Middle East Journal of Agriculture Research
ISSN 2077-4605

Volume : 05 | Issue : 02 | April-June | 2016
Pages:161-170

The Sprout Production and Water use Efficiency of some Barley Cultivars under Intensive Hydroponic System

Emam M. S. A.

Central Laboratory for Agricultural Climate, Agricultural Research Centre, Giza, Egypt

Received: 27 February 2016 / Accepted: 28 March 2016 / Publication date: 30 April 2016

ABSTRACT

The experiment was conducted under net house in modern intensive hydroponic system and replicated Three times at January, February and March 2014 in the experimental site of Central Laboratory for Agriculture Climate (CLAC), Agriculture Research Center, Giza, Egypt. The study aimed to evaluate green fodder production and quality of six barley cultivars (Giza 128, Giza 127, Giza 130, Giza 129, Giza 126, and Giza 123) under hydroponic conditions in a randomized complete block design. The vegetative characteristics and quality properties of produced green fodder were recorded.

The results showed that green forage could be produce in 8 days from seeding to harvest using intensive hydroponic technique. The production values of barley sprouts were recorded as follows Giza 127, Giza 128, Giza 129, Giza 123, Giza 130 and Giza 126 which gave (65.5, 62.5 and 62.1), (56.1,53.4 and 52.9), (53.5,51.6 and 51.1), (47.7,45.5 and 45.1), (46.3,44.6 and 44.1) and (43.4,41.7 and 41.3) Kg/m^2, during the growth periods of January, February and March respectively. However, only Giza 127 gave the lowest dry matter (%). It was determined that the dry matter content was decreased with increasing moister content. Giza 127 gave the highest water use efficiency (316.7 Kg/m^3) while the lowest value (211.4 Kg/m^3) recorded by Giza 126. This result support the need to extend sprout production hydroponically under expected climate change impacts compared to conventional culture of Egyptian clover (Berseem).

The study recommended that using barely cultivar Giza 127 for the highest sprout yield production, crude fat, fiber, ash contents and water use efficiency in intensive hydroponic system. With the respect of the animal nutrition needs, the study recommended the use of Giza 123 and Giza 130 regarding to their highest dry matter. For maximizing the yield per area unit, water use efficiency and matching food security needs, the intensive hydroponic system for barely sprout production as a green fodder could be fruitful to achieve these targets.

Keywords: Green forage, fodder, barley cultivars, hydroponic culture, water use efficiency intensive culture and climate change.

Introduction

The use of hydroponic in producing green fodder under Egyptian condition take more attention in the last few years to cover the fodder gab especially under the population increment, food security demands and climate change impacts. The high Egyptian population creates high pressure under the current condition of water scarcity and expected impacts of climate change on agriculture system. Otherwise, that will led to depend more on soilless culture system in agriculture production for increasing the water, fertilizers and area use efficiencies to meet the high demand of food production.

Agriculture was the most critical sector under the global climate change impacts. Natural water resources are affected by global climate change so food production and sustainability are endangered (Falkenmark, 2007). It's expected that the global climate change cause negative impact on the grazing lands in the arid and semi-arid regions (Hoffman and Vogel, 2008). The rainfall is reduced while environmental temperature is increased, so the grassland yields decrease and range and meadow deteriorated over the time. The concept of putting one kilogram of grain into a hydroponic system and producing 6 to 10 kilograms of fresh green sprouts, independent of weather and at any time of year, is of interest by Kruglyakov, 1989.

Hydroponic fodder production is a technique for germinate fodder seeds such as barley, cowpea, sorghum, wheat, maize and etc. to sprout into a high quality, highly nutritious, disease free animal food in a hygienic environment free of chemicals like insecticides, herbicides, fungicides, and artificial growth promoters (Jensen and Malter, 1995; Al-Hashmi, 2008). Fodder produced hydroponically has a short growth period 7-10 days and requires only a small piece of land for production to take place (Mooney, 2005; Cuddeford, 1989).

This process takes place in a very versatile and intensive hydroponic growing unit, where only water and nutrients are used to produce a grass and root combination that is very high in nutrients. This green fodder is

Corresponding Author: Emam M. S. A., Central Laboratory for Agricultural Climate, Agricultural Research Centre, Giza, Egypt
E-mail: mohamedsaad2005@yahoo.com

extremely high in protein and metabolic energy, which is highly digestible by most animals. Research on hydroponically sprouted barley has shown an increase in fresh weight over the sprouting duration as well as changes in dry matter (Peer and Leeson 1985a). The gain in fresh weight has been mainly attributed to imbibition of water constituting up to 80-90% of the fresh weight (Sneath and McIntosh, 2003). Sprouting of grains activate the enzyme performance, increased total protein and changes in amino acid profile, increased sugars, crude fiber, certain vitamins and minerals, but decreased starch and total dry matter (Lorenz, 1980).

The sprouting of barely under net house system recorded the highest values of physical characteristics and chemical analysis compared to sprouting under control cooling room. The economic factor is considered when comparing the high cost of control cooling room and energy needs with the net system (El-Morsy *et al.,* 2013). Germination and sprouting activates enzymes that change the starch, protein, and lipids of the grain into simpler forms, for example, starch changes to sugars. There were some arguments about the sprouting grains for convenience of green forage production in hydroponics system to compensate the feed resources for animals (Rajendra *et al.,* 1998; Tudor *et al.,* 2003). One of the modern techniques that are considered important for better water use efficiency as well as for fodder production is hydroponic culture.

Generally, the seeds are allowed to germinate and grow for about one week when a forage mate made up of the germinated seeds, their interwoven white roots, and the green shoots is obtained (Cuddeford, 1989). The whole product is then fed to the animals and the empty space in the chamber is used to germinate a new set of seeds (Mukhopad, 1994). Green fodder has high feed quality, rich with proteins, fibers, vitamins, and minerals (Bhise *et al.,* 1988; Chung *et al.,* 1989; Lorenz, 1980) with therapeutic effects on animals (Kanauchi *et al.,* 1998; Boue *et al.,* 2003). All these special features of produce green fodder in hydroponic culture, in addition to others make it one of the most important agricultural techniques currently in use for green forage production in many countries especially in arid and semi-arid regions. However, some barley cultivars might differ than others in the forage productivity under hydroponic conditions.

Many different types of small grains such as wheat, oats, corn and legumes can be used in hydroponic systems, barley is the most common. Barley is an important raw material for feed industry and widely used for animal feeding as grain in livestock (whole grain, the form of cracked or pomade, particularly in the breeding season) also green fodder (Yılmaz, 2007). *Chung et al.*, 1989 found that the fiber content increased from 3.75% in un-sprouted barley seed to 6% in 5-day sprouts. Peer and Leeson 1985b found significant losses in dry matter digestibility, which declined progressively during 7 to 8-day growing period nevertheless the digestibility of 4-day old sprouts barley was superior to original grain. However, according to Mansbridge and Gooch 1985 in vitro digestibility of sprouts grown at 6 or 8 days ranged 72-74 percent that were not significantly different.

In a study conducted by Al-Karaki and Al-Hashimi (2010) to compare five forage crops (alfalfa, barley, cowpea, sorghum and wheat) for green fodder production and water use efficiency (WUE) under hydroponic conditions, the results indicated that barley was one of the crops which gave high fodder yield and used water efficiently. However, some barley varieties might differ than others in the forage productivity and WUE under hydroponic conditions. Water use efficiency and quality under hydroponic conditions. It has been reported that about 1.5-2 liters are needed to produce 1 kg of green fodder hydroponically in comparison to 73, 85 ،and 160 liters to produce 1 kg of green fodder of barley ،alfalfa, and Rhodes grass under field conditions ،respectively (Al-Karaki, 2010).

The study aimed to evaluate the potential of some barley cultivars for green fodder production, quality and water use efficiency under intensive hydroponic conditions. The main objectives of this study are localize the know-how of using hydroponic culture in producing green fodder (sprout) in Egypt while investigated the suitable barely cultivar use under hydroponic culture.

Materials and Methods

The experiment carried out at the experimental site, Central Laboratory for Agriculture Climate (CLAC), Agriculture Research Center, Giza, Egypt at January, February and March 2014 located in 4 x 6 m^2 under net house (18 x 40 x 4.5 m). The investigation canceled the work under control cooling chamber regarding to there is no difference between net house and control cool chamber during the cool months (El-Morsy *et al.,* 2013).

Plant material

Six Barely (*Hordeum vulgare* L.) cv. cultivars were evaluated in this study: Giza 128, Giza 127, Giza 130, Giza 129, Giza 126, and Giza 123. The different cultivars seeds were soaked in water separately; with the purpose of eliminate the float materials (straw, wastes and etc.). Then barely seeds were soaked in warm water (40 ºC) containing 0.1% Sodium hypochlorite (5%) for 30 minutes then washed by tap water for 10 minutes. Planting trays also were cleaned and disinfected by using 0.1% Sodium hypochlorite (5%) later on washed by tap water to remove any chemical traces. Three growing cycle during 3 months from January to March 2014 were cultivated through one production cycle for each month 11-18 January, 8-15 February and 8-15 March

2014. Average, minimum and maximum air temperature under the net house was recorded during the different production cycles illustrate in Table 1.

Hydroponic system

Using intensive hydroponic system without inert material or soil for the process of barely germination, during each production cycle (8 days) was done. The intensive hydroponic system constructed by using a steel stand, size 2.10 m X 0.50 m X 1.9 m (L X W X H) equipped containing 6 shelves (30 cm apart shelves) with capacity of 42 polyethylene trays sized 60×30x3 cm (0.18 m^2) 1.8 Kg/tray each (equivalent to about 10 kg/m^2) according to the results obtained by El-Morsy *et al.,* 2013. The hydroponic unit located under white net house during the studied periods for protecting the system, seeds and sprout.

The irrigation of different shelves was designed depending fog irrigation system. The irrigation water was delivered via four foggers (32 l/hour) for each shelf. The fog system automated by using digital timer (2 minutes/hour/24 hours) to control water pumping (water pump 0.5 horse power) from water tank. Black polyethylene tank 1 m^3 was used as water tank. The base of trays was holed to allow drainage of excess water of irrigation. The used water was tap water with free nutrient solution or any additives. The leaching water collected and determined to calculate water consumption.

Sprout Yield characteristics

At the end of experiment (8 days after seeding), the produced barely sprouts (green fodder) was ready for harvesting. Barely shoots and root mats (sprouts) in the trays of different cultivars were harvested and the following data were recorded: total fresh and dry sprouts yield (Kg/m^2). Shoot height (cm), and conversion factor (ratio of produced barely sprouts to the initial planted seed weight (Kg/Kg).

Water Use Efficiency (WUE) and water consumption calculation

The results of water use efficiency and water consumption were calculated depend on:
Standard production area of hydroponic sprout = 60 m2
The number of stand per area = 24 Stands x 6 shelves.
The season of cultivation barely cultivars hydroponically regarding to Egyptian clover season (from October to May) = 7 months = 26 growing sprout hydroponically periods. (National Program for forage crops, 2007)
The water consumption (m^3) and yield (ton) per season of clover was calculated depending on evapotranspiration method and Ministry of Agriculture and Reclaimed lands survey data.
The yield of different barley cultivars = yield of barley cultivar per standard area x 26 growing sprout hydroponically periods.
The water consumption of different barley cultivars (m^3) = Irrigation water – leaching water.
The water use efficiency (WUE) was calculated according to FAO (1982) as follows: The ratio of crop yield (y) to the total amount of irrigation water used in the field for the growth season (IR), WUE (Kg/m^3) = Y (kg)/IR (m^3).

Chemical and quality Analysis

Three samples of each barely sprout (leaves plus roots) cultivar about (500 grams) from each plot were dried at 70 ^oC in an air forced oven for 48 h. Dried sprouts were digested in H_2SO_4 according to the method described by Allen (1974). Total nitrogen of sprouts (%) was determined by Kjeldahl method according to the procedure described by FAO (1980).

Crude protein (CP) was calculated by multiplying N x 5.83 (Merrill and Watt 1973). Ash content was determined by igniting plant samples in a muffle furnace at 550 ^0C for 4 hour (Protherm, PFL 110/10 model). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest *et al.*, (1991) with using sodium sulfide by ANKOM 200 Fiber Analyzer (ANKOM, 2005).

Climatic data during the growing period

Maximum and minimum thermometer was used to measure temperature (model, 5458 Fetcher, NC 28732); the mean temperature has been calculated by dividing the maximum temperature by the minimum one as presented in Table. 1.

Table 1: Max, min and Average temperature from January, February and March 2014 under the net house.

Date	Max	Min	Aver.	Date	Max	Min	Aver.	Date	Max	Min	Aver.
11 Jan.	24.8	8.4	14.1	8 Feb.	24.2	8.6	15.3	8 Mar.	28.4	16	20.4
12 Jan.	24.7	8.8	14.5	9 Feb.	25.7	7.4	15.5	9 Mar.	29	14.1	19.9
13 Jan.	25.1	8.9	15.3	10 Feb.	26.3	8.2	16	10 Mar.	30.9	10.7	18.9
14 Jan.	25.2	11.7	16.5	11 Feb.	27.9	9.4	17.6	11 Mar.	27.7	11.2	18.5
15 Jan.	24.4	10.9	15.7	12 Feb.	28.7	11.7	19.3	12 Mar.	27.1	11	16.7
16 Jan.	25.6	8.2	14.6	13 Feb.	28.4	9.9	17.3	13 Mar.	27.1	10.8	16
17 Jan.	24.1	8.3	14.7	14 Feb.	25.3	11.9	16.9	14 Mar.	32.2	9.3	17.4
18 Jan.	22.5	10.7	13.5	15 Feb.	25	11	16.3	15 Mar.	30.1	7.6	17.1

Experimental Design and Statistical Analysis

Completely randomized blocks design was used with four replicates. Statistical analysis was determined by computer, using SAS program for statistical analysis and data were transformed by the technique described by Box *et al.* (1978). The differences among means for all traits were tested for significance at 5 % level according to the procedure described by Snedicor and Cochran (1981).

The data of the three growing periods were analyzed and presented in this study as an average according to the high similarity results and to avoid the results duplication.

Results and Discussion

The vegetative characteristics of different barley cultivars

Table 2 presented production of different barley cultivars in hydroponic system (Kg/m^2) during the three production cycles. The obtained results indicated that the green barley fodder can be produced in 8 days from planting to harvest using hydroponic technique for tested barley cultivars crops (Giza 128, Giza 127, Giza 130, Giza 129, Giza 126, and Giza 123). The data revealed that the changes of average sprout weight were non-significant until the fourth day of the growing cycle while in the fifth growing day tested cultivars start changed in their weight of sprouts significantly. The change in average sprout weight differs according to the cultivar. The highest average sprout weight value was recorded by Giza 127 in January, February and March (65.5, 62.5 and 62.1 Kg/m^2, respectively) followed by Giza 128 (56.1, 53.4 and 52.9 Kg/m^2, respectively). On the other hand, Giza 126 had the lowest average fresh barley sprout weight (43.4, 41.7 and 41.3 Kg/m^2, respectively). This value is the same to that was reported previously (Shtaya, 2004). Grains of barley gained weight over the 8 days sprouting period as a result of water imbibitions. Bradley and Marulanda (2000) reported that hydroponic green fodder production requires only about 10–20% of the water needed to produce the same amount of crop in soil culture.

Table 2: The production of different barley cultivars in hydroponic system (Kg/m^2) during the growing three period.

The weight of barley sprouts (Kg/m^2)								
Days after sowing								
First growing period (January 2014)								
Cultivar	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Giza 128	10	17.2 a	20.6 a	24.4 a	32.9 b	42.9 b	59.8 b	56.1 b
Giza 127	10	17.3 a	21.1 a	26.8 a	36.3 a	47.5 a	57.4 a	65.5 a
Giza 130	10	17.1 a	19.9 a	23.4 a	28.8 e	36.7 b	43.2 e	46.3 e
Giza 129	10	18.3 a	21.4 a	25.4 a	32.4 c	41.2 c	47.7 c	53.5 c
Giza 126	10	16.7 a	21.9 a	23.2 a	29.4 d	38.0 d	45.2 d	43.4 f
Giza 123	10	16.3 a	18.9 a	22.3 a	27.8 f	34.6 f	42.1 f	47.7 d
Second growing period (February 2014)								
Giza 128	10	17.1 a	20.5 a	24.2 a	31.7 b	39.6 b	48.2 b	53.4 b
Giza 127	10	17.2 a	21.1 a	26.6 a	35.2 a	44.4 a	54.9 a	62.5 a
Giza 130	10	17.0 a	19.9 a	23.2 a	28.1 e	33.9 e	41.6 e	44.6 e
Giza 129	10	18.2 a	16.6 a	25.5 a	31.5 c	38.2 c	46.6 c	51.6 c
Giza 126	10	16.7 a	19.9 a	23.2 a	28.5 d	35.2 d	43.4 d	41.7 f
Giza 123	10	16.3 a	18.6 a	22.1 a	27.0 f	31.1 f	40.3 f	45.5 d
Third growing period (March 2014)								
Giza 128	10	17.0 a	20.4 a	24.0 a	30.1 b	39.2 b	47.5 b	52.9 b
Giza 127	10	16.9 a	20.9 a	26.5 a	33.1 a	44.1 a	54.2 a	62.1 a
Giza 130	10	16.9 a	19.7 a	23.0 a	26.4 c	34.3 d	40.7 e	44.1 e
Giza 129	10	18.1 a	16.6 a	25.2 a	29.8 b	37.7 c	45.9 c	51.1 c
Giza 126	10	16.6 a	19.7 a	23.0 a	27.1 c	34.6 d	42.6 d	41.3 f
Giza 123	10	15.9 a	18.6 a	21.9 a	26.6 c	32.0 f	39.7 f	45.1 d

** Similar letters in each column indicate non-significant at 0.05 levels.*

The average daily increasing ratio of fresh barely sprouts weight during the growing period showed in Fig. 1. The average daily increasing ratio of fresh sprouts weight in general increased about 1.55 times their original pre-steeped weight after first day, 1.18 times after second day, 1.19 times after third day, 1.18 times after fourth day, 1.28 times after the fifth day then the incremental ratio start to go down to record 1.22 times after the sixth day and 1.09 times after seventh day. According to Peer and Leeson, (1985b) fresh weight increased from 1.72 times of the original seed weight, after the first day of sprouting, the white tip of the radical is visible. By the third day, the radical has branched and the blade inside the heath has turned green. After the fourth day of seedling, a green blade has protruded above the sheath and the roots of the kernels have formed a definite mat with other kernels. From the first to the eighth day, the main visible change is the increase in root length and thickness.

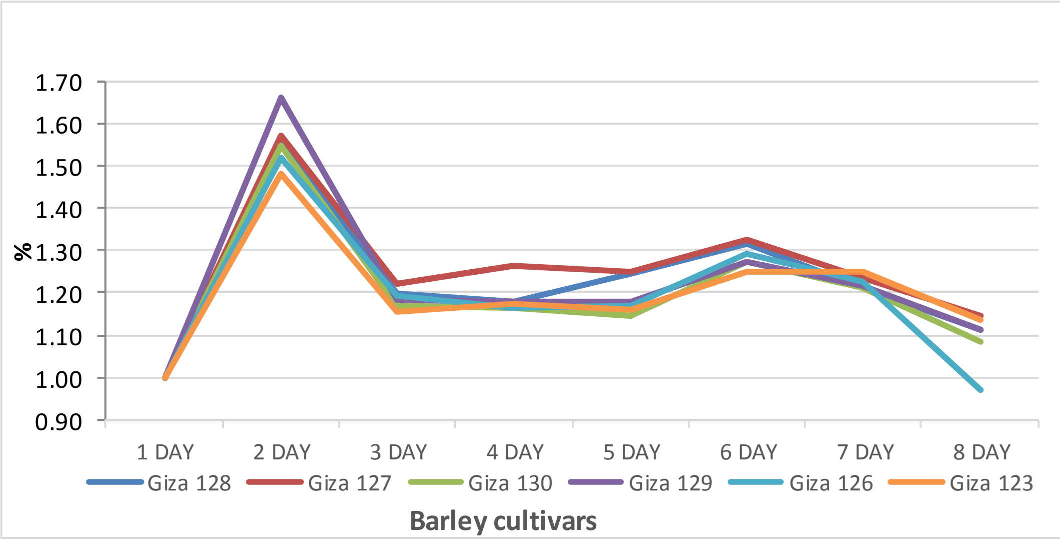

Fig. 1: The average of fresh barely sprouts weight increase / day ratio during the growing period.

Fig. (2) presented the dry matter content % of different barely cultivars and moister content %, the results indicated that increasing moister content led to decreasing dry mater content, the highest dry mater content and the lowest moister content obtained by Giza 127 but the highest moister content and the lowest dry matter content observed by Giza 123 and Giza 130. The moister content of barley green fodder obtained moister content was several times but this increase was due to the large uptake of water during germination of the seeds, resulted in a sharply reducing of dry matter percentage in green fodder. Peer and Leeson, (1985a) found that after sprouting for 1 day, to 5.7 folds after 7 days but a negative relation was found in dry matter content with fresh weight yield. Such low dry matter content would have a limitation effect on intake of green fodder when fed to animals.

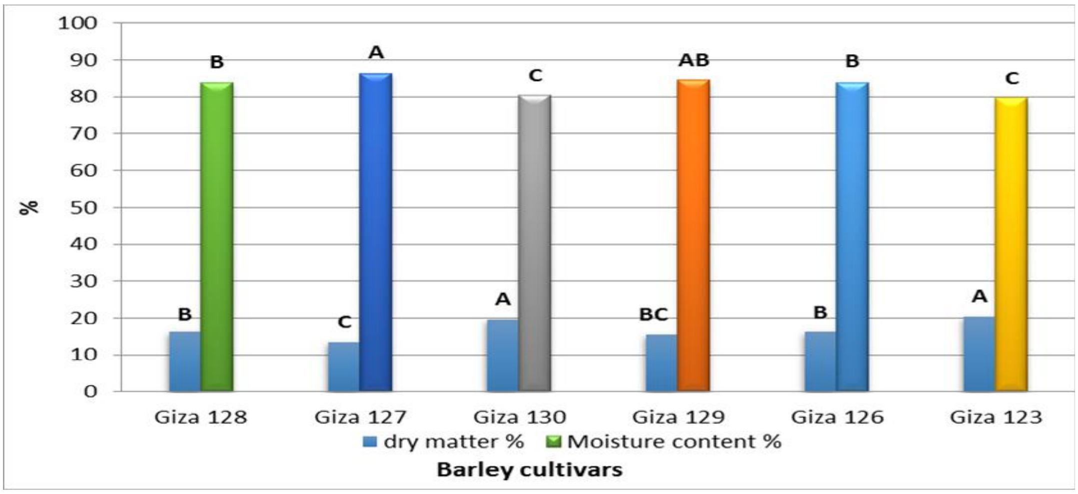

Fig. 2: The humidity and dry matter content % of different barley cultivars in intensive hydroponic system under net house.

Seed soaking leads to the activation of enzymes and solubilisation and digestion of starch stored in the endosperm to simple sugars of the starch stored in the endosperm to simple sugars. This provides substrate for the young developing plant for metabolic activities. These substrates are respired to produce energy, giving off carbon dioxide and water. This loss of carbon dioxide leads to a loss in dry matter. These results were in accordance with those of Morgan *et al.*, (1992) who reported a significant difference in wet weight (WW) and dry weight (DW) of the hydroponic fodder.

The height of barley sprouts ranged from 10 cm for Giza 127 to about 6.2 cm obtained by Giza 123 (Fig. 3). Al-Hashmi (2008) obtained similar values regarding to the sprouts height of hydroponic barley. However, the average sprout heights of barely cultivars showed significant differences among them.

Fresh sprout weight: seeds weight ratio of different cultivars illustrated in Fig. (4). the results indicated that the highest significantly value of fresh sprout: seeds weight ratio (6.7) was recorded by Giza 127 compared to the other five cultivars. The fresh sprout weight: seeds weight ratio ranged from 6.7 to 4.4 (Kg/Kg). Similar results were obtained by Al-Hashmi (2008) and Al-Karaki (2010) they reported that the ratio reached up to 8 times in barley sprouts produced via intensive hydroponic system but under full control system.

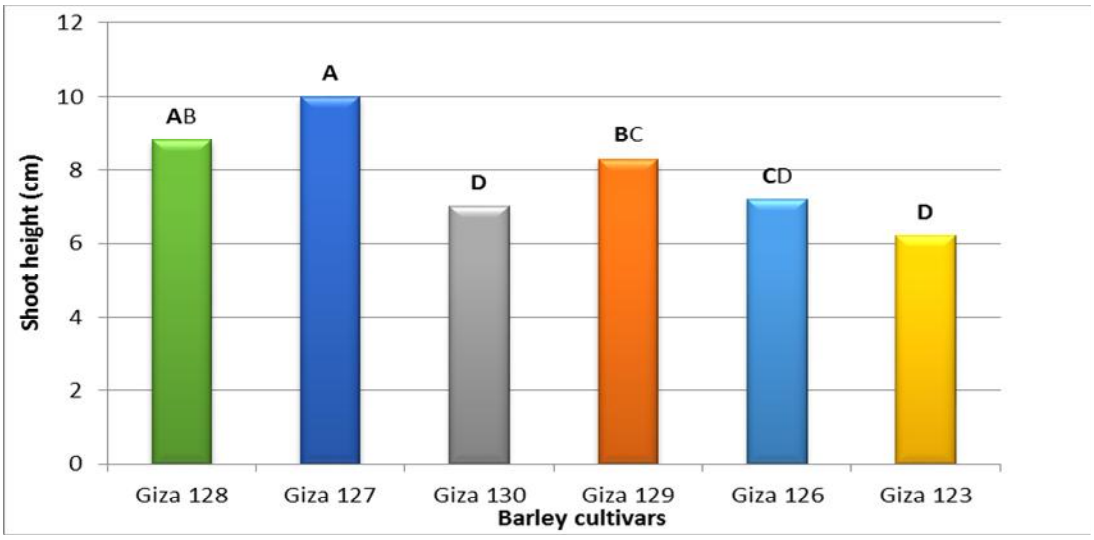

Fig. 3: The shoot height (cm) of different barley cultivars in intensive hydroponic system under net house.

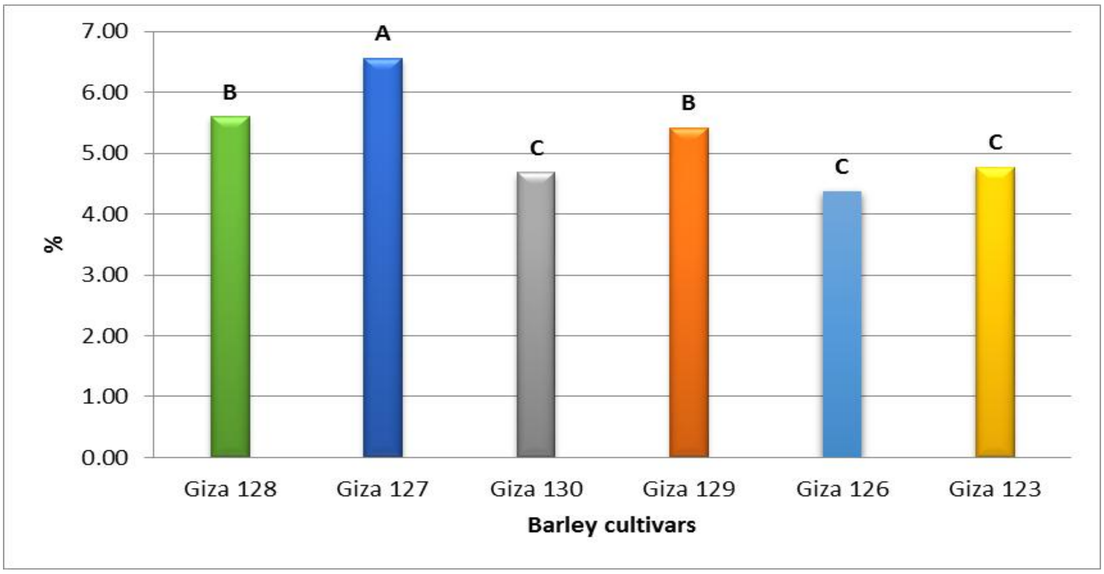

Fig. 4: The average of barley sprout: seeds weight ratio of different barley cultivars.

The Quality characteristics of different barley cultivars

Data in Table 3 presented the effect of barley cultivar on the quality characteristics of produced sprout, the highest values of nitrogen and crude protein contents (2.11 and 13.20 % respectively) were recorded by Giza 129 while there are no significant between Giza 128,127,130 and Giza 126 under the intensive hydroponic system. Giza 123 gave the lowest values of nitrogen and crude protein (1.46 and 9.16 % respectively) as presented in Table 3.

Table 3: The average quality characteristics of different barley's sprout cultivars in intensive hydroponic system.

Cultivar	Nitrogen (%)	Protein %	Crude fat %	Fiber %	Ash %
Giza 128	1.69 ab	9.90 ab	3.91 a	10.64 bc	2.98 b
Giza 127	1.73 ab	10.13 ab	3.82 a	12.43 a	3.43 a
Giza 130	2.13 ab	12.43 ab	3.57 ab	9.39 c	2.27 c
Giza 129	2.26 a	13.20 a	3.34 b	8.13 d	2.37 c
Giza 126	2.07 ab	12.12 ab	3.27 b	12.07 a	2.58 bc
Giza 123	1.57 b	9.16 b	2.72 c	11.66 ab	3.00 b

** Similar letters indicate non-significant at 0.05 levels.*

The crude protein obtained in this study was comparable with those reported by Al-Ajmi *et al.*, 2009 who found about 14 percent of crude protein in hydroponically barley green fodder. Morgan *et al.*, 1992 reported that crude protein content was increased from 10.8 at day 4 to 14.9 percent at day 8 in hydroponically barley fodder that were in accordance with our findings. Sneath and McIntosh 2003 evaluated the composition of sprouted barley and reported that the crude protein ranged from 11.38 to 24 percent. However, protein content may be influenced as a result of the nitrogen supplementation and other nutrients changes in sprouting grains. Morgan *et al.*, 1992 and Peer and Leeson (1985b) reported that protein content of green fodder is similar to barley grain, where the crude protein was higher in the green barley because of the relative decrease of other components.

Concerning the effect of barley cultivar on the dry matter, the data in Table (3) illustrate that Giza 127 had the highest fiber and ash contents (%) (12.43 and 3.43 respectively) and Giza 130 recorded the lowest results of fiber and ash contents.

The obtained results of crude fat (%) of different barely sprout cultivars, the results indicated that the highest value of crude fat (3.91 and 3.82) was recorded by Giza 128 and Giza 127 respectively and Giza 130 recorded the lowest results of (2.72) of crude fat as presented in Table 3.

Morgan *et al.* (1992) found that ash content of sprouts increased from day 4 corresponding with the extension of the root, which allowed mineral uptake. They reported that Ash content changed from 2.1 in original seed (barley) to 3.1 day 6 that were relatively similar to our findings.

The water use efficiency of different barley cultivars

Data in Table 4 show the comparison between average seasonal productivity of Egyptian clover (Berseem) National Program for forage crops, 2007, (during the last five years according to the Ministry of Agriculture statistics) and sprout production from different barley cultivars.

Table 4: The sprout production and WUE of different barley cultivars

Crop	Area (m^2)	Yield / season (ton)	Water consumption (m^3)	Yield (Kg/m2)	WUE (Kg/m^3)
Egy. clover	4200.0	70.0	4000.0	16.7	17.5
Giza 128	60.0	220.1	814.4	3669.1	270.3 b
Giza 127	60.0	257.9	814.4	4298.1	316.7 a
Giza 130	60.0	184.0	814.4	3066.3	225.9 c
Giza 129	60.0	213.1	814.4	3551.2	261.6 b
Giza 126	60.0	172.2	814.4	2869.8	211.4 c
Giza 123	60.0	187.5	814.4	3125.3	230.3 c

It is clear that the productivity of area unit under the hydroponics technique significantly higher than the productivity of clover under the conventional cultivation. The seasonal water consumption of conventional clover cultivation was very high compared producing barley green fodder by using hydroponics technique. The water use efficiency of hydroponics system for producing green barley fodder was significantly higher for all tested barley cultivars than the conventional clover production. Giza 127 gave the highest water use efficiency compared to the other barley cultivars followed by Giza 128; while the lowest WUE was obtained by Giza126 Barley cultivar. The same results was found by Ghazi and Al-Hashimi, (2012) who found that hydroponics green fodder has higher water productivity than the conventional production of green fodder. Water was one of the basic requirements for seed germination and seedling growth as it was essential for enzyme activation, reserve storage breakdown, translocation, and use in seed germination and seedling growth (Copeland and Mcdonald 1995). Hydroponically produced fodder was found to enhance the efficiency of water use (WUE). Bradley and Marulanda (2000) reported that hydroponic green fodder production technique requires only about 10–20% of the water needed to produce the same amount of crop in soil culture. While (Tudor *et al.,* 2003) reported that only 3–5% of water is needed to produce the same amount of fodder in comparison to that produced under field conditions. Ghazi and Al-Hashimi, (2012) concluded that barley and cowpea crops were found to use water more efficiently than the other tested crops when used only 1.55 and 1.58m3 water, respectively, to produce 1ton of hydroponic green fodder in comparison to 1.71, 1.80, and 1.92m³ water in sorghum, wheat, and alfalfa, respectively.

Water use efficiency (WUE) of only 14 and 12 Kg forage fresh matter/m³ water for field irrigated barley and alfalfa, respectively, compared to that of 645 and 521 kg fresh matter/m³ water in barley and alfalfa obtained in hydroponic system, respectively reported by Al-Krari and Al-Momani (2011).

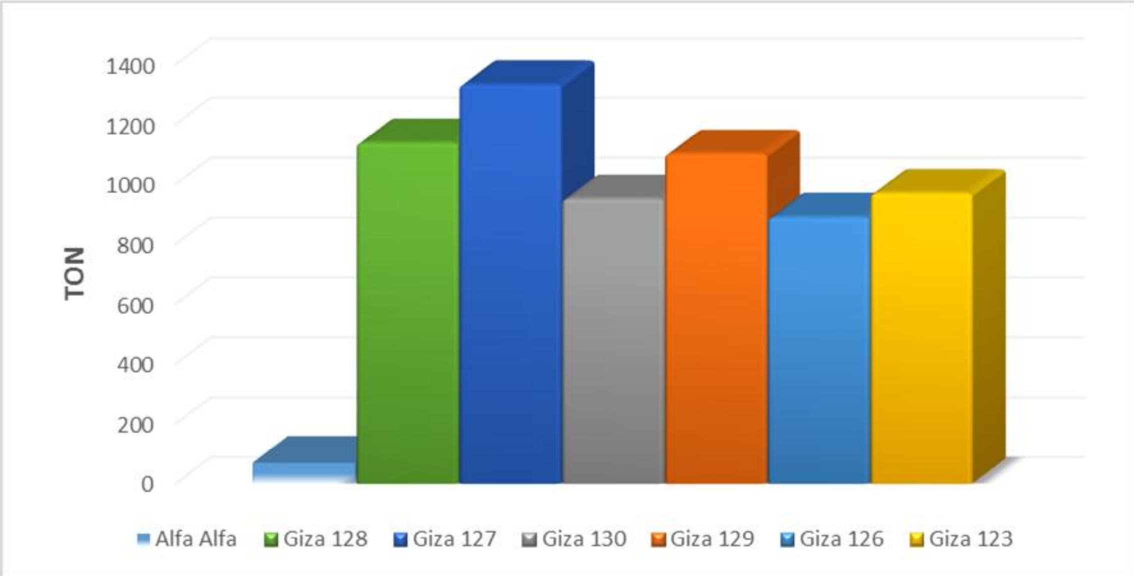

Fig. 5: The expected sprout yield of different barely cultivars in hydroponic system in case of water consumption 4000 m^2.

Conclusions

The gap between the need and the available of animal products could be satisfied by using intensive hydroponic system for producing barely sprouts as green forage in short period (8 days – 3.5 production cycles /month) and at the same time offer effective adaptation option for the negative impacts of climate change risks related to water and soil availabilities. The recommendation of this study that barley green sprout production by using Giza 127 barely cultivar while with respect the animal nutrition needs Giza 123 and Giza 130 considered the best option because Giza 123 and Giza 130 produced the highest dry matter, protein contents and fiber content. Such low dry matter content would have a limitation effect on intake of green fodder when fed to animals.

Barley sprouts was considered the best choice that can be used for production of hydroponic green fodder with less water consumption and land use. Barely seeds are mostly available in the market at lower price than others which reduce the cost of hydroponic fodder production.

More studies need to investigate the real water use efficiency of producing barely seeds under expected climate change impacts, carbon foot print, water foot print and energy use.

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