STUDY REGARDING THE SUITABILITY OF CULTIVATING MEDICINAL PLANTS IN HYDROPONIC SYSTEMS IN CONTROLLED ENVIRONMENT

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Abstract: *This paper focuses on growing medicinal plants in hydroponic systems. Medicinal herbs cultivation is widespread and the interest for this kind of cultures is growing on a fast pace. Harvesting the raw material from the wild can be very difficult due to the little control one can have dealing with problems like: misidentification, genetically and phonotypical variability, active substances variability and toxic compounds. Cultivating the medicinal plants in a more controlled environment can overcome these difficulties and more than that, recent studies showed that cultivating medicinal plants in controlled environment improves the concentration of bioactive substances. Hydroponic cultures getting very popular because of the results it showed in recent practices. The main plants cultivated in this kind of system are vegetables, or other plants used in food industry. The hydroponic system can improve the yield and have showed a huge economical advantage. This system is also used in green walls or vertical farms clearly being a tool of the future in agriculture sciences. The hydroponic system is a rigorous way of cultivating controlling the temperature, humidity, light, irrigation and fertilization of the plants that are growing in an inert substrate that can be rock wool, clay pebbles, vermiculite, perlite, coco peat and others. The goal of cultivating medicinal plants in hydroponic systems is to attain unequalled growth allied with excellent crop quality and high bioactive substance. The risks of hydroponic cultivation of medicinal plants are low germination rate and ecological problems that can be overcome by controlling the optimal parameters to obtain the best environment for germination; another risk is that it may need artificial pollination. Having all aspects taken in consideration, hydroponic cultures can have relevant results like uniform yield, with high percentage of bioactive substances and this kind of system can be the way to cultivate the medicinal plants in commercial purpose. Beside the economical and chemical advantages, the hydroponic systems of cultivating medicinal plants, helps protecting spontaneous flora and the diversity of the species that can be found in the wilderness. The challenge is that the synergistic effects can be not only conclusively demonstrated but also realistically defined for biotechnological intervention.*

Key words: *medicinal plants, hydroponic, bioactive substances, future prospects*

INTRODUCTION

„Consumption of herbal medicines is widespread and increasing. Harvesting from the wild, the main source of raw material, is causing loss of genetic diversity and habitat destruction. Domestic cultivation is a viable alternative and offers the opportunity to overcome the problems that are inherent in herbal extracts: misidentification, genetic and phenotypic variability, extract variability and instability, toxic components and contaminants. The use of controlled environments can overcome cultivation difficulties and could be a means to manipulate phenotypic variation in bioactive compounds and toxins. Conventional plant-breeding methods can improve both agronomic and medicinal traits, and molecular marker assisted selection will be used increasingly. There has been significant progress in the use of tissue culture and genetic transformation to alter pathways for the biosynthesis of target metabolites. Obstacles to bringing medicinal plants into successful commercial cultivation

include the difficulty of predicting which extracts will remain marketable and the likely market preference for what is seen as naturally sourced extracts."(CANTER,*et.al.*, 2005)

Hydroponic cultures represent a technology of cultivating plants using solutions of water with nutrients, without soil. The terminology of the word derives from the greek word ύδορ (hudor) that means water and εργασία (ponos) that means work. Growing plants on other substrates than soil developed from experiements that have determined what substances are used by the plants in order to grow. This kind of works on plant constituents date back in 1600's. Yet the hanging gardens of Babylon, the floating gardens of the Aztecs and the Chinese ancient gardens, are examples of „hydroponic" cultures and how people tried to combine the plant knowledge with the resources they had in order ot obtain best results.

MATERIALS AND METHODS

The materials used for documentation were books, scientific articles, thesis and other works on the subject of medicinal plants, hydroponic cultures and greenhouse tehcnologies. The selection of the papers was made regarding the information on the content that was being considered valuable for the documentation.

The documentation was being made in phases based on the category of the subject. Therefore medicinal plants was the first subject of interest, studying the traditional technology of cultivation, plant biology and the content of bioactive substances together with the way of harnesing the active compounds from the plant vegetative parts. The geographical area of the plants that were analysed was included in the limits of Romania, even though articles and book written by authors form other countries were relevant on the subject.

The second pahse of documentation was on the subject of hydroponcs culture. The technologies, materials and uses of this soilless systems were analysed comparing yields obtained in hydroponics comparing with the ones from soil. There was conducted a study on the plants that are worldwide cultivated using hydroponics, comparing it with the state from Romania.

Having this two phases completed, the third and last one started having the subject of hydroponic cultures on medicinal plants. The plants studied in first phase were being searched in articles, books and scientific papers regarding their cultivation in hydroponic cultures. The number and content of articles regarding a number of species could define the ones that will be studied furthermore.

RESULTS AND DISCUSSIONS

From the ancient time, humans used vegetal and animal resources from his environment in order to survive. Onver many generation that succeded, he managed to identify, beside the edible plants, the ones that have beneficial effects for his health, for healing wunds or illness, together with the toxic plants (MUNTEAN *et.al.*, 2007). „During harvesting, handling, storage and distribution, medicinal plants are subjected to contamination by various fungi, which may be responsible for spoilage and production of mycotoxins. The increasing consumption of medicinal plants has made their use a public health problem due to the lack of effective surveillance of the use, efficacy, toxicity and quality of these natural products."(SAMINA ASHIQ, 2014). Knowing the traditional way of harvesting is very important for biodiversity and discovering new entities that could be studied for a further evaluation on their biological activity. (BENALE AND MUNOIO, 2014).

Medicinal plants, whatever the origins and sistematic clasification, owns their terapeutic actions because of a complex of chemical substances that are synthesized by their cells and are named vegetable active principles. The criterias of the clasification of medicinal and aromatic herbs are chemical nature, physicochemical propreties and biological action. The most important active principles groups are: proteins, glucides, lipides, aminos, volatil oils, saponins, tannins, resins, organic acids, alkaloids, vegetable dyes, mineral substances, glycosides, pectins and vitamins (TELEUȚĂ, 2008).

Among the medicinal plants (some even edible) used since the tracians time until present days, on Romania's territory are: *Alium cepa, Aconitum napellus, Hypericum perforatum, Sarothamnus scoparius, Sambucus nigra, Chelidonium majus, Gentiana lutea, Verbascum thapsus, Mentha piperita, Salvia officinalis, Thymus vulgaris, Achillea millefolium, Arthemisia obsinthium, Taraxacum officinale, Pimpinella anisum, Carum carvi, Eryngium planum, Conium maculatum etc*. (MUNTEAN *et.al*, 2006) Overall, Romania shares many conservation concerns with other Eastern and Central European countries. A regional approach to conserving biodiversity based on spatial prioritization, rigorous scientific documentation, and social acceptance is needed for the Natura 2000 network to achieve its goals. (LOJĂ *et.al., 2010*).

Hydroponic cultures represent possibly the most intensive method of cultivation that is now availabale in the agricultural domein. (JENSEN *et.al.*, 2010). The classification of the soilless cultures are regarding to substrates and container, how the nutrient solution is delivered to the plant, driping wattering, substrate irigation, imersing in stagnant solution or through mist spray and it depends of the faith of the drained solution, wether is an open system or a colsed one where the solution is recycled. (PARDOSSi *et.al.,* 2011)

The interest in practical implementation of hydroponic cultures wasn't developed until 1925, when the greenhouse industry expressed interess in using this technologies. At the beggining of 1930's, W.F. Gericke from University of California have put the experiements that were conducted in laboratories on plant nutrition at a commercial scale. This way the hydroponic cultures has been defined. (RESH, 2013)

Producing edible plants using protected environments it was not established until the introduction of polyethylene. In United States of America, the polyethylene was introduced by proffessor Emery Myers Emmert, from the University of Kentucky, who used this kind of material that is more efficient from the economical point of view comparing with the glass that is more expensive. (JENSEN *et.al.*, 2010).

Growing plants in Controlled environment has gained popularity in horticultural and agricultural domeins. In the last 15 years it has been recorded a grotwh in controlled environment cultivation using hydroponic cultures. The balance between the implementation cost and the yield obtained is a valid argument which makes the siolless cultures more suitable than the field ones (Table1). „Many facets of the field are rapidly changing so that the state-of-the-art is continuing to advance. Several areas in particular are in flux. Two such factors are the advent of governmental pressures to force commercial soilless production systems to recycle irrigation effluent and a desire for society to use fewer agricultural chemicals in food production."(RAVIV AND LIETH, 2008)

Table 1

World hydroponic production – systems and cultures (1980-2001)

Country	Date	Area	Main systems	Major crops	Reference
The Netherland	1987	3,500	Rockwool, other substrates	Tomates, cucumbers, bell pepper, eggplant, beans, lettuce, cut flowers	Annon (1990)
	2001	10,000	Rockwool	Tomates, cucumbers, bell pepper, eggplant, strawberries,roses, gerbera, fresia,	NDEFRA
Spain	1996 2001	1,000 4,000	Perlite, sand, rockwool	Tomates, cucumbers, bell pepper, lettuce	Donnan(1998)
Canada	1987 2001	100 1,574	Rockwool, sawdust, NFT rockwool, perlite	Tomates, cucumbers, bell pepper, lettuce	Donnan(1998)
France	1996	1,000	Rockwool	Tomates, cucumbers, bell pepper, eggplant	Donnan(1998)
Japan	1984	293	Water, Rockwool, NFT	Tomates, cucumbers, lettuce, leaf onion, melon	Kobayashi et.al. (1998)
Israel	1996	650	Perlite, sand, aeroponic,		Donnan(1998)
Belgium	1996	600	Rockwool		Donnan(1998)
Germany	1996	650	Rockwool		Donnan(1998)
New Zealand	1996 2001	200 550	NFT, sawdust, pumice	Tomates, cucumbers, bell pepper, lettuce, cut flowers, melon, chilli, asian vegetables	Donnan(1998) Chris Winslade (2001) Horticultural News (NZ)
Australia	1996	500	NFT, rockwool, sawdust, sand, clay	Tomates, cucumbers, lettuce, cut flowers, herbs, strawberries	Donnan(1998)
United Kindom	1988	392	Rockwool	Tomates, cucumbers, bell pepper	Vaughan(1990) Adams(1990) Chamber(1990)
South Africa	1984 1996	75 420	sawdust, husk	Tomates, cucumbers, lettuce, flowers	Smith(1986) Donnan(1998)
Italy	1990 1999	50 400		Roses, tomates, gerbera, strawberries	Pardossi et.al., 1999
USA	1984 1999	228 400	Perlite, gravel, sand, NFT	Tomates, cucumbers, lettuce	Carpenter 1985 Sullivan et.al. 1999
Finland	1996	370			Donnan(1998)
Korea	1987 1996	274	Vată minearlă, NFT, perlit, NFT, DFT, aeroponic	Tomates, cucumbers, lettuce	Donnan(1998) Kim et.al. (1999)
Mexico	1996 1999	15 120			
China	1987	5	Gravel bed	Tomates, cucumbers, lettuce, melon, chilli, pak choi, flowers, chive	Shijun (1999)
	1999	120		Tomates, cucumbers, bell peppers, melon, strawberries	Xing et. Al. 1999
Greece	1996 1999	33 60	Rockwool, perlite, NFT	Tomates, cucumbers, lettuce, bell peppers	Donnan(1998) Mavrogianopoulos(1999)
Brasil	1999	50	NFT	Lettuce, watercress	Furtani(1999)
Taiwan	1996	35			Donnan(1998)
Singapore	1996	30	Aeroponic, NFT		Donnan(1998)
Total Yield: End of 1980s – 5,000 până la 6,000 Ha 2001 – 20,000 până la 25,000 Ha					

Source: CARRUTHERS S., 2002

„Substrates can be organic such as peat, pine bark, sawdust, rice hulls etc.. They can be petroleum based such as polymeric foams or plastic beads or they can be inorganic mineral based as are sand, gravel, perlite and rockwool. There are a number of reasons for using

substrates to support the plant root system in a hydroponic growing system. In addition, an effective substrate should possess certain qualities"(MICHAEL AND DOWGERT, 2013). One important thing in choosing substrates is relation between growing media and irrigation systems and cycles. Rockwool will retain more water than coconut fibers and even more than clay pebbles (KEHDI, 2012).

A good substrate it has to be of particles no more than 7 mm large or 2mm small, it has to be capable of retaining moisture but also drainage the excessive liquid, it must not degrade or decompose easy, it must not hold microorganism that can be dangerous to plant or human life, it shouldn't be contaminated with residual waste, it has to be readily available and also potable. (MUNOZ, 2010).

Rockwool is the most common growing media. It is a man made mineral material, and the most uses of this material is for insulation, much like fiberglass. In 1960's it was found that with small adjustments of the production technology, rockwool will support and with care for handling, promote plant growth. This special manufactured horticultural product is what is primarily sold as hydroponic growing media. While rockwool provides good plant growth, JENSEN *et.al.,* (2010) says that is expensive and have a disposal problem, so she conducted a study on different substrates.(Table2).

The water holding capacity of the substrates are, in aprticular very important because this way the plants cand take the nutrients and minerals from the solution in the optimal time. Also the drainage of the solution is as important as the holding capacity because the root system can take up oxygen and the roots would not rot. When allowed to drain by gravitational pull, rockwool, generaly, contains 80% nutrient solution, 15% air and 5% rockwool fibres. The ratio of solution to air promotes vigurous growth of the root system. One other advantage of the rockwool substrate is that the easinest of the solution to be removed changes slightly when the grow media is dry.Having this, the grower have a wide flexibility because the plant will not have water stress until the rockwool si almost completly dried, but a rigurous watch on the humidity of the substrate is adviced, because the plant will not show any signes of stress until it's too late. (DOWGERt, 2013).

Table2

Comparing 5 growing media for hydroponics for tomato yield and obtaining of fructification.

Growing media(bag culture)	Yield		Size gms/fruit
	Plts/bag	kg/m^2	
Coconut coir	10,63	26,58	196
Perlite(3 plts/bag)	10,27	25,69	195
Peat-lite	9,92	24,81	193
Coir with perlite	9,71	24,27	192
Rockwool	9,61	24,02	185
Perlite(6plts/bag)	9,36	23,40	192

Source: Jensen,2010

Clay pebbles are round small pellets that are man made. They are burnt in ovens at high temperature so they expand and become porous, providing a sterile and light media that gives enough oxygen and retain water and nutrient solution (Table 3) in order for the plant to grow and develop healthy root system. The pebbles are in different sizes from 2mm up to 24mm, giving the grower the possibility of choosing regarding his needs; the smaller one are

known for their good capillarity capability and the larger ones are used for their rapid drainage.(KEHDI, 2012).

The Clay pebbles come in neutral pH, close to 7.0 and are really easy to clean. Using an acid solution, pH 4.0 or Chlorine will clean or the deposits of salts. So this material is suitable to recycling.

Coconut fiber is a natural waste material that is can be valued in hydroponic systems having high amount of oxygen and a good holding water capacity. Some researches showed that the coconut husk is also a good repellant for insects which means that it has great advantage for cultures conducted in protected environments (WHITE, 2004).

Table3

Coconut coir and soil media feed sheet

Stage of growth	Seedlings/ Clone	Vegetative			Bloom Transition				Flowering/ Fruits			Ripening	Flush
Photoperiod	18	18	18	18	12	12	12	12	12	12	12	12	12
Number of weeks	W1	W1	W2	W3	W1	W2	W3	W4	W5	W6	W7	W8	W9
Nutrients	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal	ml/ gal
Kind Base	3	4	5	6	10	10	10	9	9	9	9	6	0
Kind Grow	6	8	10	12	6	4	0	0	0	0	0	0	0
Kind Bloom	0	0	0	0	6	8	14	15	15	16	16	12	0
Approximate ppm	630	840	1050	1260	1572	1576	1732	1722	1722	1722	1790	1284	0
Approximate EC (1.0=700ppm)	0,90	1,20	1,50	1,80	2,25	2,25	2,47	2,46	2,46	2,46	2,56	2,83	0

Source: www.botaniccare.com

Soilless cultures come in many forms, not only by different substrates but also the way that the nutrient is delivered to the plant. One of the most innovative and new technologies includes Aeroponic systems which consist in growing system that mist the solution at the root level in a fog form. This way the plant take up the amount of nutrient necessary for their growth and development and pleanty of oxygen. Usually this systems can only be fond in laboratories and research center and is not yet at a commercial scale.

One of the most popular hydroponic system is NFT(nutrient film tehnique) which is a closed system in which the nutrients are circulated constantly on a grow tray. The roots are growing from the pots, in the nutrient solution and are feeding directly from the solution. This system need a close supervision and many test done for pH and nutrients and adjustments are needed constantly. Other than that complex technology, the results shown in the researches conducted before, show great prospects for the future.

The aeroponics are derived from aero-hydroponics. In the 1980s Laurence Brooke tried to bring aero-hydroponics into the mainstream market, with the Ein Gedi System, a unit developed at University of Davis, California, that was used to study oxygen in water but turned out ot be one of the most effective propagation system. (KEHDI, 2013).

Medicinal plants and aromatic herbs are more and more demanded and so, cultivated at a large scale and intensivly. In this context producers turned towards hydroponic cultures that showed a great yield and a feaseble alternative for traditional agriculture. The main question was the quality of the plants, because medicinal and aromatic herbs are valuable for

their bioactive substances. Many researches and works on this domein were conducted until today and still are being started helping in growing popularity and interestworldwide.

Hydroponic cultivation of medicinal plants can result higher concentrations of bioactive substances because of the total control the grower can have. The controlled environment give the possibility for mainupaltion of fenotipical variation and important compounds from the plant. The objectives are for growing the potential of bioactive substances, reducing toxins and resulting in an uniform and superior product. The compunds targeted are often the ones resulted in secondary metabolism which is influenced by electric conductivity, pH, humidity, that need to be carefully monitorised (CANTER *et.al.*, 2005).

Aromatic herbs are used frequently if not all the time in restaurants and other facilities with food services. Having fresh plants it's a sensible process because it's difficult to estimate how much it's going to be used for a period of time. High level of service demand high standards for plants. These facts determined for more and more companies that develop in food domain, to invest in small hydroponic units. This way, they will have constant aromatic herbs, and not only and they are eliminating the waste but also the incapacity to forecast the quantity it is needed for a period of time. Producers of medicinal plants are also attracted to hydroponic systems for cultivation because recent studies proved that growing in soilless cultures in protected environments results in higher concentrations of active principles found in plants comparing with traditional soil cultivation.

"Not only do hydroponic herbs grow faster, they have significantly more flavor and aroma than herbs grown in soil. According to research performed at the University of Minnesota, it is a known fact that herbs grown hydroponically have 20-30% more aromatic oils than field grown. Therefore, a small hydroponic herb garden can provide a continuous harvest of gourmet-quality produce in a relatively small space."(SMITH, 2013).

When growing herbs it is essential to know the plant biology and cultivation technology. Plants that need dryer conditions for growing and developing are no as suitable as those which need high procentage of humidity in the substrate (TYSON *et.al*, 1999), because hydroponics are by deffinition systems that are using steril neutral growing media that is being kept moist, in different ways, depending on the system, in order for the plants to take up minerals and nutrients. Choosing the system in which to grow hydroponically it is important to think of the vegetative part of the plant that will be valued as medicinal treatment or alimentary and also the root system, in order to obtain the best results and the optimum relation between irrigation system and the plant and delivering the nutrient solution to the roots. Aeroponic system appeared to be the most effective for growing medicinal and aromatic herbs in controlled environment, where the herb or roots were harvested.(HAYDEN ANITA, 2006).

CONCLUSIONS

- There is a high demand for medicinal and aromatic herbs
- Harvesting from the spontaneus flora is dangerous for the biodiversity
- Intensive cultures and traditional agricultre is difficult in actual context
- Soilless cultures and protected environment facilities cand be implemented everywhere and are not dependent on climatic factors
- Hydroponic cultures represent the most intensive method of cultivation
- Hydroponic cultures have higher yields than traditional agriculture

- There is an ascendent trend in popularity and implementation of hydroponic cultures worldwide
- Substrated used in hydroponic systems are steril, neutral and have a high capability of holding moist and nutrient solution, and good drainage of solution excess
- There are different hydroponic ssytems by the way the nutrient solution is delivered
- Growing medicinal and aroamtic plants in hydroponic systems need a rigourous monitoring and good knowledge on plants biology and cultivation technology in order to have the best relation between the type of the system and plant
- Medicinal plants cultivated in hydroponic systems resulted in higher concentrations of bioactive substances than those cultivated in soil
- The aromatic herbs grown in hydroponic systems have signifently more flavour and aroma than those cultivated in soil

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