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Biological and Economic Feasibility of Growing Mint (*Mentha sylvestris* L.), Mustard (*Brassica integrifolia* L.) and *Asamodagam* (*Trachyspermum involucratum* L.) under Hydroponics

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ABSTRACT. *As the demand for herbal medicines is growing at an increasing rate, it has become essential to commercially cultivate medicinal plants to enhance safety and quality of the herbs and to prevent biodiversity and habitat loss because larger proportion of medicinal plants comes from the wild. In this study biological and economical feasibility of hydroponically growing three highly demanded medicinal plants in Sri Lanka, namely mint, mustard and asamodagam were evaluated against soil cultivation in a planthouse experiment. Leaf area, dry matter accumulation shoot:root ratio and nitrogen (N), phosphorus (P) and potassium (K) contents were significantly higher in hydroponically grown plants whereas leaf:stem ratio was significantly higher in soil grown plants. Mean number of pods per plant and number of seeds per plant were higher in hydroponically grown mustard 1.5 and 1.7 times, respectively. Hydroponically grown mint and asamodagam yielded twice higher plant fresh weight than that of soil grown counterparts. Oil yields of mint were also 2.12 times higher in hydroponically grown plants. These results suggested that growing mint, mustard and asamodagam under normal Sri Lankan climatic conditions hydroponically is biologically and economically more feasible than soil cultivation.*

INTRODUCTION

More than eighty percent of the population in developing countries is primarily dependent on herbal medicine (WHO, 2003). A larger proportion of the local demand for medicinal plants is met through the collection from the wild. This has created an adverse effect on the biodiversity such as species extinction and habitat loss (WHO, 2003). Moreover, due to contaminations and wrong identification of plant species, an alarming health risk has been imposed on the patients relying on traditional medicine (Canterl *et al*., 2005; WHO, 2004). To fulfill the growing demand for safe and quality plant material, commercial cultivation in hydroponic systems can be adopted. It has been shown by many authors (Mairapetyan, 2007; Canterl *et al*., 2005) that many medicinal plants can be successfully grown under hydroponics and can produce three to four times more herbage and essential oil yields than in soil cultivation. Thus, in this study it was investigated whether it is biologically and economically viable to grow medicinal plants hydroponically

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using a simple hydroponic system suitable to Sri Lanka. Three medicinal plant species which have a high demand in Sri Lanka (Abeywardana and Hettiarachchi, 2001) were used for the study.

MATERIALS AND METHODS

The plant house used for growing plants received approximately twelve and half hours of daylight with mean irradiance value of 800 Wm^{-2}. The mean temperature and relative humidity (RH) values were 27.5±5.5°C and 63±7%, respectively. Mint, mustard (*aba*) and *asamodagam* plants were evaluated for their biological and economical feasibility under the commercially available Albert's solution in Sri Lanka (CIC Fertilizers (Pvt) Ltd.) which contained 11% N, 8% P_2O_3, 15% K_2O, 14% CaO and 4% MgO along with S, Fe, Mn, B, Zn, Cu and Mo in balanced form. Electrical conductivity (EC) and pH values along with visual observations for nutrient deficiencies were used to decide when to change the solution.

Regifoam boxes with 50 x 33 x 13 cm^3 (length x width x depth) specification were used. Holes were made in the regifoam lids used, in 30 x 20 cm spacing to accommodate five plants per box. Only 2/3 of the regifoam box was filled with the solution to ensure the presence of adequate air inside the box so that a special aeration mechanism was not necessary as we have used a static system. Net cups, filled with coir dust were used to place the plant roots into the solution as well as to provide anchorage. One healthy plant was transferred per net cup from the seedling tray.

As the control, the same species were grown in soil with initial EC of 43 mS/m, pH of 7.1 and N, P and K values of 7.224 mg/100g, 1.548 mg/100g and 0.118 mg/1g, respectively under the same conditions in black polythene (gauge 500) bags which were 20cm in height and 15cm in diameter. Twenty five bags were prepared for each species and one healthy plant was transferred per bag from the seedling tray. Soil was mixed with dried cattle manure in 1:1 ratio. Fertilizer applications were done according to Department of Agriculture (DOA) recommendations where nitrogen, phosphorus and potassium (N, P and K) contents per bag in grams for mustard, *asamodagam* and mint were 1, 1 and 1, 1.5, 0.5 and 0.5, 1.7, 2.5 and 2, respectively. For *asamodagam,* DOA fertilizer recommendation of *Trachyspermum ammi* was used as mentioned above along with sulphur at the rate of 1 g/bag as recommended.

Plants were arranged in completely randomized design and were sampled randomly. All the parameters were measured when the plants were 30, 47 and 64 days old. Four plants were taken each from hydroponic cultured and soil grown plants for destructive sampling. Leaf area, dry matter accumulation, dry matter partitioning and chlorophyll a, b and total chlorophyll contents were estimated to evaluate the biological feasibility. Leaf area was measured using a leaf area meter (LI-3050A, LI-COR, USA) in square centimeters. Dry matter accumulation was quantified by obtaining dry weights of plants at 80°C for 72 hrs in a dry oven. Dry matter partitioning to shoots and roots was estimated by calculating shoot:root and leaf:stem ratios in dry weight basis. Total chlorophyll contents were measured using the chlorophyll meter (SPAD 502, Minolta, Japan) and the results were confirmed using the spectrophotometric method suggested by Witham *et al.* (1971). N, P and K levels of the plants were determined by modified micro-Kjeldhal method (Horneck and Miller, 1998), spectrophotometry and flame emission spectrophotometry (Miller, 1998), respectively. Youngest mature leaves were sampled for the purpose as suggested by Jones (1998).

Yield parameters were also quantified to evaluate the biological feasibility. Number of pods and seeds and dry weight of seeds were quantified in mustard. In *asamodagam* it was determined by measuring the whole plant fresh weight just before flowering. In mint, fresh weight of leaves and content of essential oils were quantified for the purpose when the plants were 72 days old. Essential oils were extracted using steam distillation and weighed.

Unpaired two sample T-test was performed using GraphPad InStat version 3.0 for Windows XP (GraphPad Software Inc., USA) for all the parameters. Correlation between dry matter accumulation and leaf nitrogen content with mint oil yield was tested by performing Pearson r test using the same software. Economical feasibility was determined by a cost profit analysis per plant basis using current prices.

RESULTS AND DISCUSSION

Leaf area and chlorophyll contents

Leaf area (Table 1) was significantly higher ($P < 0.05$) in hydroponically grown plants (HGPs) than that of soil grown plants (SGPs) whereas chlorophyll contents were not significantly different in any of the plants under both cultivation systems. SPAD meter measurements were also not significantly different from the spectrophotometric values. Carbon partitioning depends on the strength of both source and sink. As the leaf provides the platform for photosynthesis leaf area indicates the strength of the source of a crop. Photosynthesis and dry matter production of a plant is proportional to the amount of leaf area on the plant (Kumar and Purohit, 1996).

Table 1. Mean leaf area (cm^2) of hydroponically grown plants and soil grown plants with age.

Crop	Age (days)					
	30		47		64	
	HGP	SGP	HGP	SGP	HGP	SGP
Mint	458.6[a]	67.3	2573.3[a]	935.3	3433.3[a]	1080.0
Mustard	172.3[a]	30.3	746.6[a]	286.6	1740.0[a]	756.6
Asamodagam	269.4[a]	41.8	983.0[a]	313.1	1484.6[a]	731.2

Note: HGP: hydroponically grown plants, SGP: soil grown plants
* Within a columns, values followed by the same letter are not significantly different at the P = 0.05.

Dry Matter Accumulation and Partitioning

HGPs showed higher dry matter accumulation and shoot: root ratio than that of SGPs (Table 2a and 2b). This was shown to be obvious in hydroponically grown medicinal and non-medicinal crops by many authors (Anver *et al.*, 2005; Mairapetyan, 2007). As the total dry matter production of a plant (biological yield) directly depends on photosynthesis, this is obvious as the leaf area was higher in hydroponically grown mint, mustard and *asamodagam* as shown in Table 1.

Table 2. Mean total dry weight per plant (a), shoot:root ratio(b) and leaf:stem ratio(c) of hydroponically grown plants and soil grown plants with age.

Crop	Age (days)					
	30		47		64	
a. Total Dry Weight per Plant (g)	**HGP**	**SGP**	**HGP**	**SGP**	**HGP**	**SGP**
Mint	14.7[a]	6.9[b]	20.8[a]	10.2[b]	58.4[a]	32.2[b]
Mustard	4.8[a]	1.9[b]	13.7[a]	4.3[b]	17.5[a]	9.0[b]
Asamodagam	2.2[a]	2.9[b]	14.3[a]	6.1[b]	23.2[a]	8.4[b]
b. Shoot : Root Ratio						
Mint	1.7[a*]	1.0[b]	3.2[a]	1.1[b]	2.3[a]	1.98[b]
Mustard	2.31[a]	2.4[a]	3.9[a]	3.3[b]	5.4[a]	3.6[b]
Asamodagam	1.94[a]	2.1[a]	3.9[a]	3.12[b]	7.92[a]	3.42[b]
c. Leaf: Stem Ratio						
Mint	1.19[a]	1.19[a]	0.76[a]	0.89[b]	0.58[a]	0.67[b]
Mustard	1.27[a]	1.31[a]	0.90[a]	0.98[b]	0.72[a]	0.81[b]
Asamodagam	1.17[a]	1.20[a]	1.12[a]	1.20[b]	0.96[a]	0.97[a]

Note: HGP: hydroponically grown plants, SGP: soil grown plants
*Within columns, values followed by the same letter are not significantly different at the P = 0.05.

Since shoot:root ratio represents the proportion of total biomass allocated to shoots, higher values obtained in HG mint and mustard indicates better production of their economically important plant parts as they occur above ground. But in asamodagam, as roots are also medicinally important this is not much advantageous. Leaf:stem ratio (Table 2c) was significantly higher in SG plants than that of HG plants. It has been shown in mint that with increasing growth and herbage yield, leaf:stem ratio goes down (Ram *et al.*, 2006). This may be due to greater senescence of lower leaves due to mutual shading caused by increased crop growth.

N, P and K contents of leaf tissues

N, P and K contents of HGPs were significantly higher than that of SGPs (Figure 1). The differences were highly significant in N contents. But the N, P and K levels of SGPs were well above the sufficiency levels, compared to standards (Munson, 1998). These significantly higher macro elemental contents, especially higher N contents should be one of the major reasons for the vigorous growth in HGPs especially for higher leaf area.

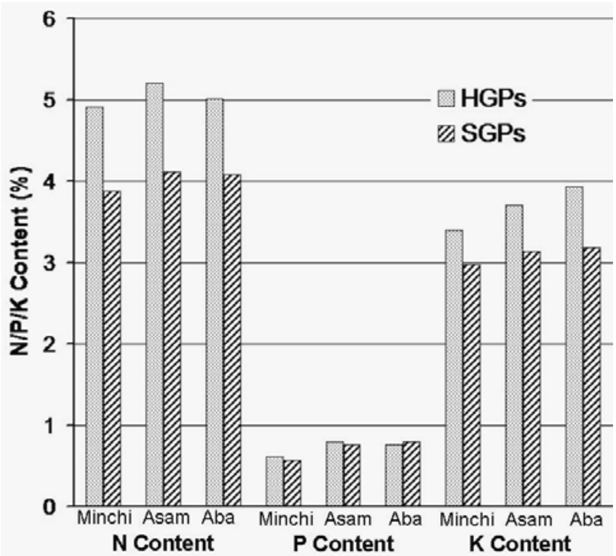

Figure 1. Nitrogen (N), phosphorus (P) and potassium (K) contents of hydroponically grown plants and soil grown plants

Note: Asam - *Asamodagam*.

Yield parameters

Growing mustard under hydroponics was economically feasible, since they showed significantly higher values for yield parameters (Table 3).

Table 3. Mean number of pods and seed dry weight per plant in mustard.

Yield parameter	Hydroponically grown plants	Soil grown plants
Mean number of pods per plant	53	35
Mean seed dry weight per plant (g)	2.854	1.69

In mint and *asamodagam* economically important part is the whole plant in the fresh form. The mean fresh weight per plant was 184.4g and 93.2g for HGPs and SGPs, respectively in mint whereas they were 72.3 g and 31.8 g in *asamodagam*. The yields were 1.98 and 2.27 times higher in HGPs than SGPs in mint and *asamodagam* respectively. This has been supported by the work of many authors (Mairapetyan, 2007). Most commonly used raw material is the fresh herb to produce mint oil. If we can produce large amount of fresh herb in a unit surface it will be more feasible in terms of economy.

Essential oil content in mint and its correlation with other parameters

According to the results HG mint leaves yielded a mean mint oil yield of 104 mg/g leaf fresh weight whereas SG plants yielded only 49 mg/g leaf fresh weight. Similar differences have been reported for *Mentha piperita* L. under field conditions (Annon, 2007). Some authors (Ram and Kumar, 1998) reported that lower leaf:stem ratio and increased herbage production similar to this study (Table 2) are negatively correlated with essential oil contents in menthol mint. However, there are many reports (Ram *et al.*, 2006) to show that herbage yield is positively correlated with essential oil contents as observed in this study ($r = 0.81$).

Monoterpene biosynthesis and accumulation in mint is specifically localized to the glandular trichomes in leaves (Burbott and Loomis, 1969; Gershenzon *et al*., 1989) where the formation of monoterpenes is highly dependent on imported carbohydrates for both carbon and energy (Gershenzon *et al.*, 2000). Moreover, the concentration of monoterpenes in mint depends on the rate of biosynthesis and not on monoterpene catabolism or volatilization (Gershenzon *et al.*, 2000). Thus higher leaf area (Table 1) and better dry matter accumulation and carbon partitioning (Table 2) may have possibly contributed to increase the biosynthesis of essential oils HGPs.

Other than the above parameters, nitrogen content of the plant also influences oil yield although the monoterpenes are of carbohydrate origin (Gershenzon *et al.*, 2000; Ram *et al.*, 2006). The correlation between leaf nitrogen contents and the mint oil yields showed high positive correlation ($r = 0.996$). Limonene synthase enzyme catalyzes the rate limiting step in monoterpene biosynthesis in mint (Turner, 2000). Monoterpene biosynthesis in mint is developmentally regulated and transcriptional and translational activity of limonene synthase genes occur during relatively shorter period of leaf development (Mc Conkey *et al.*, 2000). The deficiency of nitrogen, during this period, will directly affect on transcriptional and translational activity of limonene synthase gene (Turner *et al*., 1999). In hydroponic systems such nitrogen deficiencies are not possible due to continuous supply of nutrients unlike in the soil where localized or short term Nitrogen deficiencies are possible (Anver *et al.*, 2005). Thus the higher essential oil yields shown in Figure 3 are further supported by this fact.

Other than the above, there seemed to be other possible reasons for higher oil yields of hydroponically grown mint. It was shown to be inducible by high light intensities (Canterl *et al*., 2005). In our study the measured mean irradiance inside the plant house was 800 Wm^{-2} (1500 µmol photon $m^{-2}s^{-1}$) which is a far higher value. This could have also played a major role in increasing the quantity of oil in HG mint where there was ample supply of N. It has been also shown that increasing stress conditions could have negative effect on the oil yield. Ram *et al*. (2006) have shown that lower nitrogen and high moisture stress could reduce the amount of oil synthesis in the trichomes. As pointed out earlier such stresses are not possible in hydroponic cultivation systems (Anver *et al.*, 2005) and thus may lead to a greater oil yield in HG mint.

Economic Feasibility

Economic feasibility of growing mint is only worked out here as shown in Table 4 as the cultivation systems used were same for all the three species. The price of fresh mint per kg is Rs.52.00 and Rs.300.00 in local and super markets respectively. The initial cost incurred in installation of a hydroponic system (capital expenditure) is higher compared to soil cultures. Thus initial cost per plant in hydroponics is estimated to be nearly Rs.22.35 if the simple and easily adoptable form is considered as experimented. The labor costs and the capital expenditure for a plant house were not included in these calculations.

Table 4. Profit margin of mint per plant (in Rs.) for hydroponically grown plants and soil grown plants.

Season	Cost of Production		Profit at LMP*		Profit at SMP*	
	HGPs	SGPs	HGPs	SGPs	HGPs	SGPs
1	22.35	9.68	-12.77	-4.83	32.97	18.28
2	3.35	9.68	6.23	-4.83	51.97	18.28
3	3.35	9.68	6.23	-4.83	51.97	18.28

Note: HGP: hydroponically grown plants, SGP: soil grown plants, LMP: Local Market Price; SMP: Super Market Price; * Profits calculated based on mean fresh weight yields of HGPs and SGPs.

Even though this indicates a higher initial cost for hydroponic systems which appears as a drawback, it can be covered easily with its higher income margin in the long run as shown in Table 4 as the system could be used for more than ten seasons. Moreover, the super markets are highly concerned on quality of products. Thus hydroponic systems will be a better solution for them where plants can be sold with the containers in the fresh form along with the hydroponic solution for even a better price. It will be a value addition for the product.

CONCLUSIONS

Growing mint, mustard and asamodagam under the commercially available Albert's solution is biologically feasible and more profitable. As the Albert's solution used in the study is easily available for a reasonable price and regifoam boxes could be used, as the hydroponic container, cultivation of theses medicinal crops is possible at the household level for part time growers. Higher quantities of essential oil could be extracted from mint plants grown hydroponically approximately under 12 and half hours of mean light values of 800 Wm^{-2} which is naturally available in most parts of Sri Lanka.

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