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Effects of Different Hydroponics Systems and Growing Media on the Vegetative Growth, Yield and Cut Flower Quality of Gypsophila (*Gypsophila paniculata* L.)

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Abstract: Horticultural production in most parts of the tropics is extremely difficult due to high rate of infection by the soil-borne diseases. At the moment, utilization of hydroponics systems for the commercial production of crops is very limited. This study, therefore, attempted to investigate the potential of growing gypsophila using different hydroponics systems. The experiments were laid out in a split-plot design. Three hydroponics systems were used as the main plots, i.e. elevated tray, ground lay bed and bag culture systems. The sub-plots were allocated to three different aggregate/medium components, i.e., sawdust, river sand and vermiculite. Throughout the production period, plants grown using river sand had the lowest plant height. The highest plant height (52.9 cm) was obtained from plants grown in vermiculite at 12 weeks after transplanting (WAT). Plant height of gypsophila plants grown using sawdust at 12 WAT was almost double that of those grown using sand. There was a significant ($P < 0.05$) reduction in number of shoots/plant in gypsophila grown in sand medium in all three hydroponics systems. The highest number of shoots/plant was obtained from plants grown in sawdust in all hydroponics systems. The highest cut flower stem length (67.0 cm) was obtained from plants grown in sawdust in the bag culture hydroponics system, while the lowest cut flower stem length (25.0 cm) was observed in plants grown in sand in the elevated tray hydroponics system. The highest number of branches/plant was generally observed in plants grown in the bag culture hydroponics system when compared to the elevated tray and ground lay bed hydroponics systems. For the hydroponics culture of gypsophila, sawdust should be used as growing medium. To induce highest vegetative growth, flower yield and quality, the plants should be grown using bag culture hydroponics system.

Key words: Gypsophila · Hydroponics · Media · Vegetative growth · Cut flower yield · Cut flower quality

INTRODUCTION

Gypsophila belongs to the Caryophyllaceae Family. The genus *Gypsophila* contains about 125 species of annual, biennial and perennial plants. They originated from Turkey, Ukraine and Iran [1]. The species G*ypsophila paniculata* is grown worldwide as a commercial filler cut flower, bedding plant or as potted plant. It has low nutrient requirement. Fertiliser application in field production is rarely necessary. It is relatively salt stress resistant. It can be used for fresh or dried flower arrangements.

The growing of ornamental plants has expanded the horizon from being mere objects of hobbyists, to products of lucrative business. In the present-day world, floriculture trade is one of the most rapidly expanding and dynamic global enterprise. Flower plants provide better income from a unit area with higher profitability as compared to fruits and vegetables. Floriculture has become a money-spinner for most Third World countries like Kenya, Zimbabwe, Zambia, Uganda, Tanzania among others [2]. Apart from domestic use, which is usually limited, many kinds of flowers and ornamental plants are grown for export by the various developed and developing countries. Increased awareness about ornamental plants can encourage many innovative and progressive growers and entrepreneurs to take up their cultivation as a commercial enterprise. Concerted efforts towards adoption, cultivation and marketing of indigenous ornamental plants can boost exports.

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Hydroponics is the growing of plants without soil [3]. It can also be defined as the science of growing plants using a solution of suitable nutrients instead of soil [4]. This can either be through the use of non-soil growing medium or no growing medium at all. The plants thrive on the nutrient-water solution alone. The growing medium, if any, is totally inert and merely acts as a support for the plants and their root systems, while the nutrient solution passes freely [5].

The earliest recordings of hydroponics in use were in the Hanging Gardens of Babylon where plants were grown in a steady stream of water [6]. Hydroponics has been used for over a century as a research technique, but not until 1929 were experiments conducted solely to determine its feasibility for growing commercial crops [7]. With the first successful application of hydroponics techniques in the 1930's, the stage was set for a paradigm shift in crop production from conventional cultivation in soil to soilless cultivation [8]. The first crops to be commercially grown in hydroponics included tomato and pepper. Nowadays, virtually any plant can be grown hydroponically, but some will do better than others. Hydroponics growing is ideal for fruit vegetables like tomato, cucumber and pepper; leafy vegetables like lettuce and herbs; as well as ornamental plants [6].

During World War II, the US army used hydroponics to grow fresh tomato and lettuce for troops stationed on infertile lands on the Pacific Islands [6, 9]. By the 1950's, there were viable commercial farms operating in USA, Britain, Africa and Asia [6]. In 1981, rockwool was used in Australia for the hydroponics culture of cut flowers [6]. Hydroponics technology can be used to generate food crops from almost anywhere, including the Artic, city roof-tops, barren deserts sand, space stations and where land is very expensive [9].

Although hydroponics is possible for most plant species, a limiting factor is the amount of physical support required. There are several different types of hydroponics system, but all share the same basic method of supplying the plants with nutrients and water. Hydroponics is perhaps the most intensive method of crop production in today's agricultural industry [10]. It uses advanced technology, is highly productive, conserves water and land, protects the environment and is often capital intensive. Since regulating the aerial and root environment is a major concern in such agricultural systems, production takes place inside enclosures that give control of air and root temperature, light, water, plant nutrition and protection against adverse climatic conditions.

Hydroponics offers opportunities to provide optimal conditions for plant growth and therefore, higher yields can be obtained using it compared to open field production [11]. It offers a means of control over soil-borne diseases and pests, which is especially desirable in the tropics where the life cycles of these organisms continue uninterrupted and so do the threat of infestation. Thus, the costly and time-consuming tasks of soil sterilisation, soil amelioration etc. can be avoided with hydroponics cultivation [11-13].

Under hydroponics, some plants can be grown closer together than in the field because roots are directly fed; thereby increasing yields per unit area and multiple cropping can be practised. Plants grow faster because they get all the nutrients they need in the proper amounts and proportions. In soil, plants develop a large root system to enable them search for nutrients and water. In hydroponics, nutrients and water are provided directly to the roots. This enables the plants to achieve higher growth of the shoot system, producing more vegetation, larger fruits, flowers and other edible parts. In addition to conserving space, hydroponics almost eliminates weed and soil-pest problems [7]. Plants in hydroponics grow up to two times faster with higher yields than with conventional soil farming methods due to high oxygen levels to the root system, optimum pH levels for increased nutrient and water uptake and optimum balanced and high grade nutrient solutions [7, 14-15].

In rapidly changing world of hydroponics technology, yields higher than never realised before are possible. Consistent efforts have been made to develop simple, labour- and cost-efficient hydroponics systems [16]. Hydroponics growing systems have been developed to get higher yield and quality, to preserve water and land, to save labour and to protect the environment through reduced use of pesticides. Important advantages of hydroponics culture, especially the closed systems, are the excess nutrient solution is recovered, management and reduction of waste material, less pollution of ground and surface water, a more efficient use of water and fertilisers, the buffer capacity for making mistakes and lower costs [17].

Growing plants in soil is unpredictable due to changing temperatures, moisture holding capacity, availability of nutrients, root aeration, disease and pest problems [6, 18-20]. Hydroponics alleviates some of these problems of nature while giving the farmer precise control of the plants and, often, the environment in which they grow. Melgarejo *et al*. [21] showed that hydroponics culture of Fig (*Ficuscarica* L.) resulted in higher profitability when compared to conventional farming. They obtained an 18-fold increase in fig fruit yield compared to traditional farming. In addition, they observed a 90% reduction in water use by applying hydroponics culture. Correa *et al*. [22] reported a higher tuber yield in potato grown in hydroponics when compared to conventional system. They attributed the higher tuber yield to uninterrupted and optimal nutrient and water supply in hydroponics culture. In addition to the higher nutrient availability in hydroponics systems, it is also possible to monitor and control solution pH and electrical conductivity (EC).

Hydroponics growing systems have been developed to get higher yield and quality, to preserve water and land, to save labour and to protect the environment [17]. Yields with hydroponics have averaged around 20 to 25% higher than in conventional cultivation [8]. Hydroponics and greenhouse yields are commonly five times the field yield for a two crop per year field harvest and 10 times the field yield for a one crop per year field harvest [9, 23]. In addition, since hydroponics plants have access to unlimited nutrition and water, they can grow up to 10 times faster and healthier than soil grown ones [24]. Growth rate of tomatoes in hydroponics culture is 30-50% faster than a soil grown plant, under the same conditions and the yield is also higher [9].

Hydroponics systems include aggregate culture system, where solid, inert materials such as peat, vermiculite, or a combination of both, coconut coir, sawdust, sand, gravel, rockwool, diahydro, expanded clay, perlite, brick shards and polystyrene or marbles supports the plant roots may be used [4, 7, 15, 25]; aeroponics; Nutrient Flow Technique (NFT); bag culture system etc.

MATERIALS AND METHODS

Experimental Site: The investigations were carried out in the greenhouse of the Horticulture Department, Faculty of Agriculture, Luyengo Campus of the University of Swaziland. The site is located at Luyengo, Manzini Region in the Middleveld agro-ecological zone. Luyengo is 26° 34’ S and 31° 12’ E. The average altitude of this area is 750 m above sea level. The mean annual precipitation is 980 mm with most of the rain falling between October and March [26-27].

Experimental Design: The experiment was laid out in a split-plot design. Three hydroponics systems were used as the main plots, i.e. elevated tray, ground lay bed and bag culture systems. The sub-plots were allocated to three different aggregates/ medium components, i.e., sawdust, river sand and vermiculite. The description of the treatments is shown in Table 1.

Table 1: Description of the treatments

Treatment code	Type of treatment
1	Elevated tray system + sawdust
2	Elevated tray system + sand
3	Elevated tray system + vermiculite
4	Ground lay bed system + sawdust
5	Ground lay bed system + sand
6	Ground lay bed system + vermiculite
7	Bag culture system + sawdust
8	Bag culture system + sand
9	Bag culture system + vermiculite

The sand and gravel was first sieved to ensure uniformity of the aggregates. The treatments were replicated four times. A total of 36 plots were used in this investigation. Four tables for the elevated tray, four beds for the ground lay and four rows for the bag systems were used (main plots). Each table or bed was applied with river sand, sawdust and vermiculite (sub-plots). Each bed or table was divided into two plots (replications).

Plant Materials: Gypsophila seeds were obtained from Carter’s Garden Centre, Mbabane, Swaziland. The seeds were germinated in seed trays in the greenhouse using compost and transplanted five weeks after germination. At transplanting, compost around the roots of the seedlings was gently removed using running tap water. The seedlings were transplanted to the different treatments as described in Table 1. After transplanting, the plants were supplied with the nutrient solution. During the culture of gypsophila plants, insect pests were controlled by use of dimethoate and fungal diseases by use of bravo.

Preparation of Nutrient Solution: The nutrient solutions were prepared using calcium nitrate fertiliser, Omnia, Nutriology, Republic of South Africa (RSA) (155 g/kg N and 195 g/kg Ca) and Hydrogro, water soluble hydroponics fertiliser mix, Ocean, Muldersdrift, RSA (Total N 64 g/kg [NH_4-N 10 g/kg, NO_3-N 54 g/kg], P 45 g/kg, K 239 g/kg, Mg 31 g/kg, S 59 g/kg, Cl 15 g/kg, Fe 1,680 mg/kg, Mn 400 mg/kg, B 500 mg/kg, Cu 30 mg/kg and Mo 50 mg/kg). The calcium nitrate was used between Monday and Wednesday and Hydrogro used for the rest of the week. The concentration of both fertilisers was 1.0 mS/cm for the first one month and then increased to 2.0 mS/cm thereafter. The same concentration of nutrients was used in all the systems. The nutrient solution was maintained at the pH range of 6.5–7.0. Potassium hydroxide was used to raise the pH of the nutrient solution if lower than the optimal pH range, while phosphoric acid was used for reducing it, if higher.

Table 2: Effects of different hydroponics systems and growing media on the plant height of gypsophila

Hydroponics system	Growing media	Weeks after transplanting 2	4	6	8	10	12
Elevated tray	Sawdust	12.2a	15.2a	18.1ab	22.3a	33.9a	39.4a
	Sand	11.4a	14.2a	15.3b	16.6b	18.9c	20.8c
	Vermiculite	11.9a	16.5a	20.4a	23.6a	27.4b	30.3b
Ground lay	Sawdust	9.3a	13.5a	17.7a	21.4a	29.1a	31.8a
	Sand	9.4a	13.2a	16. 4a	19.5a	26.3a	28.4a
	Vermiculite	10.9a	16.0a	19.9a	23.9a	29.5a	32.4a
Bag culture	Sawdust	10.0a	19.1a	29.2a	36.9a	44.2a	48.7a
	Sand	9.9a	16.8a	26.3a	32.3a	42.0a	45.7a
	Vermiculite	10.1a	18.1a	29.7a	37.1a	48.0a	52.9a

Means followed by same letter along columns for each hydroponics system not significantly different at5% level. Mean separation by DNMRT

Data Collection: A random sample of five plants per plot (replicate) was used for data collection. The data collection was non-destructive, and the same plants were used throughout the duration of the experiments. The data collected included: plant height and number of shoots/plant. These parameters were determined after every two weeks between two and 12 WAT. Flower harvesting was performed when all the buds were opened, i.e., 13 WAT. Quality of the cut flowers was determined by the length of the flower stem and number of branches/flower.

Data Analysis: Data collected were subjected to analysis of variance (ANOVA) using the Statistical Programme for the Social Sciences (SPSS). Mean separation was performed using the Duncan's New Multiple Range Test (DNMRT) at 5% level of significance [28]. Interaction between hydroponics systems and different aggregates used was statistically determined using the SPSS programme.

RESULTS AND DISCUSSION

Plant Height: Between 2 and 8 WAT in the elevated tray system, gypsophila plants grown using vermiculite had higher plant height when compared to those grown in sawdust and river sand (Table 2). Throughout the production period, plants grown using river sand had the lowest plant height (Table 2). There was no significant ($P < 0.05$) difference in plant height of plants grown under different media up to 4 WAT. The highest plant height (39.4 cm) was obtained from plant grown using sawdust at 12 WAT. The lowest plant height (20.8 cm) was obtained from plants grown using river sand (Table 2). Plant height of plants grown using sawdust at 12 WAT was almost double that of those grown using sand. From 2 to 12 WAT, plant height increased more than three fold in plants grown using sawdust but less than double in those grown using sand.

In the ground lay bed hydroponics system, gypsophila plants grown using vermiculite had the highest plant height from 2 to 12 WAT (Table 2). The lowest plant height during the same period was recorded in plants grown using river sand. There was no significant ($P < 0.05$) difference in plant height in plants grown under the different growing media at all stages of determination. The highest plant height (32.4 cm) was obtained from plants grown using vermiculite at 12 WAT and the lowest (28.4 cm) from those grown using sand.

In the bag culture hydroponics system, the highest plant height of gypsophila was observed in plants grown using vermiculite from 6 to 12 WAT (Table 2). From 2 to 12 WAT, the lowest plant height was obtained from plants grown using sand (Table 2). However, there was no significant ($P < 0.05$) different in plant height at the different stages of determination in plants grown under different growing media. The highest plant height (52.9 cm) was obtained from plants grown in vermiculite at 12 WAT and the lowest (45.7 cm) from those grown using sand. Plants grown in bag culture hydroponics system exhibited higher plant height when compared to elevated tray and ground lay bed hydroponics systems (Table 2).

Correa *et al*. [23] reported a higher tuber yield in potato grown in hydroponics when compared to conventional system. They attributed the higher tuber yield to uninterrupted and optimal nutrient and water supply in hydroponics culture. The higher plant height obtained from gypsophila grown using sawdust and vermiculite in this investigation could be attributed probably to better physical environment in terms of aeration and nutrient holding capacity, which probably enhanced root and shoot growth. Growing media containing organic matter like coco peat can stimulate root growth and provide high water holding capacity, which provide a buffer in high temperatures and crop load demand without compromising air supply [29]. The high plant height observed in gypsophila grown using sawdust when compared to sand under all hydroponics systems in this investigation can also be attributed to the same attributes.

Table 3: Effects of different hydroponics systems and growing media on the number of shoots/plants of gypsophila.

Hydroponics system	Growing media	Number of shoots/plant	Cut flower stem length	Number of branches/flower
Elevated tray	Sawdust	12.4a	44.0a	18.3a
	Sand	9.6b	25.0b	7.7b
	Vermiculite	12.3a	48.5a	15.1a
Ground lay	Sawdust	11.7a	51.9a	17.5a
	Sand	8.1b	29.4b	12.4a
	Vermiculite	10.1ab	51.3a	14.0a
Bag culture	Sawdust	14.3a	67.0a	34.2a
	Sand	10.8b	44.3b	13.6b
	Vermiculite	14.4a	61.2a	36.1a

Means followed by same letter along columns for each hydroponics system not significantly different at 5% level. Mean separation by DNMRT

Number of Shoots/Plant: There was a significant ($P < 0.05$) reduction in number of shoots/plant in gypsophila grown in sand in all three hydroponics systems (Table 3). However, there was no significant ($P < 0.05$) difference in number of shoots/plant between the plants grown in sawdust and vermiculite in all hydroponics systems (Table 3). The highest number of shoots/plant was obtained from gypsophila grown in sawdust in all hydroponics systems. There was a more than 20% reduction in number of shoots/plant between gypsophila grown in sawdust and those grown in sand. The difference in number of shoots/plant between plants grown in sawdust and vermiculite in elevated tray and bag culture hydroponics systems was only 0.1 cm. Gypsophila grown in bag culture hydroponics system had generally higher number of shoots/plant while the lowest number of shoots/plant was observed in plants grown in ground lay bed hydroponics system (Table 3).

High water holding capacity induced higher vegetative growth in hydroponics culture of ornamental plants like Oriental hybrid lily (*Liliumasiatic*) [30]. *Tageteserecta*, *Salvia splendens, Scaevolaaemula* and *Verbena hybrida* [31]. The higher number of shoots/plant observed in gypsophila grown using sawdust and vermiculite in this investigation could probably be attributed to higher vegetative growth as a result of high water holding capacity.

Cut Flower Stem Length: There was a significant ($P < 0.05$) reduction in cut flower stem length in gypsophila grown in sand in all hydroponics systems when compared to sawdust and vermiculite (Table 3). There was no significant ($P < 0.05$) difference in cut flower stem length between the plants grown in sawdust and vermiculite in all hydroponics systems (Table 3). The highest cut flower stem length (67.0 cm) was obtained from plants grown in sawdust in the bag culture hydroponics system, while the lowest cut flower stem length (25.0 cm) was observed in plants grown in sand in the elevated tray hydroponics system. In the ground lay and bag culture hydroponics systems, the highest cut flower stem length was obtained from plants grown using sawdust. Growing gypsophila in sand in all hydroponics systems resulted in more than 30% reduction in cut flower stem length. The difference in cut flower stem length in gypsophila grown using sawdust and vermiculite in the bag culture hydroponics system was just 5.8 cm.

Schnitzler *et al.* [16] observed better plant growth, fruit yield and quality in bell pepper (*Capsicum annuum* L.) grown in wood fibre substrate. The higher cut flower stem length observed in gypsophila grown using sawdust and vermiculite in this study could probably be attributed to their higher nutrient holding capacity as compared to sand. Inden and Torres [17] reported that utilisation of rockwool and perlite in hydroponics culture results in higher yields as compared to other inert materials. Although sand is cheap and easily available, it is heavy and does not drain well [4]. This reduced drainage in sand probably caused the significant reduction in cut flower stem length when compared to plants grown in sawdust and vermiculite.

High quality cut flowers of oriental hybrid lily were obtained in solid medium hydroponics system when compared to mist culture system [30]. They observed that broken chaff substrate, which had high water absorption and water holding capacity induced higher quality lily cut flowers as compared with chaff, hydro-ball or carbonised chaff substrate. Hsu *et al.* [32] grew *Oncidium* orchids in rockwool, sphagnum peat moss and mixed medium containing crushed stone, bark and charcoal. They found that pseudobulbs mass, root activity, cut flower quality (flower length, floret number) and number of shoots were higher in rockwool compared to other media. A similar significant ($P < 0.05$) difference was observed in cut flower stem length in gypsophila grown using different aggregates in this investigation.

Number of Branches/Flower: There was a significant ($P < 0.05$) reduction in number of branches/flower in gypsophila grown in sand when compared to those grown in sawdust and vermiculite in all hydroponics systems (Table 3). However, there was no significant ($P < 0.05$) difference in number of branches/flower between the plants grown in sawdust and vermiculite in all hydroponics systems (Table 3). The highest number of branches/flower (36.1) was obtained from plants grown using vermiculite in the bag culture hydroponics system, while the lowest number of branches/flower (7.7) from those grown in sand in the elevated tray hydroponics system (Table 3). The highest number of branches/plant was generally observed in plants grown in the bag culture hydroponics system when compared to the elevated tray and ground lay bed hydroponics systems (Table 3). There was up to 62% reduction in number of branches/flower in plants grown using sand when compared to other growing media. However, the difference in number of branches/flower between plants grown in sawdust and vermiculite in bag culture hydroponics systems was just 1.9.

High number of branches/flower of gypsophila grown using sawdust and vermiculite could probably be due to higher water holding and nutrient holding capacities of the medium as compared to sand. Hsu *et al*. [32] observed a higher flower stem length and number of flowers per stem in Oncidium orchids (*Oncidiumaltissimum*) grown using rockwool when compared to peat moss, crushed stone, bark and charcoal. Inden and Torres [17] reported that utilisation of rockwool and perlite in hydroponics culture of tomato results in higher yields as compared to other inert materials.

CONCLUSIONS

The highest vegetative growth of gypsophila in terms of plant height was obtained from plants grown using vermiculite in ground lay and bag culture hydroponics systems. However, the highest number of shoots/plant was observed in plants grown using sawdust under all hydroponics systems. The lowest plant height and number of shoots/plant were obtained from plants grown using sand under all hydroponics systems. The highest plant height and number of shoots/plant were observed in plants grown under bag culture hydroponics system when compared to the elevated tray and ground lay bed hydroponics systems. The highest quality cut flowers in terms of stem length and number of branches/flower were obtained from plants grown using sawdust and under bag culture hydroponics system. For the hydroponics culture of gypsophila, sawdust should be used as growing medium. To induce highest vegetative growth, flower yield and quality, the plants should be grown using bag culture hydroponics system.

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