Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 2, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

EFFECT OF LIGHT INTENSITY ON DRY MATTER ACCUMULATION OF BARLEY FODDER IN A VERTICAL FARMING GROWTH MODULE

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Abstract

Considering the increase in forage requirement in livestock, lack of same quality products throughout the year, fertilizer and chemical costs, insufficient water resources and environmental restrictions caused by climate change; studies providing solutions for forage production are getting more attention. Vertical farming which is the method of growing crops in vertically stacked layers under controlled environment is one of the promising techniques to protect environmental resources, provide continuous and sustainable forage production. Effect of light intensity on dry matter accumulation and physiology of barley fodder in a vertical farming growth module was investigated in the present study. The experiment was consisted of eight micro chambers represented the growth modules of vertical farming system placed in fully controlled growth chamber. There were four different light intensity, two repetitions each of 40, 100, 160 and 220 µmol/m^2.s. Plants were sampled every day during all experimental period (8 days). Leaf area and fresh/dry weight of root and leaves were determined. Furthermore, chlorophyll a, chlorophyll b and carotenoid contents of leaves were analyzed. Module based water use of each light treatments were calculated. In line with the results, higher light intensity was found to affect the dry matter accumulation positively; since the physiological properties of barley fodder growing under 160 and 220 µmol/m^2.s. light intensity are almost the same, it is recommended to use 160 µmol/m^2.s. light intensity in terms of energy saving. Based on the data obtained from the present micro-level lab-scale study revealed that the effect of factors such as temperature, humidity, water use and seeding density should also be examined in order to provide the best growing conditions for the future studies.

Key words*: barley fodder, growth parameters, light intensity, vertical farming.*

INTRODUCTION

Undoubtedly, livestock industry is one of the important sectors affected by changing climate conditions. Considering the increase in forage requirement in livestock, lack of same quality products throughout the year, economical reasons, insufficient water resources and extreme weather conditions caused by climate change; studies providing solutions for forage production are getting more attention (Kumar, Mathur, Karnani, Choudhary & Deepika, 2018).

Nowadays the majority of the forage needed is supplying by maize silage (Acosta Aragón, Jatkauskas, & Vrotniakiene, 2012; Şahin & Zaman, 2010). In addition to the hungar and food security problem posed by organizations such as FAO (2019) and European Union (2019), 43% of wheat and maize, which have an important place in human nutrition, are used for animal feeding (Germer et al., 2011); thus alternative feed sources will play an important role both in obviation the forage shortage in livestock and ensuring food security. At this point, the use of barley fodder as forage has recently been a matter of debate. Therefore, studies about this subject have gained speed (Del Castillo, Del Carmen Moreno Pérez, Magaña & Gómez, 2013; Dung, Godwin & Nolan, 2010; Gebremedhin, Deasi & Mayekar, 2015; Islam, Nabilah & Md Ali, 2016; Karaşahin, 2017)

Taking into account the advantages of vertical farming, growing barley fodder in these systems will increase the yield and reduce the impact of agriculture on the environmental burden (Banerjee & Adenaeuer, 2014; Despommier, 2009; Despommier & Ellingsen, 2008). On the other hand, this yield is closely related to environmental conditions such as light intensity, temperature, humudity and amount of carbon dioxide received by the plant.

Light which an important component for the success of vertical farming systems, is provided artificially in these systems (Al-Kodmany, 2018). The light intensity used in in-door

systems is generally between 50-200 µmol/m^2.s and the lighting time is between 18-20 hours (Kalantari, Mohd Tahir, Mahmoudi Lahijani, Kalantari, 2017).

Physical energy from the sun or artificial light is converted into chemical food energy by photosynthesis by plants containing chloroplasts (Kacar, Katkat & Öztürk, 2013). Light is a crucial source to complete growth and development in the plant. Although the general opinion is that as the light intensity increases, the rate of photosynthesis increases, this does not apply to all situations. Photosynthesis rate can be limited by other factors (Kadioğlu, 2016). Therefore, these conditions need to be optimized optimally to save more energy by using less energy.

The aim of this study, thus, investigate the effect of light intensity on dry matter accumulation and physiology of barley fodder in a vertical farming growth module.

MATERIALS AND METHODS

A micro chamber experiment was carried out in Department of Field Crops, Ege University, Turkey. The experiment was consisted of eight micro chambers represented the growth modules of vertical farming system placed in fully controlled growth chamber. There were four different light intensities (40, 100, 160 and 220 µmol/m^2.s) and two replications. Each pots contained 16.8 g seeds of the barley (*cv.* Lord, *Hordeum vulgare* L.) and these were germinated in micro chambers for eight days and treated 20 hours light during each day. In this process, other environmental conditions such as temperature (25°C) and relative humidity (70%) were kept constant. The pots were weighed in everyday in order to estimate evapotranspiration and were irrigated as considering to water loss.

The barley sprouts were sampled in every day during all experimental period (8 days). The sampled barley sprouts were separated as leaf and root. The leaves and roots were weighed to calculate fresh weights and then leaf area of each pots were estimated by help of digital imaging based on pixel counting method. Furthermore, dry weights of leaves and roots were determined by drying in 105°C oven in a day. Chlorophyll a, chlorophyll b and carotenoid analysis were performed according to Arnon (1949) and Jayaraman (1988) by using Cary 50 brand UV/VIS spectrophotometer.

Statistical analyses were made using the Excel program and the differences between the values were grouped according to the LSD test comparison method.

RESULTS AND DISCUSSIONS

Despite the plant germination and increased fresh weight, there was almost no change in dry matter (Figure 1a). For this reason, the dry matter rate has decreases day by day (Sneath & Mclntosh, 2003; Fazaeli, Golmohammadi, Tabatabayee & Asghari-Tabrizi, 2012). In addition, although the amount of dry matter is high at 160 and 220 µmol/m^2.s light, the difference is very small (Figure 1). There was no significant increase in dry matter from the first day to the 8th day. In contrast, evapotranspiration increases day by day in direct proportion to the intensity of the light (Figure 1b). Photosynthesis starts with the formation of chloroplasts, but since the harvest cycle is short, dry matter accumulation is very low (Dung, Godwin & Nolan, 2010). The water content increased by 72-78% in the form of inverse proportion for high light intensity and low light intensity (Figure 1c). Karaşahin (2017) concluded that low light intensity has less water content. This data does not match our study.

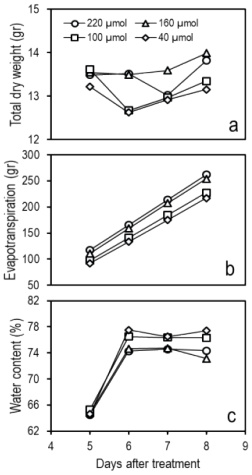

Figure 1. Changes in the dry matter, evapotranspiration and water content of the barley plant during the application of different light intensity

As the light intensity decreases, the leaf area of the barley increases (Figure 2a). If the light intensity is not at the desired level, the plants expand the leaf areas and send less photosynthesis products and root development slows down (Kacar, Katkat & Öztürk, 2013). Total chlorophyll and carotenoid amount in barley grown under 220 µmol/m^2.s light intensity was higher than barley grown in other light intensities (Figure 2c, d).

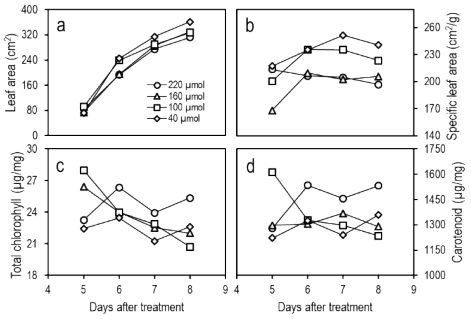

Figure 2. Changes in the leaf area, specific leaf area, amount of total chlorophyll and carotenoid the barley plant during the application of different light intensity

From the general framework, an inverse relationship was found between the light intensity and the specific leaf area, and between the specific leaf area and evapotranspiration (Figure 3).

A positive correlation was determined between evapotranspiration and total dry matter (Figure 4). Similarly, a positive correlation was determined between total chlorophyll and light intensity, and between carotenoid amount and light intensity (Figure 3).

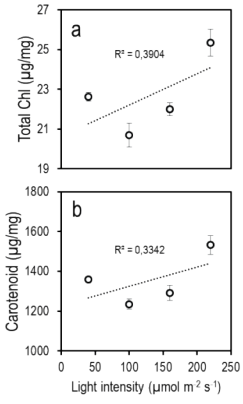

Figure 3. Correlation between total chlorophyll and light intensity, and between carotenoid and light intensity

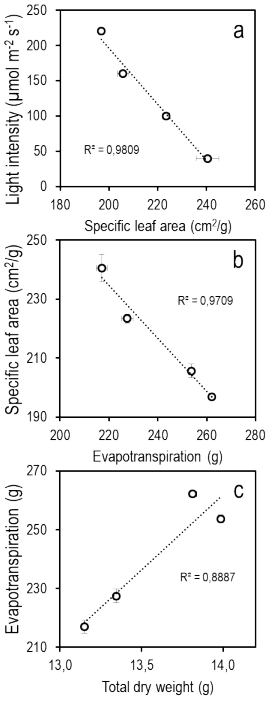

Figure 4. Correlation, between light intensity and specific leaf area, between specific leaf area and evapotranspiration, between evapotranspiration and total dry matter

CONCLUSIONS

The main aim of the study was to determine the effect of different light intensity on dry matter accumulation and physiology of barley fodder, which will be grown in the vertical farming growth module. In this context, a slight increase in the luminous intensity of 160 and 220 µmol/m^2.s. was observed in the accumulation of dry matter. On the other hand, this dry matter content remained almost the same as on the first day. It can be said that the plant almost does not photosynthesize or the rate of photosynthesis is very low. Despite the increase in total chlorophyll, it is recommended to conduct studies to determine the process in which photosynthesis accelerates since the dry matter does not increase almost compared to the first day. In addition, studies aimed at optimizing environmental factors such as irrigation, seed frequency, humidity, and temperature and increasing the dry matter content are thought to be important for the future of barley feed.

There is almost no difference between dry matter and other physiological contents of barley under light intensity of 160 and 220 µmol/m^2.s. For this reason, it is recommended to use 160 µmol/m^2.s light intensity in terms of energy saving.

ACKNOWLEDGEMENTS

The seeds of barley were supplied by Tareks A.Ş. Thanks for this.

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