

Research Article

An Intelligent Hydroponic Device for *Astragalus membranaceus* Bge. var. *mongolicus* (Bge.) Hsiao

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Astragalus membranaceus Bge. var. *mongolicus* (Bge.) Hsiao roots are widely used as raw materials of medicine. Due to the limited arable land, cultivating medicinal plants hydroponically is increasingly concerned. However, whether the quality of *A. membranaceus* grown hydroponically is better than that produced in a field is still unknown. In this study, we designed an intelligent hydroponic device for *A. membranaceus*, and quality of the medicinal plant cultivated by this device was compared with that cultivated in the field. Results showed that hydroponics significantly increased effective components in *A. membranaceus* when compared with field. Specifically, astragaloside IV contents in *A. membranaceus* grown hydroponically for four weeks were higher than those cultivated in the field for two years. The biomass is not significantly different between four-week hydroponics and annual cultivation. Therefore, hydroponics with our intelligent device can be used for the sustainable production of *A. membranaceus* in the future.

1. Introduction

Astragalus membranaceus (Fisch.) Bge. is a medicinal plant which is widely used in modern medicine [1–3]. It is distributed in north China and widely cultivated in Inner Mongolia [4, 5]. To date, the available agricultural land is decreasing in recent decades which limited the development of *A. membranaceus*. Facility agriculture is one of the important strategies to solve the problem of cultivated land utilization in the modern agriculture [6].

In the facility agriculture, the soilless cultivation has the advantages of saving fertilizer and water, saving labor, decreasing disease and insect, and improving high yield [6]. Among them, hydroponic nutrient mixing system can cultivate the higher-quality plant varieties [7], such as soilless cultivation of vegetables in ornamental greenhouse and the cultivation of strawberry (*Fragaria × ananassa* Duch.) [8, 9]. In addition, hydroponics can quickly cultivate plants, shorten plant culture

period, and improve yield. Thus, making special hydroponic device for plant growth is a determinant of sustainable plant growth and industrial development [10].

Hydroponics is a good way to produce high-yield crops by taking minimal space, makes work easier for farmers in growing of plants, and also consumes less amount of water when compared to traditional method resulting in conservation of water [11]. In production, strawberry hydroponics can avoid the occurrence of some soil-borne diseases and pests [8]. Here, an intelligent hydroponic device for cultivating *A. membranaceus* was designed.

2. Materials and Methods

2.1. *A. membranaceus* Cultivation Conditions. Seeds of *A. membranaceus* were collected in Chifeng City, Inner Mongolia, China, and then, seeds were sown in nutrient soils (vermiculite and nutrient soil ratio was 1 : 3). The seeds were

planted with sufficient water. Then, the seedlings were cultured under 16 h light/8 h darkness and 25°C for 30 days. Watered every two days. Then, the one-month plants were cultivated in a hydroponic device. The root of these plants was harvested in one, two, and four weeks, respectively.

For Field conditions, the seeds of *A. membranaceus* were planted directly in the field, and the plants grew for one and two years in Hohhot, Baotou, and Chifeng, Inner Mongolia. The root of *A. membranaceus* in the field was harvested with four-week hydroponic plants. Collect these roots, dry them in an oven at 45°C, weigh, and count 10 roots. These roots were used in HPLC.

2.2. Structure of Designed Hydroponic Device. The intelligent hydroponic device is designed according to the needs of *A. membranaceus* growth. It has hydroponic tank, support seat, and support leg, which are bolted with each other; the surface of the support leg is bolted with a water pump. The water outlet end of the water pump is connected with a water injection pipe and a water extraction pipe. The water extraction pipe far away from the end of the water pump is connected with a three-way water valve. The water inlet ends at the top and bottom of the right side of the three-way water valve are, respectively, connected with a nutrition pipe and a water supply pipe. The water supply pipe away from the three-way water valve is connected with a special water pipe. Both sides of the top of the hydroponic tank are bolted with a support plate. The gap inside the support frame is penetrated with a moisture discharge pipe which is connected with a moisture discharge cover. The inner part of the fixing frame is bolted with a moisture exhaust fan. The pump operates 24 hours every work day, at 25°C, humidity 30%; the cultivate medium was modified Hoagland nutrient solution (Table 1).

2.3. High-Performance Liquid Chromatography (HPLC) Determination. Take 2.0 g of medicinal powder (passing through 100-mesh sieve) and accurately weigh it. Put it into a 150 ml Soxhlet extractor, add 40 ml methanol, soak it overnight (12 h), add 20 ml methanol, and heat and reflux at 85°C for 4 h. The solvent was recovered and concentrated to dryness. The residue was dissolved with 10 ml water and shaken with water-saturated n-butanol for 4 times, 40 ml each time. Wash thoroughly with ammonia test solution for 2 times, 40 ml each time. Discard ammonia solution, and evaporate with n-butanol solution. The residue was dissolved with 5 ml water and cooled down. The residue was washed off with 50 ml water and then eluted with 30 ml 40% ethanol. The eluent was continued to be eluted with 80 ml 70% ethanol. The eluate was collected and evaporated to dryness. The residue was dissolved in methanol and transferred to 5 ml volumetric flask; add methanol to volume to the scale, shake well, filter with 0.45 μm microporous membrane, and set aside.

For the chromatographic column, Agilent Zorbax sb-c18 column (250 mm \times 4.6 mm) was used. The mobile phase was acetonitrile water (32 : 68); the flow rate was 1.0 ml·min⁻¹; the column temperature was 27°C; the ELSD parameters are as follows: evaporator temperature: 112°C, nebulizer tempera-

ture: 85°C, gas flow rate: 1.5 SLM, data rate: 80 Hz, led intensity: 100%, smoothing: 50 (5.0 seconds), and PMT gain: 10.0; the theoretical number of astragaloside IV was not less than 4 μl , 10 μl , 20 μl , and 10 μl of the reference solution, and the test solution was, respectively, injected into the liquid chromatograph. The determination was carried out according to the above chromatographic conditions, and the HPLC liquid chromatograms were recorded.

2.4. Data Analysis. All experiments were conducted with three biological replicates. The HPLC statistical analyses data were performed using one-way ANOVA by SPSS software (version 13.0) at the significant level of $P \leq 0.01$. All figures were generated using Origin 9.0 software.

3. Results

3.1. The Hydroponic Device Design for *A. membranaceus* Cultivation. In order to alleviate the problem of land use efficiency in *A. membranaceus* planting, this research designs an intelligent hydroponic device for its cultivation. In the hydroponic device, a camera is fixed at the bottom of the bracket for the interior watching of the hydroponic tank. The top of the front side of the hydroponic tank is fixedly installed with a water temperature and a water level meter for the monitor of its temperature and moisture insufficiency (Figure 1). The equipment can not only reduce the staff entry but can also discharge the moist air. It can solve the problem that the current *A. membranaceus* hydroponic device still needs the staff to enter the hydroponic greenhouse for water supplement and fertilization.

3.2. The Biomass and Astragaloside IV Contents between Hydroponic Culture and Cultivation. In order to further study whether the selected cultivation has the representativeness of astragaloside IV content in the root of *A. membranaceus* in Inner Mongolia, three different production areas cultivation were selected for comparison. The results show that the content of astragaloside IV in hydroponic root is significantly higher than that in other areas (Figure 2(a)). At the same time, in order to understand the biomass difference between hydroponics and cultivation, their biomass was statistically analyzed. The results showed that there was significant difference between hydroponic culture, annual cultivation, and biennial cultivation (Figure 2(b)). Therefore, *A. membranaceus* used in this study is universal. The nutrient solution is changed every 2 weeks in the intelligent hydroponic device which can be grown continuously for 2 months of *A. membranaceus*.

3.3. The Astragaloside IV Contents Increased in Hydroponic Device Than Cultivation. To understand the cultivation status of *A. membranaceus* in hydroponic device, we blasted the astragaloside IV between the hydroponic device and filed cultivation. Interestingly, the content in hydroponic cultivation was higher than that in the field. The astragaloside IV contents is 0.218 mg/g in two years of cultivation; its content is 0.627 mg/g in two-month seedling with four-week hydroponic cultivation (Figure 3). Meanwhile, the elapsed time of hydroponic cultivation is significantly

TABLE 1: Hoagland nutrient formula.

Macroelements	Final concentration (mM)	Stock solution concentration (mM)
KNO ₃	5	1000
Ca(NO ₃) ₂ ·4H ₂ O	5	1000
MgSO ₄ ·7H ₂ O	2	400
KH ₂ PO ₄	1	200
Microelement	Final concentration (μM)	Stock solution concentration (mM)
H ₃ BO ₃	46.1	46.1
MnCl ₂ ·4H ₂ O	9.1	9.1
ZnSO ₄ ·7H ₂ O	0.76	0.76
CuSO ₄ ·5H ₂ O	0.32	0.32
Na ₂ MoO ₄ ·2H ₂ O	0.24	0.24
Fe ²⁺	Final concentration (μM)	
EDTA-Fe-Na	50	

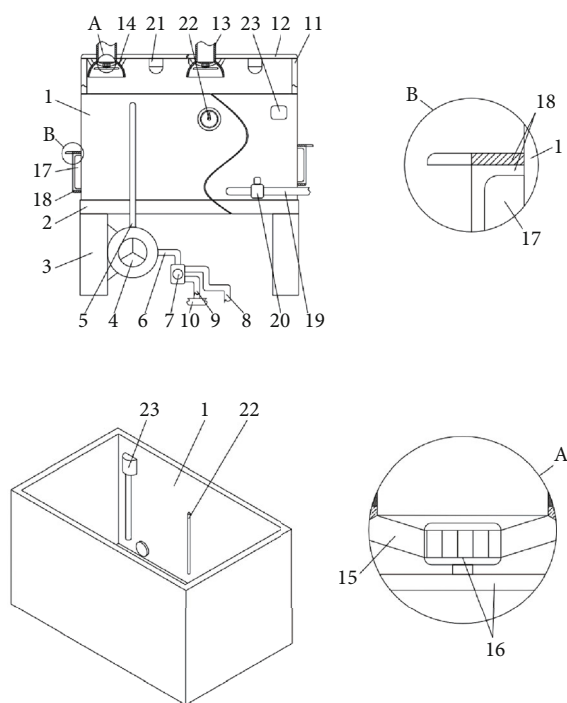


FIGURE 1: The hydroponic device structure of *Astragalus membranaceus* Bge. var. *mongolicus* (Bge.) Hsiao. An intelligent controlled *Astragalus* hydroponic device includes a hydroponic tank (1), a support seat (2), a support leg (3), a water pump (4), a water injection pipe (5), a water extraction pipe (6), a three-way water valve (7), a nutrition pipe (8), a water make-up pipe (9), one end of the support plate (11), a special water pipe (10), a support plate (12), the gap in the support plate (12), a moisture drainage pipe (13), a moisture drainage cover (14), a fixed pipe the inner part of the fixing frame (15), a moisture exhaust fan (16), socket (17), waterproof cover (18), drain pipe (19), drain valve (20), camera (21), water temperature gauge (22), and water level gauge (23).

shorter than that of common cultivation. From two years to two months is the significantly time efficiency improvement for *A. membranaceus*.

4. Discussion

The nutrients of plant growth come from the root absorption [12]. Field planting and indoor soil culture are common plant culture methods. At present, with the limited area of soil cultivated land in China, soilless cultivation is one of the effective ways to solve this problem [13]. The soilless cultivation technology through hydroponics, fog culture, and other ways has been widely used in vegetable and flower cultivation. The greater environmental and ecological awareness is growing the farmers who want to adopt sustainable and efficient cultivation systems [14]. Sustainable and modern cultivation systems contain cultivation devices and organic fertilization [10]. In modern agriculture, the hydroponic device is the growing process of the plant root cultivated in the nutrient-rich solutions, such as the official Real-Time Operating System (RTOS) for ARM Cortex-M microcontroller [15]. The hydroponic devices were used to produce “Biquinho” pepper with brackish water [16]. However, there are few reports on soilless cultivation of medicinal plants, such as *Coptis chinensis* Franch. [17]. *A. membranaceus* is a typical medicinal material in China. Due to the limitation of cultivated land area, developing soilless cultivation is a good way to develop plant factory production in the future [18].

In addition to the limited land use, the soil-borne disease of *A. membranaceus* is one of the main factors affecting its industrial development [19]. The soilless cultivation completely avoids this problem. But the frequent in and out of the equipment easily brings in foreign bacteria, which will affect the production of *A. membranaceus*. Moreover, the air is often humid in the hydroponic planting process, which further provides conditions for the reproduction of pathogens [6, 10]. This *A. membranaceus* hydroponic device can reduce these effects on its soilless production by external visual monitoring system. Astragaloside IV is the main active component in *A. membranaceus* that determines its quality [9, 20, 21]. In this study, the active ingredients of four-week hydroponic cultivated

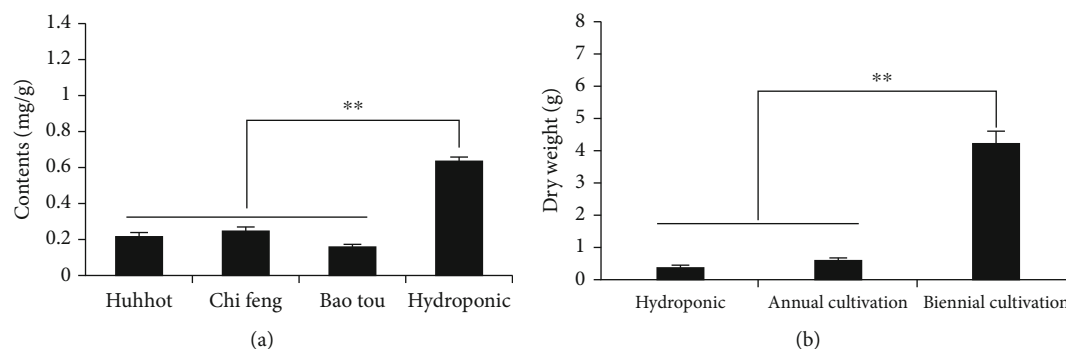


FIGURE 2: The astragaloside IV contents and dry weight of different cultivation areas or years in *A. membranaceus* Bge. var. *mongolicus* (Bge.) Hsiao: (a) the astragaloside IV contents of different cultivation areas in *A. membranaceus* Bge. var. *mongolicus* (Bge.) Hsiao; (b) dry weight of different years in *A. membranaceus* Bge. var. *mongolicus* (Bge.) Hsiao. Data are shown as the mean \pm SD ($n = 3$), and the double asterisk indicates the significance ($P < 0.01$) according to one-way ANOVA tests. The double asterisk above bars represents significant differences at the level of 0.01.

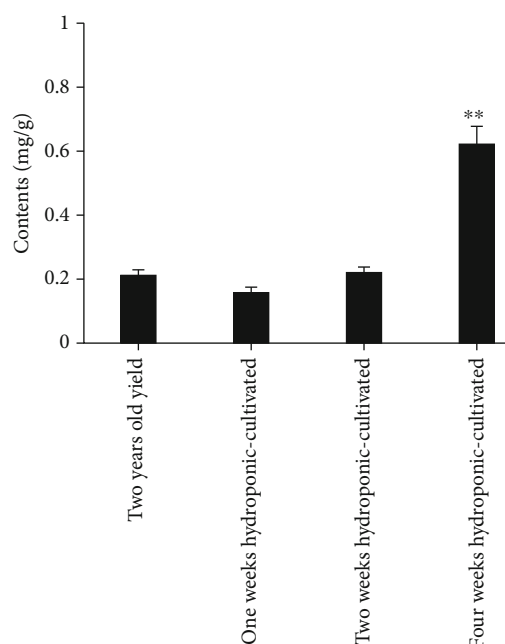


FIGURE 3: The contents of astragaloside IV in hydroponic device and yield plants. Data are shown as the mean \pm SD ($n = 3$), and the double asterisk indicates the significance ($P < 0.01$) according to one-way ANOVA tests. The double asterisk above the bar represents significant differences at the level of 0.01.

plants can reach 2 times more than those of a two-year-old field *A. membranaceus*. Moreover, astragaloside IV contents in Hohhot cultivation used in this study are representative. There is no difference in biomass between hydroponic and annual *A. membranaceus*, which greatly shortens its culture time and unaffected by the external environment. Meanwhile, hydroponics of *A. membranaceus* can realize its sustainable culture.

In conclusion, based on the soilless cultivation of *A. membranaceus*, the intelligent hydroponic device was designed to improve its cultivation efficiency and the content of active ingredients. Meanwhile, this method avoids soil-

borne diseases. Soilless culture avoids continuous cropping obstacles in conventional cultivation [22]. Therefore, this study provides theoretical support for the soilless cultivation and the development of the *A. membranaceus* industry.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors have declared no conflict of interests.

Authors' Contributions

BZQ conceived the research and wrote the manuscript. CQY performed the experiments and data analysis and revised the manuscript. ZXJ gave the project support and the design guidance of the experiment.

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