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Evaluating different Hydroponics Systems for Growth, Flowering and Quality of Gladiolus (*Gladiolus grandiflorus*)

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ABSTRACT

The contribution of floriculture towards both small-scale and large-scale farm incomes, employment opportunities and foreign exchange earning has experienced un-precedented growth in recent years. The aim of this investigation was to determine the effects of different hydroponics systems and growing medium components on growth, yield and quality of gladiolus. 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 hydroponics systems. The sub-plots were allocated to the different medium components i.e., crushed stone, sawdust, sand and vermiculite. The highest plant height (91.7 cm) was observed in 'Praha' grown using sawdust. A reduction in plant height of about 42 and 30% was observed between 'Nagarit' and 'Praha' grown in crushed stone and sawdust, respectively. Gladiolus plants in the bag culture hydroponics system had higher plant height than in the other systems. 'Traderhorn' and 'White Friendship' flowered only, when grown using sawdust. However, all plants of 'Praha' flowered, when grown using all the medium components. The highest number of flowers per spike for 'Praha' (27.8), 'Traderhorn' (17.0) and 'White Friendship' (18.4) was observed in plants grown using sawdust. The highest cut flower stem length for 'White Friendship' (104.0 cm) was obtained from plants grown using sawdust in bag culture hydroponics system. For the hydroponics culture of gladiolus, bag culture hydroponics system may be used with sawdust as growing medium.

Key Words: Gladiolus; Hydroponics; Plant height; Flowering; Flower stem length

INTRODUCTION

Gladiolus (*Gladiolus glandiflorus* L.) is a native of sub-saharan Africa, mostly South Africa (Gardenshop, 2008; Hickman, 2008; Milandri *et al*., 2008; Riaz *et al*., 2009). It is one of the world's leading cut flowers, but is also used as a bedding plant (Milandri *et al*., 2008). Gladiolus plants and corms are susceptible to diseases caused by fungi, bacteria and viruses (Pfleger & Gould, 2008). One of the most destructive diseases of Gladiolus is Fusarium rot caused by *Fusarium oxysporium* f. sp *gladioli*, a soil-borne fungus (Pfleger & Gould, 2008). Plants growing from infected corms may develop arching young stalks or premature yellowing of leaves and faded flower colours. Often, plants are stunted and fail to bloom.

Hydroponics is growing plants without soil (Dan, 2007), or defined as the science of growing plants using a solution of suitable nutrients instead of soil (Hydroponics Gardening Information, 2007). 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 solution passes freely (Anonymous, 2006).

Hydroponics is perhaps the most intensive method of crop production in today's agricultural industry (Jensen, 2008). It uses advanced technology, is highly productive, conserve water and land, protects the environment and is often capital intensive. Hydroponics offers opportunities to provide optimal conditions for plant growth and therefore, higher yields can be obtained, when compared to open field production. 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 continues un-interrupted and so does the threat of infestation. Thus, the costly and time-consuming tasks of soil sterilisation, soil amelioration etc can be avoided with hydroponics cultivation (Jensen, 2008; Techinformation, 2008).

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

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and other edible parts. 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 (Anonymous, 2007; Ghazvini *et al.*, 2007; Infoplease, 2007; ShamanShop, 2007).

Horticultural production in most countries, especially in summer is extremely difficult due to high rate of infection by the soil-borne diseases. Large-scale production of gladiolus and other bulbous cut flowers, especially in open fields is hindered by attacks by soil-borne diseases. Currently, utilisation of hydroponics systems for the commercial production of crops in Swaziland and most other developing countries is very limited. Hydroponics culture of gladiolus and other susceptible bulbous cut flowers can facilitate their successful and profitable production. The aim of the study was to determine the influence of different hydroponics systems and medium components on the vegetative growth, yield and quality of gladiolus cut flowers.

MATERIALS AND METHODS

Experimental site: The investigations were carried out in the greenhouse in 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 (FAO, 2006a & b).

Experimental design: 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 hydroponics systems. The sub-plots were allocated to the different medium components i.e., crushed stone, sawdust, sand and vermiculite.

The hydroponics systems were supplied by FlowGrow Hydroponics (PTY) Ltd, Crestholme, Kwazulu Natal, Republic of South Africa. The elevated tray system consisted of 115 cm-wide trays divided into two 50 cm-wide partitions. Each partition had a water tap in the middle on the upper side. The trays were 200 cm long and 8 cm deep. On the lower side of the tray was the drainage outlet, one on each side of the partition. The trays were 92 cm high on the backside and 87 cm on the front side. The nutrients and/or water were pumped to the elevated trays by a submersible pump, which was placed into a 2000 L tank. The inlet pipes had gate valves for regulating water application. Surplus water returned to the tank by gravity through the drainage pipes.

The ground lay beds had two 45 cm-wide partitions. They had a water tap in the middle of each partition on the upper side. On the lower side, they had drainage opening again in the middle of each partition. The beds were 7 m long and 8 cm deep. The slope of the beds was 1:40. The nutrients and/or water were pumped to the ground lay beds by a sub-mersible pump, which was placed into a 2000 L tank. The inlet pipes had gate valves for regulating water application. Surplus water returned to the tank by gravity through the drainage pipes.

The bag culture hydroponics system consisted of black plastic bags (16 L) filled with the four different media components. Drip irrigation system was used to supply the plants with water and nutrients. Two bags were placed at each station. Each bag was supplied by two drippers. The nutrients and/or water were pumped to the bags by a submersible pump, which was placed into a 2000 L tank. This system was non-circulating. The inlet pipes had gate valves for regulating water application.

The sand and gravel were first sieved to ensure uniformity of the aggregates. The treatments were replicated four times. Four tables for the elevated tray system, four beds for the ground lay and four drip lines, each with 60 drippers (two drippers for each pot), for bag culture systems were used (main plots). Each table, bed or bag was filled with gravel, sand, sawdust and vermiculite (sub-plots). Each bed or table was divided into four plots of 1.0 x 1.0 m (replications).

Plant materials: Gladiolus corms were obtained from Carter's Garden Centre, Mbabane, Swaziland. They consisted of four varieties: 'Traderhorn' (red) 'White Friendship' (white), 'Nagarit' (orange) and 'Praha' (pink). The corms were planted in one row in the middle of the elevated tray and ground lay beds at a spacing of 15 cm. A single corm was planted per pot in the bag culture hydroponics system. The plants were supported as they grew by tying them with strings on wire trellis. During the culture of gladiolus plants, insect pests were controlled by use of Malathion and fungal diseases were controlled by use of Bravo. The experiment was conducted from December, 2008 to March, 2009.

Preparation of nutrient solution: The nutrient solutions were prepared using calcium nitrate fertiliser, Omnia, Nutriology, RSA (155 g/kg N & 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, & 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 treatments. 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.

Data collection: A random sample of five gladiolus plants per plot was used for data collection. The data collection

was non-destructive and the same plants were used throughout the duration of the experiments. Plant height was determined every week from third to ninth week after planting. Cut flowers were harvested, when all the flower buds were opened. After harvesting, the number of flowers per spike was counted and the cut flower stem length determined. Harvesting of cut flowers began in February, 2009.

Data analysis: Data collected was subjected to analysis of variance using the Statistical Programme for the Social Sciences (SPSS) programme. Mean separation was performed using the Duncan's New Multiple Range Test (DNMRT) at 5% level of significance (Steel *et al*., 1997). Interaction between hydroponics systems and medium components used was statistically determined using the SPSS programme.

RESULTS AND DISCUSSION

Plant height: In the elevated tray hydroponics system, 'Nagarit' had significantly ($P < 0.05$) lower plant height from week 3 to 9 as compared to 'Traderhorn', 'White Friendship' and 'Praha', when grown using crushed stone (Fig. 1). 'Nagarit' reached a maximum plant height of 51.4 cm in week 9. The highest plant height of 88.1 cm was obtained from 'Praha' determined nine weeks after planting. The second highest plant height was observed in 'Friendship', but was not significantly ($P<0.05$) different from that of 'Praha'. The difference in plant height between 'Nagarit' and 'Praha' was more about 37 cm, a reduction of about 42%.

Similarly, in the plants grown using sawdust, 'Nagarit' had the lowest plant height from week 3 to 9, when compared to the 'Traderhorn', 'Friendship' and 'Praha' (Fig. 1). The highest plant height too, was recorded from 'Praha' (91.7 cm) in week 9, followed by 'White Friendship' with 87.1 cm. The difference in plant height between 'Nagarit' and 'Praha' was about 28 cm, a reduction of about 30%. Plants grown in sawdust had a slightly higher plant height than those grown using crushed stone (Fig. 1).

In the plants grown using sand, 'Nagarit' exhibited the lowest significant ($P < 0.05$) plant height compared to the other three varieties (Fig. 1). Similarly, the highest plant height (33.9 cm) was observed from 'Praha'. 'Nagarit' reached a maximum height of 15.9 cm, which was almost half that of 'Praha'. Miller (2008) reported that not all cultivars of tulips are adapted to hydroponics production. Sanchez-Garcia *et al.* (2004) also found significant variations in plant height in the hydroponics culture of different cultivars of Alstroemeria. The plant height of gladiolus grown in sand was almost three times lower than those grown in crushed stone and sawdust (Fig. 1).

In the plants grown in vermiculite, there was no significant ($P < 0.05$) difference in plant height between the four different varieties from week 3 to 9. However, like in the plants grown using crushed stone, sawdust and sand, the lowest plant height was observed in 'Nagarit' (49.6 cm) and highest in 'Praha' (60.4 cm) in week 9 (Fig. 1). In general, plants grown in sawdust had the highest plant height and lowest found in plants grown in sand (Fig. 1).

In the ground lay bed hydroponics system, the lowest plant height was observed from 'Nagarit' grown in crushed stone (Fig. 2). The highest plant height of 83.0 cm was recorded from 'White Friendship' in week 9. 'Nagarit' reached a maximum plant height of 42.3 cm in week 9, which was almost a half that of 'White Friendship'. 'Praha' had the second highest plant height of 72.1 cm. In the plants grown using sawdust, 'Nagarit' had the lowest plant height from week 3 to 9 (Fig. 2). The highest plant height was obtained from 'Praha' (110.6 cm) in week 9. 'Nagarit' reached a maximum of 72.9 cm, which was a reduction of about 34%, when compared to 'Praha'. In the gladiolus plants grown in sand, there was no significant ($P < 0.05$) difference in plant height among the four varieties from week 3 to 8. However, the highest plant height was observed in 'Praha' (81.7 cm) in week 9, although it was not significantly ($P<0.05$) different from those of 'Nagarit' and 'Traderhorn' varieties (Fig. 2).

In the plants grown in vermiculite, the lowest plant height was again observed from 'Nagarit' from week 3 to 9 (Fig. 2). The highest plant height (108.5 cm) was obtained from 'Praha' in week 9. There was no significant ($P < 0.05$) difference in plant height between 'Traderhorn', 'White Friendship' and 'Praha'. 'Nagarit' reached a maximum height of 82.6 cm, which was a reduction of about 24%, when compared to 'Praha'. In the ground lay bed hydroponics system, the highest plant height was observed in gladiolus plants grown using sawdust, followed by vermiculite and lowest was obtained from plants grown in crushed stone (Fig. 2). High water holding capacity induce higher vegetative growth in hydroponics culture of ornamental plants like Oriental hybrid lily (*Lilium asiatic*) (Ryota *et al*., 2008), *Tagetes erecta*, *Salvia splendens*, *Scaevola aemula* and *Verbena hybrida* (Strojny & Nowak, 2004). The higher plant height observed in gladiolus plants grown using sawdust and vermiculite could probably be attributed to high water holding capacity as compared to sand and crushed stone. According to Salvador and Minami (2004), substrate's most important physical characteristic is the presence of pores able to promote adequate aeration, store and provide water to plants.

In the bag culture hydroponics system, the lowest plant height was obtained from 'Nagarit' grown using crushed stone (Fig. 3). The highest plant height (94.0 cm) was observed from 'Praha'. However, there was no significant ($P < 0.05$) difference in plant height between 'Traderhorn', 'White Friendship' and 'Praha'. 'Nagarit' reached a maximum height of 66.4 cm in week 9, which was reduction of about 30%, when compared to 'Praha'. There was no significant ($P < 0.05$) difference in plant height between the four varieties from week 3 to 6.

In the plants grown using sawdust, the lowest plant height was again observed in 'Nagarit' from week 3 to 9

Table I: Number of flowers per spike of different gladiolus varieties grown in different hydroponics systems and medium components

Growing medium	Hydroponics system/variety/number of flowers per stem			
	'Praha'	'Traderhorn'	'White Friendship'	'Nagarit'
Elevated tray				
Crushed stone	14.8 a[a]	0.0 b	0.0 b	0.0 b
Sawdust	15.6 a	10.2 b	10.4 b	0.0 c
Sand	7.0 a	0.0 b	0.0 b	0.0 b
Vermiculite	8.6 a	0.0 b	0.0 b	0.0 b
Ground lay bed				
Crushed stone	15.4 a	15.3 a	15.3 a	0.0 b
Sawdust	14.0 ab	17.0 a	11.4 b	4.0 c
Sand	13.8 a	9.8 b	10.5 b	0.0 c
Vermiculite	16.2 a	11.6 b	9.8 b	6.0 c
Bag culture				
Crushed stone	16.6 a	11.0 b	12.5 b	0.0 c
Sawdust	27.8 a	15.4 b	18.4 b	0.0 c
Sand	21.6 a	12.2 b	17.6 ab	0.0 c
Vermiculite	17.0 a	19.6 a	16.0 a	0.0 b

[a]Mean separation by DNMRT, $P \leq 0.05$. Means along rows for each growing medium followed by same letter not significantly different

Table II: Cut flower stem length of different gladiolus varieties grown in different hydroponics systems and medium components

Growing medium	Variety/hydroponics system/cut flower stem length (cm)			
	'Praha'	'Traderhorn'	'White Friendship'	'Nagarit'
Elevated tray				
Crushed stone	78.4 a[a]	0.0 b	0.0 b	0.0 b
Sawdust	71.8 a	55.1 b	59.8 b	0.0 c
Sand	37.8 a	0.0 b	0.0 b	0.0 b
Vermiculite	48.4 a	0.0 b	0.0 b	0.0 b
Ground lay bed				
Crushed stone	72.2 b	68.3 b	78.8 a	0.0 c
Sawdust	69.8 a	64.8 a	65.7 a	26.0 b
Sand	70.4 a	50.2 b	50.2 b	0.0 c
Vermiculite	68.0 a	60.9 a	61.5 a	28.6 b
Bag culture				
Crushed stone	77.1 a	80.7 a	80.4 a	0.0 b
Sawdust	93.6 ab	79.4 b	104.0 a	0.0 c
Sand	98.6 a	71.9 b	101.7 a	0.0 c
Vermiculite	96.9 a	87.0 a	89.1 a	0.0 b

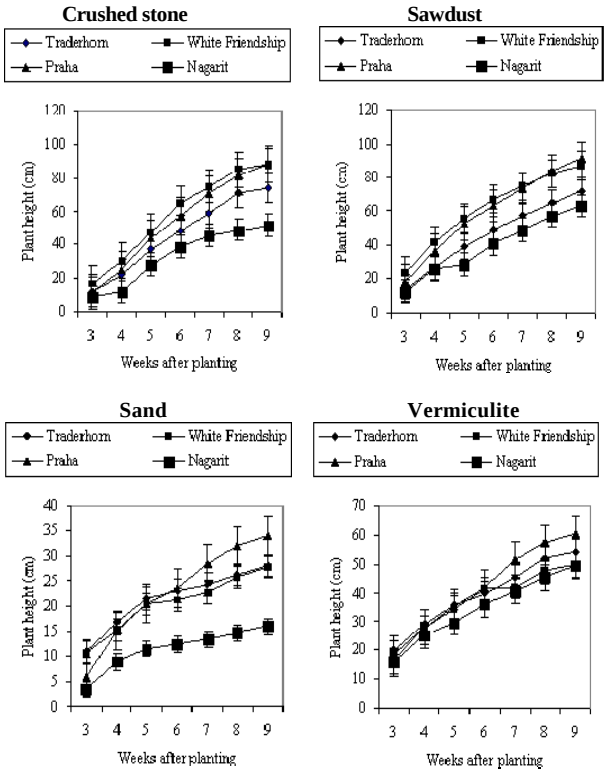
[a]Mean separation by DNMRT, $P \leq 0.05$. Means along rows for each growing medium followed by same letter not significantly different

(Fig. 3). The highest plant height (112.3 cm) was obtained from 'Praha' in week 9. 'Nagarit' reached a maximum plant height of 65.5 cm in week 9, which was almost half that of 'Praha'. There was no significant ($P < 0.05$) difference in plant height between 'Traderhorn', 'White Friendship' and 'Praha' from week 6 to 9.

In the plants grown using sand, the lowest plant height was observed in 'Nagarit' from week 4 to 9 (Fig. 3). There was no significant ($P < 0.05$) difference in plant height between the four varieties in week 3. The highest plant height (112.4 cm) was observed in 'White Friendship'. 'Nagarit' reached a maximum of 73.0 cm, which was about 35% reduction, when compared to 'White Friendship'in week 9.

In the plants grown in vermiculite, the lowest plant height again was obtained from 'Nagarit' from week 4 to 9 (Fig. 3). There was no significant ($P < 0.05$) difference in

Fig. 1: Plant height of different gladiolus varieties grown in elevated tray hydroponics system using different growing media



plant height between the four varieties in week 3. The highest plant height (120.3 cm) was found in 'White Friendship' in week 9. The second highest plant height of 103.8 cm was obtained from 'Praha'. 'Nagarit' reached a maximum plant height of 65.4 cm, which was almost half that of 'White Friendship'. In the bag culture hydroponics system, gladiolus plants grown using vermiculite had in general the highest plant height and the lowest was recorded among the plants grown using crushed stone (Fig. 3).

Number of flowers per spike: In the elevated tray hydroponics system, no flower formation occurred in 'Nagarit' grown in the four different medium components (Table I). 'Traderhorn' and 'White Friendship' formed flowers only from plants grown using sawdust. They formed 10.2 and 10.4 flowers per spike, respectively. However, 'Praha' flowered in all the medium components used. The highest number of flowers (15.6) was obtained from 'Praha' grown using sawdust, while the lowest (7.0) was observed from plants grown in sand. The ability of 'Praha' to flower in the different medium components could probably be attributed to its better adaptation to hydroponics culture as compared to the other varieties.

In the ground lay bed hydroponics system, 'Nagarit' flowered when grown using sawdust and vermiculite but not in crushed stone and sand (Table I). However, 'Traderhorn', 'White Friendship' and 'Praha' flowered in all medium components. The highest number of flowers per spike was

Fig. 2: Plant height of different gladiolus varieties grown in ground lay bed hydroponics system using different growing media

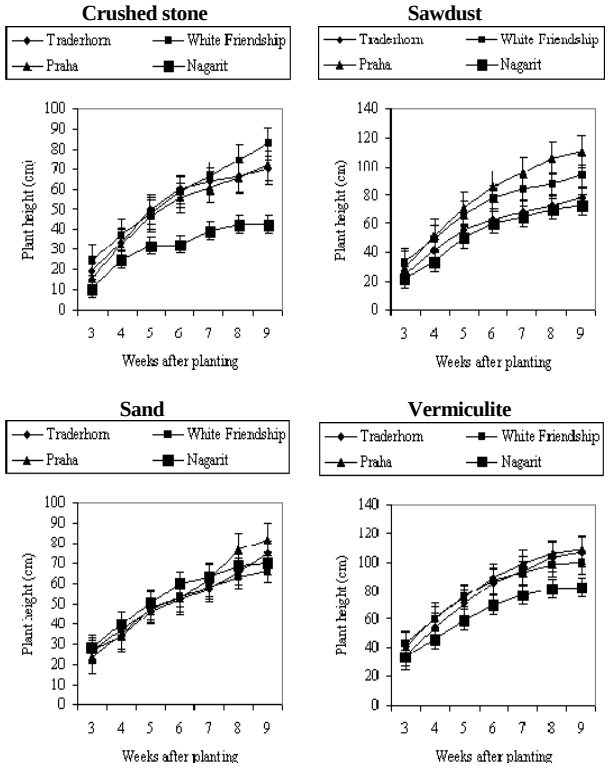
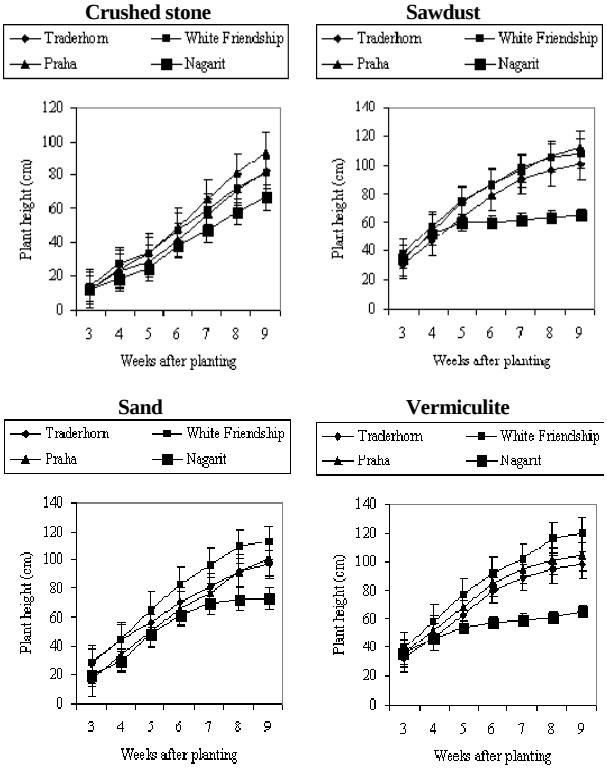


Fig. 3: Plant height of different gladiolus varieties grown in bag culture hydroponics system using different growing media



observed in plants grown using vermiculite for 'Praha' and in crushed stone for 'Traderhorn' and 'White Friendship'. However, there was no significant ($P < 0.05$) difference in the number of flowers per spike between 'Praha', 'Traderhorn' and 'White Friendship' grown in crushed stone (Table I). The lowest number of flowers per spike was observed in plants grown in sand for 'Praha' and 'Traderhorn' and in vermiculite for 'White Friendship'.

In the bag culture hydroponics system, 'Nagarit' failed to flower in all the four different medium components (Table I). However, 'Praha', 'Traderhorn' and 'White Friendship' flowered in all medium components. The highest number of flowers per spike for 'Praha' (27.8), 'Traderhorn' (15.4) and 'White Friendship' (18.4) was observed in plants grown using sawdust (Table I). Similarly, for all these three varieties, the lowest number of flowers per spike (16, 6, 11.0 & 12.5, respectively) was observed in plants grown using crushed stone. High productivity of gladiolus grown using sawdust could probably be due to higher water holding and nutrient holding capacities of the medium as compared to sand and crushed stone. Hsu *et al*. (2008) observed a higher flower stem length and number of flowers per stem in Oncidium orchids (*Oncidium altissimum*) grown using rockwool, when compared to peat moss, crushed stone, bark and charcoal. Inden and Torres (2004) reported that utilisation of rockwool and perlite in hydroponics culture of tomato results in higher yields as compared to other inert materials. However, no significant differences in yields of hydroponics tomato grown using sand, vermiculite, rice halls, redwood bark, pine bark, perlite and peat moss (Jensen, 2008).

Cut flower stem length: In the elevated tray hydroponics system, the highest cut flower stem length (78.4 cm) was obtained from 'Praha' grown using crushed stone (Table II). The lowest cut flower stem length (37.8 cm) in 'Praha' was observed from plants grown using sand. 'Traderhorn' and 'White Friendship' cut flowers in sawdust medium attained a stem length of 55.1 and 59.8 cm, respectively. Blom (1999) also observed marked variation in cut flower stem length and fresh mass in hydroponics production of roses using coco coir and granulated rockwool.

In the ground lay bed hydroponics system, the highest cut flower stem length was observed in plants grown using crushed stone for 'Praha' (72.2 cm), 'Traderhorn' (68.3 cm) and 'White Friendship' (78.8 cm) (Table II). The lowest cut flower stem length was observed in plants grown using vermiculite for 'Praha' (68.0 cm) and in sand for 'Traderhorn' (50.2 cm) and 'White Friendship' (50.2 cm). The maximum cut flower stem for 'Nagarit' was 28.6 cm in plants grown using vermiculite, which was less than half that of all the other varieties. Correa *et al*. (2008) reported a higher tuber yield in potato grown in hydroponics, when compared to conventional system. They attributed the higher tuber yield to un-interrupted and optimal nutrient and

water supply in hydroponics culture. The higher yield obtained from plants grown using sawdust 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. Schnitzler *et al.* (2004) observed better plant growth, fruit yield and quality in bell pepper (*Capsicum annuum* L.) grown in wood fibre substrate.

In the bag culture hydroponics system, the highest cut flower stem length for 'White Friendship' (104.0) was obtained from plants grown using sawdust (Table II). The lowest cut flower stem length was observed in crushed stone for 'Praha' (77.1 cm) and 'White Friendship' (80.4 cm). There was no significant ($P<0.05$) difference in cut flower stem length between 'Praha', 'Traderhorn' and 'White Friendship' grown using crushed stone and vermiculite (Table II). In general, gladiolus grown in bag culture hydroponics system had higher cut flower stem length than the elevated tray and ground lay bed systems (Table II).

CONCLUSION

In all the hydroponics systems investigated, sawdust induced the highest vegetative growth of gladiolus. 'Praha' out-performed all the other varieties, while the vegetative growth of 'Nagarit' was highly inhibited. The bag culture hydroponics system induced a higher plant height, when compared to the other systems. The highest quality of gladiolus cut flowers was obtained from sawdust and in bag culture hydroponics system. For the hydroponics culture of gladiolus cut flowers, sawdust may be used as growing medium. To induce highest vegetative growth, flower formation and quality, gladiolus may be grown using bag culture hydroponics system.

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