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AN INNOVATIVE APPROACH TO PRODUCE FORAGE CROPS: BARLEY FODDER IN VERTICAL FARMING SYSTEM

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Abstract

The rapid growth of the world`s population, limited natural resources and environmental challenges caused by climate change have had brought up global food security to the agenda. Scientific researches and new practices considering sustainable food production and efficient use of natural resources are getting more attention during last decades all around the world. Furthermore, advanced technological applications that enable new agricultural production systems such as vertical farm have been starting to emerge to provide a solution on this issue. 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 plant production. Applications of vertical farming have already experienced in many countries such as Japan, Singapore, England, USA, Netherlands and the vertical agricultural market is expected to increase by 25% by 2024 to reach 11.4 billion Euro. Plant groups that are widely grown with vertical farming system are mostly; carrot, radish, potato, tomato, pepper, pea, cabbage, spinach, lettuce and strawberries. Although, cereal grain production in the vertical systems is not economically profitable today, considering remarkable increase in demands on forage crops, barley fodder production seems to have great potential for vertical farming systems. The benefits of the system such as less water use (about 90%), no herbicides, pesticides and fertilizer application relative to conventional production would be more pronounced for barley fodder in vertical system comparison to other conventional forage crops production systems. In this review, potential of barley fodder production in vertical farming system was discussed.

***Key words**: barley fodder, sustainable agriculture, vertical farming.*

INTRODUCTION

As stated by the United Nations (2017), the world population, which is currently about 8 billion, is expected to be 9.8 billion in 2050. In addition to limited natural resources such as agricultural land and water, environmental challenges caused by global climate change have increased the interest on global food security. According to the United Nations Food and Agriculture Organization (FAO) report, the most urgent problem faced with increasing needs on safe, adequate and appropriate food supply for the growing population (Besthorn, 2013).

Within the same report, it is underlined that, by maintaining existing agricultural practices and even with the best efforts in sustainable land use, there will not be enough space to meet the world's increasing food needs. Therefore problems such as climate change and drought and extreme weather events that are rapidly increasing their impact reveal that agricultural resources should be used more effectively (Jia, 2019).

Totally, 70% of the clean water in the world is used for irrigation in agriculture.

Predictions indicate that water scarcity will be inevitable especially in the regions where the population is dense as a result of the continued use of clean water in the current situation (Despommier, 2009).

In this context, research and applications on implementation of developing technologies and technological equipments, which are becoming accessible, in order to efficient use of resources in agriculture and production of environmentally friendly and sustainable foods are increasing rapidly (Jia, 2019).

Beside, widespread use of technological applications integrated into existing agricultural systems such as agricultural machine control systems, equipment automations, remote sensing methods, drone use, agricultural information system, farmer portal and electronic crowning, advanced technological applications which offer a different agricultural production system, such as vertical farming, have also begun to develop.

Vertical farming is an alternative method to efficient use of resources (e.g. 70-80% less water) to achieve much more efficient use of unit area than traditional agriculture, to ignore seasonal effects, and to remove substances such as herbicides and pesticides. Thus, it has promising potential to provide an environmental friendly and sustainable agricultural production (Despommier, 2013).

On the other hand, one of the most important agricultural activities affected by environmental restrictions such as limited resources and climate change is livestock production. High quality green feed should be provided to animals regularly for sustainable livestock production. However, despite the increase in animal husbandry, the decrease in land in forage production, insufficient water resources, inability to find the same quality product throughout the year, and input costs such as fertilizer and diesel fuel are among the biggest obstacle in production (Gebremedhin et al., 2015; Rajesh et al., 2018). Therefore, barley fodder production in vertical farming system using with advanced technology could be accepted as a future solution to provide sustainable and continues feed to livestock industry.

In this review, vertical farming system, which offers a different production technique against traditional agriculture and production of barley fodder potentially seen in livestock forage problem in vertical farming system, has been examined within the conceptual framework. It has been aimed to assist in the future studies on this subject by making national and international literature reviews about the subject.

Vertical Farming

The idea of vertical farming is based on the Hanging Gardens of Babylon in 600 BC (Despommier, 2014). On the other hand, the concept of vertical farming in its current sense was introduced in 1999 by an American professor of public health and microbiology, Dickson Despommier and his students, at the University of Columbia.

The vertical farming system is based on the principle of growing plants with low agricultural input, using the technological elements and stacking them vertically, and it is presented as an important potential by different disciplines such as agricultural experts and city planners (Despommier, 2009). It is also thought to produce concrete results that will contribute to food safety in the future (Besthorn, 2013).

Vertical farming types appear in three ways as roofs of buildings, multi-storey buildings and medium sized facilities according to the production target (Al-Kodmany, 2018). The vertical farms already exist and active are generally medium size enterprises. The success of these medium-sized enterprises will form the basis of more visionary multi-storey vertical farming systems that will be established in the future (Despommier, 2014).

Vertical farming promises to offer best growing conditions to plant using with technological equipments during the processes from seeding to harvest. Therefore, factors such as light, humidity, temperature and carbon dioxide should be optimized according to plant species (Banerjee & Adenaeuer, 2014). For that reason, fully controlled indoor systems instead of open or semi-open facilities are recommended to obtain satisfactory product amount and quality.

Currently, commercial enterprises investing on vertical farming systems have been rapidly emerging in America, China, Japan, Singapore, Italy, the Netherlands, England, Jordan, South Korea, Saudi Arabia, the United Arab Emirates and Canada (Besthorn, 2013). Accordingly, the vertical farming global market is expected to increase by 25% by 2024 to reach around 11.5 billion Euros (Askew, 2019).

Why Vertical Farming?

The increasing demand for agricultural products over the years has been generally met by expanding cultivated areas (FAO, 2011). Given that traditional agricultural production is limited by land availability and production intensity, land per capita has been decreasing day by day due to rapidly increasing population, and as a result, approximately one billion people are malnourished especially in developing countries (Germer et al., 2011).

Traditional farming techniques, excessive use of water and unsustainable soil management, chemical uses, contamination of natural water resources and released greenhouse gases harm the environment in a way that will weaken future food production. Moreover, deforestation for agricultural production, extracting water from lakes and rivers greatly damage biodiversity (Godfray et al., 2014).

From this point of view, the solution is not only to increase food production, but also to supply sustainability by increasing agricultural production in harmony with the environment (Godfray et al., 2014).

Agronomists and other disciplines have a great responsibility to about ensuring the sustainability, to use resources most efficiently and to use new methods and technologies to protect the ecosystem (Germer et al., 2011). In this context, adopting new technologies and using them in agricultural activities will be the key solution to ensuring a sustainable production (Hakkim et al., 2016).

Undoubtedly, a single technological strategy will not be enough to solve the ever increasing food supply, but it is an important step to be taken in this regard. Considering the changing climate, the restriction of other natural resources, especially water, and the harm of fossil fuels, the need for a rapid transition is rather than behaving optimistically. At this point, vertical farming is one of the most promising solution to adapt new technologies to agricultural system with its numerous opportunities (Godfray et al., 2010).

Opportunities and Curiosities Offered by Vertical Farming

Vertical farming provides maximum yield per square meter, and year-round production without being affected by climatic conditions (Despommier, 2013). Considering that the economy of developing countries was damaged by crop and livestock production worth 96 billion dollars due to the natural disasters experienced between 2005 and 2015 with the effect of changing climate conditions (FAO, 2018), importance of an isolated production system from the environmental conditions could be better understood. However, unlike growing conditions in field, a well-designed vertical farming systems can minimize or even eliminate the risk of various harmful pests and weeds beside other naturel disasters (Despommier, 2009).

On the other hand nitrogen and phosphorus which are excessively used in crop production do not leak into natural water sources and environmental burden is reduced, as forest areas will not need to be converted into agricultural land (Germer et al., 2011).

Furthermore, vertical farming systems save up to 95% water use compared to the traditional agriculture systems. In addition, storage risks and costs of agricultural products are limited in this system since it provides continuous production.

Besides to these advantages of vertical farming, many uncertainties are concerned about this new production system (Epting, 2016). For instance, installation costs and energy requirement (lighting, heating, cooling etc.) of the system are still under discussion. For this purpose, an economic analysis performed with simulated 37-storey vertical agriculture centers (Banerjee & Adenaeuer, 2014). The authors suggested that vertical agricultural production systems are still profitable as all the costs are considered. However they also stated that the real systems should be evaluated instead of the simulations to conclude. Although limited researches have been published on economic analysis of vertical farming systems, at least many of processes and productivity of vertical farming system are still open to improvement from the economical point of view.

Another discussion point on vertical farming systems is its effects on environment. Al-Chalabi (2015) found that lettuce grown in vertical agriculture system has higher carbon footprint than lettuce produced in traditional system. However, he also stated that using renewable energy sources in the system could be changed the results other way around. Although several advantages of the system are predicted, further studies have to be performed from the technical, environmental and economic aspects.

Barley fodder in vertical farming system

Animal feed production is one of the important agricultural activities that affect food safety and environment in the face of changing climate and increasing population. Totally 33 million cattle were raised in the USA in 2003 and millions of hectares of forest were damaged to produce cereals to feed these animals (Despommier & Ellingsen, 2008). On the other hand approximately 43% of the wheat and maize products in the world are used for animal feed. Therefore, decreasing feed demand has an remarkable importance to struggle with food safety problem (Germer et al., 2011). From this point of view, alternative high quality forage sources have great importance to reduce the constraint on products such as wheat and maize which are mainly needed for human nutrition.

Taking into account that livestock is an important source as income of rural community especially in developing countries, economic profitability and quality of forage sources both play crucial role in decision mechanism (Godfray & Garnett, 2014). For these regions, providing forage, especially in winter period is one of the most important restricting factor for livestock industry beside negative effects of changing climatic conditions. Because of these limiting factors, poor quality feed sources such as straw are used (Kılıç, 2016). Consequently, increasing proportion of low quality feeds in animal diet leads several health problem and reduces productivity (Godfray & Garnett, 2014). From this point of view, using barley fodder as forage is an important topic of argument.

The plant groups that are widely grown with vertical farming system today are mostly carrots, radishes, potatoes, tomatoes, peppers, peas, cabbage, spinach, lettuce and strawberries (Şahin & Kendirli, 2016). On the other hand producing grain crops in such systems currently seems not economic (Hughes, 2018). However, considering deficit in livestock feed (30 million tons in Turkey according to do Özkan & Demirbağ, 2016) and environmental restrictions, using vertical systems have also become a remarkable option for this purpose. Beside other forage crops, barley fodder production in vertical systems has specific advantages because of vigor of barley seeds, content of the product and environmental requirements of the plant.

Several studies have been reported on growth and quality of barley in fodder production systems. Most of the studies indicated that barley fodder reach highest nutrition value in 7 days after seeding (Akbağ et al., 2015). After the first week of the growth, decreasing energy and organic matter contents of the product were observed (Fazaeli et al., 2012). Considering several studies, fresh barley fodder weight increases to 20-30 kg/m^2 until 7 days after seeding under controlled environment (Al-Karaki & Al-Hashimi, 2012; Del Castillo et al., 2013; Dung et al., 2010; Fazaeli et al., 2012). According to these findings, production amount of barley fodder in a 0.1 ha vertical system consisting of 10 layers (52 growth period) reaches 10.400-15.600 ton fresh fodder per year. Considering maize silage production in a same size of land and period [approx. 5 tons in Turkey (TUIK, 2018)], these results are perceived quite tempting although several points such as quality, water content, energy content etc. of end products and inputs of the system are still under discussion.

However, environmental benefits of the vertical system are better revealed. Beside no-chemical use in vertical barley fodder production, 95-97% of water saves if irrigation water regain by suitable drainage system (Ajmi et al., 2009; Karaşahin, 2014).

CONCLUSIONS

In general, a vertical farming facility to be established is expected to be affordable, operable, sustainable and reliable (Kalantari et al., 2017). In this context, when the researches, studies and inferences made in the literature are evaluated. Barley fodder, which will be produced as forage in the vertical farming system, has an significant potential in reducing the negative impact of agriculture on environment and ensuring food safety by using resources such as water and soil in the most efficient way. On the other hand, the efficiency and cost level of the system to be installed is directly related to the optimization of growing conditions such as temperature, humidity, seed frequency, water and energy requirements of barley fodder. Consequently, further studies on technical, environmental and economic aspects of the issue should be conducted.

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