Journal of Medicinal Plants and By-products (2020) 1: 91- 99

Original Article

Production of Some Medicinal Plants in Aeroponic System

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Article History: Received: 21 October 2019/Accepted in revised form: 24 February 2020

Abstract

In other to study the effect of the production system (aeroponic and soil production system), an experiment was conducted based on a completely randomized design with five replication. In this study plants were obtained from seed culture (*Cichorium*, *Withania* and *Echinacea*) in pot for 1 month in greenhouse and then, uniform plants (20 cm height, approximately) were transferred to aeroponic system and soil. The plants were harvested after six months and their vegetative traits and root characteristic were measured. The results indicated that the effects of production system were significant in terms of plant height, root length, number of leaves, shoot and root fresh and dry weights and photosynthetic pigments. The result showed that aeroponic system in comparison with soil system has produced the highest of leaf number, root length, plant height, root and shoot dry weight, root and shoot fresh weight and photosynthetic pigments. It can be concluded that aeoponic systems could be used for production of *Cichorium, Echinacea* and *Withania* under greenhouse.

Keywords: Aeroponic system, Chicory, Echinacea, Morphologic traits, Withania.

Introduction

Production of some of plant in controlled environments (CE) provides opportunities for improving the quality, purity, consistency, bioactivity, and biomass production of the raw material [1]. The aeroponic system culture is an alternative of the soil-less culture method in growth-controlled environments. The underground organs are enclosed in a dark chamber and supplied with a solution of mineral nutrients with a mist device. Aeroponic system optimizes root aeration, which a major factor is leading to a yield increase as compared to classical hydroponics [2]. Other advantages have been including the recirculation of nutrient solution, a limited amount of water used, good monitoring of nutrients. This technique has been applied successfully for the production of different plants [3,4]. Harvesting in aeroponics is convenient, clean, and allows a greater size control by repeated harvesting [5]. Aeroponics optimizes aeration of roots, which is a main factor leading to increasing plant yield as compared to common hydroponics systems and also planting in soil [6]. The production of root in medicinal plant is labor and cost intensive, because of the necessity of hand hoeing by workers as well as the time and energy consuming for harvest and drying of the roots [7].

Whereas there has been extensive use of aeroponics in studies related to plant physiology, its methods have been applied less than hydroponic ones commercially [8]. That being said, aeroponics has seen a rise in its application in the cultivation of many products including lettuce, cucumber, melon, tomato, herbs, potato, and flowers and especially root crops [9,10].

Other uses of aeroponics have also been described: as a system for the production of high-value crops, such as great burdock (*Arctium lappa* L.) [11], ginger (*Zingiber officinale* Roscoe) [12], and medicinal crops, such as *Urticadioica* L. and *Anemopsis californica* (Nutt.) Hook. & Arn. [1] and saffron (*Crocus sativus* L.) [13]; as the cultivation method for herbs like valerian (*Valeriana officinalis* L.), used to produce essential oils [14] and as a quick and cost-effective method for root induction and clonal propagation of three medicinal plant sat risk of extinction [15].

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According to previous research, it is clear that, by fully exposing the plant to the oxygen content in the air, aeroponics improves its growth [9]. Main factors affecting the plant access to oxygen are the size of droplets and how often the roots are provided with the nutrient solution [16]. Whereas smaller droplets provide more access to oxygen, if they are too small, they result in too much root hair and the absence of a lateral root system needed for plant growth [10].

The therapeutic use of medicinal plants such as *Echinacea, Cichorium* and *Withania* has gained widespread acceptance in many countries in the last two decades. Chicory (*Cichorium intybus* L.) is a member of the Asteraceae family. According to Vavilov [17] the species originates from the Mediterranean region. *C. intybusis* a medicinal plant used to promote apetite and digestion, contains bittertastingsesquiterpene lactones. Roots of the plant elaborate eudesmanolides, germacranolides and guaianolides, accumulated mainly as glycosides [18,19].

*Withaniacoagulans*Dunal.is important for the property of coagulating milk, possessed by its berries; they are used for this purpose in North-West India and adjoining country. The leaves contain four steroidal lactones called Withanolides and Withaferin A that is the most important of the withanolides isolated so far. It has good antibiotic and anti-tumoractivities [20].

Echinacea is one of the most popular herbal supplements among the general public in the United States and the popularity of this medicinal plant is due to its use in the treatment of infections and colds, based on its immune-stimulant and anti-inflammatory effects [21]. The main constituents of *Echinacea* are alkamides, polysaccharides, caffeic acid derivatives, and glycoproteins [22,23].

The aim of the present study was the effects of system production on the growth, quantitative and qualitative characteristics of *Cichorium, Withania* and *Echinacea*.

Material and Methods

The seeds of *Cichorium* and *Echinacea* were provided by Pakan Bazr Company (Isfahan, Iran) and Withania seeds were collected from Sistan and Baluchestan. The seeds (Cichorium, *Withania* and *Echinacea*) were washed with water and immersed in 5% (v/v) sodium hypochlorite solution containing one drop of Tween 20 (Merck) per 50 mL for 20 min and were then washed three times (5 min) with water. The petri dishes were placed in a germinator (16 hours light, 8 hours dark) at 25 °C and 45% relative humidity.

The plants were obtained from seed culture (*Cichorium, Withania* and *Echinacea*) in pot for one month in greenhouse. The uniform plants (20 cm height, approximately) were transferred to aeroponic system in a controlled greenhouse. Two cultivation systems (conventional soil and aeroponic) were performed. This experiment was conducted in greenhouse conditions with day/night temperatures of 25 °C/20 °C and a photoperiod of 16 hours light, using sodium-vapor lamps.

Aeroponic system

In the present study, a research aeroponic system (phytorhizotron) was used for production of plant [24]. The phytorhizotron consisted of two compartments: the upper compartment was supplied with photoperiod control and the lower compartment was kept in darkness. The plants were cultured on the board of the upper compartment with spacing 13 × 13 and about one- third of the length of the stems was placed inside the lower compartment. The shoots grew in the upper compartment and the roots were developed in the lower compartment under dark conditions. The lower compartment was a closed container (100 × 100 × 120 cm; deep × width × length), which had a removable front panel for monitoring and harvesting. The plant roots were periodically sprayed (every 20 min. for 20 sec.) with nutrient solution using twelve fog nozzles per m^2. Nutrient solution was renewed weekly. Residual nutrient solution flowed back into a collecting tank and was recirculated.

In other to study the effect of the production system (aeroponic and soil production system), an experiment was conducted based on a completely randomized design with five replication.

Nutrient solution and growing conditions

The component of nutrient solution used showed in the table 1. Solution electrical conductivity (EC) was adjusted 1.6 ± 0.2 dS/m. The initial pH was adjusted 5.8 ± 0.2, whereas after that pH was not controlled. The plants grew in a greenhouse under a 16-h photoperiod.

Table 1 Concentrations of nutrients used in aeroponic system (mg/L)

Elements	Concentration (mg/l)	Elements	Concentration (mg/l)
K	200	Fe	1
N	190	Mn	0.5
Ca	150	B	0.5
S	70	Zn	0.15
Mg	45	Cu	0.1
P	35	Mo	0.05

Data Recorded

The plants were harvested six month after transplanting. The plant height, root length, number of leaf, leaf area, volume of root, root fresh weight, root dry weight, shoot fresh weight, shoot dry weight traits were recorded per plant. In order to measure the photosynthetic pigments, a 300 mg sample of fresh leaves was ground in liquid nitrogen. Then, five mL 80% acetone was added to it and it was kept in the dark for 30 minutes and, thereafter, it was centrifuged at 3000 rpm for 15 minutes at 4°C. After filtering the sample, the absorptions were examined for wave lengths of 663, 645, and 470 nano meter using a spectrophotometry device. The chlorophyll concentrations were calculated by the formulae below [25]:

Formula 1: Chlorophyll a (g/mg)=$W \times V/1000 \times [A_{663} \times 12/7 - A_{645} \times 2/69]$

Formula 2: Chlorophyll b (mg/g) = $W \times V/1000 \times [A_{645} \times 22/9 - A_{663} \times 4/86]$

Data Analysis

Primary statistical analyses such as normality test (Kolmogorov-Smirnov test) and homogeneity of variances (Levene test) were conducted. All the above statistical analyses were carried out using SPSS version 14.

Results

The results of Kolmogorov-Smirnov normality test for all the measured traits in aeroponic and soil system indicated that all variables were normal for traits of *Cichorium*, *Withania* and *Echinacea*. The results of Levene test proved the assumption of homogeneity of variances.

Comparison of Aeroponics and Conventional Soil Systems for Production of Chicory

Accordingto the analysis of variance (Table 2), the effect of production system was highly significant at 0.01 probability level for all studied traits except carotenoid.

Mean comparison between aeroponic system and soil system indicated that Chicory in aeroponic production (AP) system had the highest plant height (80.6 cm), root length (42.2 cm), number of leaves per plant (20.8), root fresh weight (14.4 g/plant), root dry weight (3.02 g/plant), shoot fresh weight (45.2 g/plant), shoot dry weight (11.6 g/plant), chlorophyll a (22.2 mg/g) and chlorophyll b (12.1 mg/g) (Table 5).

Table 2 Analysis of variance for the effect of production system in Chicory

		Mean of squares				
S.O.V	Df	plant height	root length	chlorophyll a	chlorophyll b	carotenoid
Treatment	1	739.6 **	240.1**	10.52 **	4.58 **	0.45 ns
Error	8	7.55	11.5	0.109	0.123	0.151

ns: non-significant,**: Significant at 0.01 probability level

		Mean of squares				
S.O.V	Df	number of leaves	shoot fresh weight	root fresh weight	shoot dry weight	root dry weight
Treatment	1	152.1**	101.76 **	33.86 **	13.92 **	3.02 **
Error	8	6.35	1.46	0.388	0.214	0.065

ns: non-significant,**: Significant at 0.01 probability level

Fig. 1 Chicory in aeroponic after 4 month

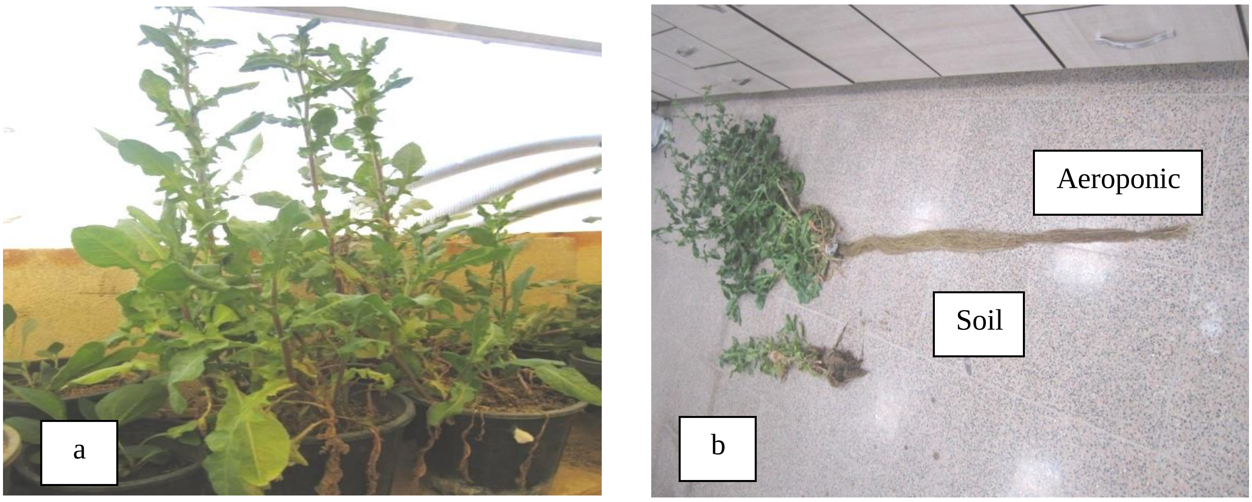

Fig. 2 (a): Chicory in pot after 4 month (b): Comparison of Aeroponics and Soil

Comparison of Aeroponics and Conventional Soil Systems for Production of Withania

According to the analysis of variance (Table 3), the effect of production system was highly significant at 0.01 probability level for plant height, root length, number of leaf, root and shoot fresh weight, root and shoot dry weight traits.

Table 3 Analysis of variance for the effect of production system in Withania

		Mean of squares				
S.O.V	Df	plant height	root length	chlorophyll a	chlorophyll b	carotenoid
Treatment	1	9078.16 **	4605.3 **	0.012 ns	0.013 ns	0.004 ns
Error	8	7.8	5.32	0.004	0.003	0.005

ns: non-significant,**: Significant at 0.01 probability level

		Mean of squares				
S.O.V	Df	number of leaves	shoot fresh weight	root fresh weight	shoot dry weight	root dry weight
Treatment	1	656.1 **	214.74 **	182.3 **	3.058 **	1.82 **
Error	8	1.3	0.446	0.57	0.012	0.001

ns: non-significant,**: Significant at 0.01 probability level

Fig. 3 Withania in aeroponic after 4 month

Fig. 4 (a): Withania in pot after 4 month (b): Comparison of Aeroponics and Soil

Table 4 Analysis of variance for the effect of production system in Echinacea

S.O.V	Df	Mean of squares				
		plant height	root length	chlorophyll a	chlorophyll b	carotenoid
Treatment	1	2934.36 **	2019.2 **	0.004 ^{ns}	0.003 ^{ns}	0.001 ^{ns}
Error	8	13.47	2.5	0.007	0.004	0.005

ns: non-significant, **: Significant at 0.01 probability level

S.O.V	Df	Mean of squares				
		number of leaves	shoot fresh weight	root fresh weight	shoot dry weight	root dry weight
Treatment	1	72.9 **	111.89 **	33.86 **	0.676 **	0.384 **
Error	8	1.5	1.85	0.177	0.006	0.001

ns: non-significant, **: Significant at 0.01 probability level

Mean comparison between aeroponic system and soil system indicated that Withania in aeroponic production (AP) system had the highest plant height (94.08 cm), root length (54.26 cm), number of leaves per plant (25.6), root fresh weight (10.76 g/plant), root dry weight (1.16 g/plant), shoot fresh weight (14.28 g/plant), shoot dry weight (1.7 g/plant) (Table 5). Comparison of Aeroponics and Conventional Soil Systems for Production of Echinacea

According to the analysis of variance (Table 4), the effect of production system was highly significant at 0.01 probability level for all studied traits except carotenoid, chlorophyll a and chlorophyll b.

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Mean comparison between aeroponic system and soil system indicated that *Echinacea* in aeroponic production (AP) system had the highest plant height (64.9 cm), root length (42.8 cm), number of leaves per plant (18.6), root fresh weight (8.27 g/plant), root dry weight (1.02 g/plant), shoot fresh weight (16.6 g/plant), shoot dry weight (1.8 g/plant) (Table 5).

Fig. 5 Echinaceainaeroponic after 4 month

Fig. 6 Echinacea in pot after 4 month

Table 5 Mean comparison for the effect of production system in Chicory, Withania and Echinacea
Means followed by the same letter(s) are not significantly different at 0.05 level of probability

Plant	Treatment	Plant height (cm)	Root length (cm)	Number of leaves	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)
Chicory	Aeroponic	80.6 ± 4.1 a	42.2 ± 3.1 a	20.8 ± 2.5 a	22.2 ± 2.45 a	12.1 ± 1.32 a
	Soil	15.2 ± 1.7 b	8.3 ± 1.2 b	6.8 ± 1.06 b	12.3 ± 1.18 b	8.2 ± 1.02 b
Withania	Aeroponic	94.08 ± 5.2 a	54.26 ± 4.3 a	25.6 ± 2.91 a	-	-
	Soil	21.3 ± 2.3 b	17.2 ± 1.1 b	8.2 ± 1.23 b	-	-
Echinacea	Aeroponic	64.9 ± 3.9 a	42.8 ± 5.1 a	18.6 ± 2.14 a	-	-
	Soil	30.2 ± 3.2 b	20.3 ± 1.4 b	10.3 ± 1.24 b	-	-

Table 6 Mean comparison for the effect of production system in Chicory, Withania and Echinacea

Plant	Treatment	Dry weight of shoot (g)	Fresh weight of shoot (g)	Dry weight of root (g)	Fresh weight of root (g)
Chicory	Aeroponic	11.6 ± 1.32 a	45.2 ± 5.2 a	3.02 ± 0.28 a	14.4 ± 1.64 a
	Soil	3.04 ± 0.52 b	15.2 ± 3.15 b	1.27 ± 0.19 b	6.2 ± 1.11 b
Withania	Aeroponic	1.7 ± 0.32 a	14.28 ± 1.17 a	1.16 ± 0.16 a	10.76 ± 1.38 a
	Soil	0.84 ± 0.14 b	4.2 ± 0.84 b	0.68 ± 0.082 b	3.19 ± 0.62 b
Echinacea	Aeroponic	1.8 ± 0.31 a	16.6 ± 2.19 a	1.02 0.085 a	8.27 ± 1.24 a
	Soil	1.19 ± 0.12 b	5.7 ± 0.93 b	0.51 ± 0.032 b	2.87 ± 0.36 b

Means followed by the same letter(s) are not significantly different at 0.05 level of probability

Discussion

Various forms of soilless culture systems with or without an inert substrate such as perlite have been described by Schwarz [26]. All systems are vital to maintain the highest possible aeration, nutrient solution availability and adjusting the concentration of nutrient at all times. The increased biomass production in soilless systems was due to increased leaf area as the photo assimilation sources for the plant that is a result of being exposed to the optimum growth condition [27,28]. Our result showed that aeroponic system might be an appropriate system for the growing of medicinal plants, which is in agreement with the result of Dorais *et al*., [29] who studied many of medicinal plants in soilless systems. Pagliarulo *et al*., [30] indicated that aeroponics cultivation of Echinacea and Burdock is superior had superior yields compared to conventional field production. In saffron (*Crocus sativus*) plants, there were significantly more roots in aeroponic systems than in hydroponic and soil culture [13].The lower FW and DW of lemon verbena and valerian grown in the soil system relative to plants grown in the soilless production system have been also reported by Tabatabaie [14,31].

The best feature of aeroponics is the good access the roots have to the air. Compared to stem cuttings in soil, aeroponic caused a significant improvement in the quick formation of adventitious roots in root induction and clonal propagation for three medicinal plants at risk of extinction [15]. In aeroponic system, the roots had more vitality compared to deep water culture [32].

Higher planting densities, adjustment of nutrient concentration and multiple harvests may increase the yield in soilless cultivation in greenhouse over those of field production. The results suggest that aeroponic system could dramatically outperform soil production system, since it appeared that the growth of the medicinal plants tended to be lower in soil production system. In medicinal plants losing of the roots in soil production in the harvest process are most likely to be representing a significant loss of yield potential. Therefore, the easily accessible roots in aeroponic and system might be trimmed and to re-growth in this biennial plant, yielding additional biomass with subsequent harvests.

There has been a rise in urban agricultural production due to growing popularity of soilless cultivation methods [33], and farming inside buildings and on the rooftops has increased and continues to do so [34]. Aeroponics is one of these methods. In this method, the nutrients are sprayed on the roots in a water solution. The water needed for aeroponic systems is, due to recycling of the water, 98% less than other traditional methods, and it uses less pesticides and produces higher yields [35,36]. Aeroponics also has better yields than other soilless methods, because the root is exposed to the air [2,5,37]. It has been shown that aeroponics is successful in the production of different plants, such as basil [38], lettuce [37,36, 39], tomato [3,33], potato [5], cucumber [40], and ornamental plants such as chrysanthemum [41 and 4] and poinsettia [42].

Conclusion

The results of Chicory, Withania and Echinacea experiments suggest that aeroponic system is capable of equivalent and superior yields compared to soil production. Higher planting densities, improved plant varieties, and multiple harvests may increase yields significantly over those of field production. Aeroponic systems also can be used for production of medicinal root crops, however sufficient care is needed to obtain higher yield. In general, it could be possible to produce some medicinal plants in different production system in greenhouse.

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