solved. Hydroponic cultivation is one of the methods that uses techniques modern cultivation significantly reduces the limitation of water and soil resources in the production of crops. The hydroponic system is a sustainable method of planting some crops that have less water and fertilizer which increase production per unit area. Therefore, to use less chemicals, environmental risks materials, hydroponic can be beneficial. Due to the novelty of this method, research on energy indicators and water use efficiency is also limited. The production system in sustainable agriculture should be planned in such a way that in addition to economic benefits in terms of energy need to be balanced [53-62]. Energy balance in agriculture is obtained by analyzing and comparing the amount of input and output energy. Therefore, the use of hydroponic fodder is

a suitable solution to provide livestock fodder in these conditions. In this research, an experimental observation on nanofarm device was done to check the grow and cultivate corn fodder with and without 202020 fertilizers. Also, the evaluated NFT system was used for prediction and simulation of hydroponic nanofarm. NFT growing is primarily used for growing leafy green plants. Using this technique, a thin stream of water flows through a rectangular channel about 3" to 10" wide (wider channels are used for fodder crops). Because the nutrient stream forms a thin film in the bottom of the channel it gives the technique its name. Plant roots are bathed in this stream of nutrients and grow very quickly.

2- Materials and methods

In order to investigate the effect of 202020 fertilizer on the growth of a corn cultivar with a fertilizer treatment by hydroponic cultivation. In this study, to cultivate corn by hydroponic method, corn was first soaked for 24 hours and transferred to a nanofarm. From the first day, corn was sprayed 3 times a day at specific times with 202020 fertilizer at a concentration of 4 g/l. Since the above three elements are needed to start the process of photosynthesis, authors accelerated the synthesis and growth by providing these essential elements. From the 2th day of seed germination began to appear from the 5th day with the formation of leaves, photosynthesis began. The buds received 16 hours of light in 24 hours (2 hours of light every 3 hours) and the amount of irrigation is about 24 hours and 1.36 minutes (every 3 hours, 12 seconds). The temperature range of the growth medium is 20-24°C. Corn seeds were divided into two groups treated with 202020 fertilizer and control. The treated group was placed on the upper floor and the control group was placed on the lower floor. All environmental conditions are completely the same for both groups.

3- Results and Discussion

3-1- Experimental procedure

On the 6th day of corn cultivation and the following results were obtained. Comparing the two groups, it is obtained that the root length of the control group is more than the treated group (14.5> 14). Also, the weight of the treated group is more than the control group (11.63> 8.11). The obtained results indicated that the mean stem length of the treated group is higher than the average stem length of the control group (5.85> 4.15) and the number of rooted corns was much higher than the control group. Since, the 202020 fertilizer contains nitrogen (N), phosphorus (P), potassium (K), and these three elements are essential elements for plant growth that spraying this fertilizer to the seed may increase the amount of usable material around it. Therefore, the plant absorbs more fertilizer and instead the root length. The fertilizer increases the number of its roots to increase the amount of absorption. The amount of seed storage is limited and the seed uses that storage until the absorption stage. The amount of absorbable substance and the ability to absorb (roots) of the treated group is higher than the control group. As a result, the treated group is heavier than the control group. In recent decades, in some parts of the world, experiments have been performed on green fodder production by hydroponic method (NFT). In this method, barley seeds are often used to produce fresh green fodder in such a way that within 6 to 7 days from the time of

planting, the seed embryo is activated and the height of the green plant may reach about 15-20 cm. At first, it seems that from 1 Kg of seed (in a short period of 6 to 7 days) 6-8 Kg of fresh forage can be obtained. The important part in forage production is the net amount of digestible nutrients and absorption in the production forage. During the germination process and the initial growth of the plant, a significant portion of the nutrients stored in the seed is consumed for the germination process. The obtained product may be a collection of roots, greens and semi-depleted seeds, which is the main part. Therefore, contradictory information has been published about the efficiency of forage production and the nutritional value of hydroponic forage [62-68].

Table 1: Investigation of control and non-control samples in hydroponic forage maize cultivation

Treated with fertilizer "202020"		Control	
Stem length	Number	Stem length	Number
5	1	4	1
6	2	3.5	2
6	3	4.5	3
6.5	4	4	4
5.5	5	4	5
6.5	6	5	6
6	7	3.5	7
5	8	4.5	8
6	9	4.5	9
6	10	4	10
5.85	Average stem length	4.15	Average stem length
14-8	Root length range	14.5-8	Root length range
11.63	Weight of 10 roots	8.11	Weight of 10 roots

The risk of fungal contamination of hydroponic fodder and poisoning for livestock and their products mentioned by researchers in which there is no valid and documented article about this issue. Plants need three things to grow such water, nutrients and sunlight. Hydroponics is a direct way to supply all these nutrients without the need for soil in controlled environmental conditions to optimize plant growth. The technology has been tested on various products such as corn, sorghum, barley, barley to produce high quality green fodder for dairy animals. Forage obtained from hydroponics includes grass with seeds, roots, stems and leaves compared to the stem and leaf section in conventional forage. Natural green fodder is the key to reducing the cost of nutrition during milk production. Fig. 1 indicate Nutrient Film Technique (NFT) cultivation or water planting technique in which the plant roots are in rotating plastic containers containing nutrients that are always available to the plant roots. The functional mechanism of this device is that it is transferred to the NFT bed through the water pump and water-soluble food through the pipe. Due to the slope in the bed, it returns to the tank and this cycle continues. However, due to climatic conditions, the unavailability of fresh land grasses is available for a shorter period of the year. Due to the unavailability and higher costs of land, the minimum use of forage production areas for animal feed which can improve the economy and sustainability of the land, providing more cultivated area for the production of other crops.

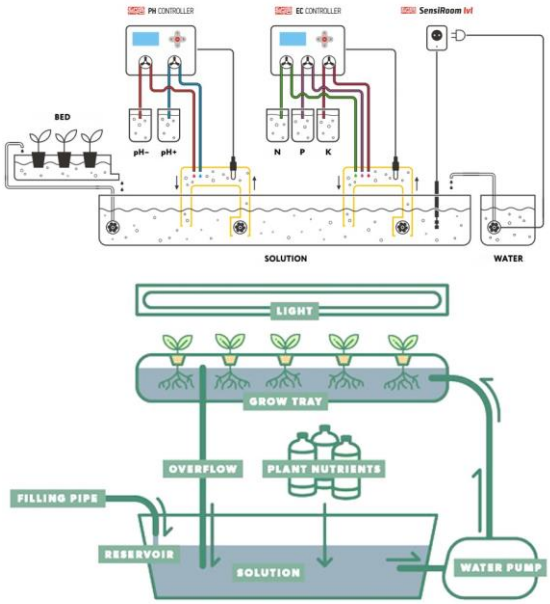

Fig. 1 The process schematic of the NFT system and how to plan for a hydroponic System

The NFT system also removes extra pressure on the pre-operated irrigation system as shown in Fig. 2. The process of growing green fodder hydroponically allows the control of climatic conditions for optimal growth with guaranteed output per day. Fig. 2 demonstrate the designed documents for the NFT system of Royeshgar nanofarm. This system has the ability to show its optimal performance with the presence of water pumps number 6 and 7, feeding pumps 3, 4 and 5, and air pump 1 and 2. In addition, in this loop, carbon dioxide and food transmission are available. In this circuit, changes in pH concentration and electrical conductivity (EC) are evaluated. Producing green fodder through hydroponic technology has proven to be a real alternative source of fodder shortages in the state.

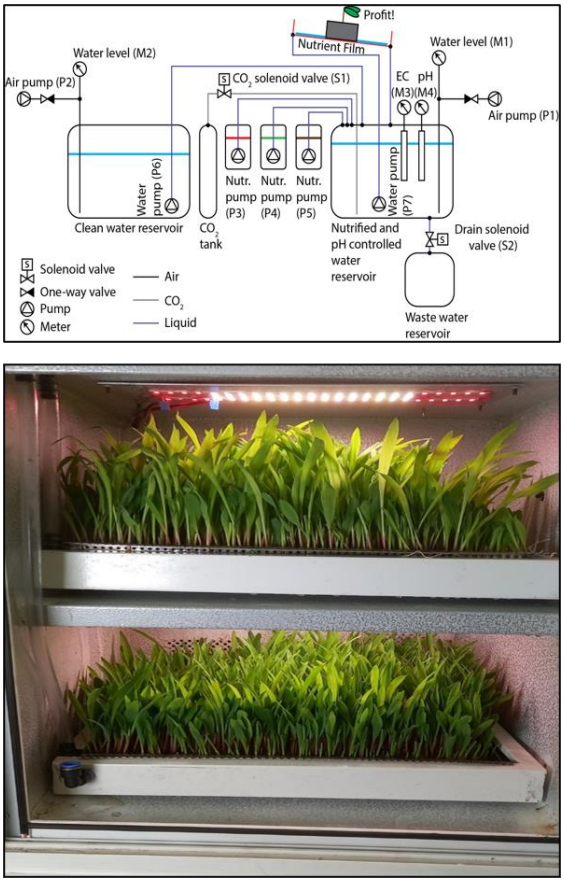

Fig. 2 The electronic part of the nanofarm machine and the NFT system and how to plan for a hydroponic System

Hydroponics has been promoting forage machines for several years [69-72]. According to experts, two decades have passed since such an issue was raised, and if such a method had a technical and economic justification, it would certainly have been exploited on a large scale to address the concerns of farmers in fodder production [69-74]. There is controversy among ranchers and experts about the effectiveness of such an idea, and it is occasionally raised in some circles by publishing an article or news item. The conversion of grain seeds into fodder in the hydroponic system is done in a short period of time (6 to 8 days). During this period, part of the stored seed material is used for germination, rooting and initial growth of the plant, during which there may be no opportunity for compensation

for the plant. Today, also in order to minimize the environmental impact, biodegradable containers such as polylactic acid (PLA) and materials like polycaprolactone (PCL) can be used instead of petroleum-based plastics [67-74]. The second way to grow microgreens in channels or on benches (made of plastic, aluminum, galvanized iron, and wood) of various sizes is by placing the growing medium right inside the channels or on the benches [32-40]. The material and structure of the floors should also be made of strong materials to withstand the weight of the hydroponic fodder trays [36].

3-2- Heat transfer model of nanoform

One of the important challenges of nanoform design is thermal modeling [75-76]. Thermal modeling helps to design and implement controllers correctly. One of the main goals of the control system in nanofarms is to control the temperature of the internal environment of nanofarm. In the study of nanoform heat transfer, various methods of heat transfer, including conduction, convection and radiation are of interest. Heat transfer from the walls, heat transfer inside the nanoform through fan air flow and outside the nanoform through heat exchange with the environment. As it is assumed that the temperature inside the nanoform is constant, the amount of thermal power produced is equal to the amount of transferred thermal power. The amount of thermal energy extracted from the walls is calculated from the following equation.

$$q = kA\frac{T_1 - T_2}{L} \tag{1}$$

In this equation, k is the coefficient of thermal conductivity, L is the thickness of the wall, and A is the surface. The amount of thermal power transferred through displacement is calculated with the following Eq. 2.

$$q = h_1 A(T_{\infty 1} - T_1) \tag{2}$$

In this equation, *h* is the coefficient of heat transfer to the environment, *A* is the effective surface in heat transfer, and *T* is the temperature of the environment, *T* is the temperature of the wall [75]. Also, *q* is the amount of thermal power produced in nanoform.

$$q = h_1 A(T_{\infty 1} - T_1) = kA\frac{T_1 - T_2}{L} = h_2 A(T_2 - T_{\infty 2}) \tag{3}$$

With the method of equivalent thermal resistance and according to the number of walls [74-75].

$$q = \frac{(T_{\infty 1} - T_1)}{R_1} = \frac{(T_1 - T_2)}{R_2} = \frac{(T_2 - T_{\infty 2})}{R_3}$$
$$R_1 = \frac{1}{Ah_1}, R_2 = \frac{1}{Ak}, R_3 = \frac{1}{Ah_2} \tag{4}$$

In this thermal modeling, assuming the availability of thermal conductivity coefficients of the walls and the coefficient of heat transfer between the internal and external environment and the temperature of the environment, the temperature inside the nanoform can be calculated by knowing the produced thermal power [74-76].

4- Conclusion

The use of 202020 fertilizer for forage cultivation by hydroponic method has a good effect on the growth of corn stem length and also causes the seeds to not consume their full length, so the treated sprout has more weight than the control sample [74-76]. It is recommended in hydroponic cultivation to use fertilizer 202020. Cultivation trays should be made

of SS or Al. Hydroponic fodder should be designed with proper spacing because improper spacing causes insufficient exposure to seeds and improper ventilation of moisture and air. The material and structure of the floors should also be made of strong materials to withstand the weight of the hydroponic fodder trays.

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