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Evaluating different soilless culture substrates for growth, flowering and quality of Gladiolus (*Gladiolus grandiflorus*)

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ABSTRACT

Gladiolus is considered one of the world's leading cut flowers, and it is one of the most commonly cultivated flowering plants world-wide. However Gladiolus flowers have a great economic return, but Gladiolus plants and corms are very sensitive to a number of soil borne diseases which may cause loss of flowers and plants. Investigations are there for being done to study the convenience of using soilless culture technology as an alternative cultivation system for producing Gladiolus. In this context, an experiment was conducted under greenhouse conditions in the experimental sites of Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt and Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center, Ministry of Agriculture and Land Reclamation, Dokki, Giza, Egypt, during seasons of 2016 and 2017 to evaluate the suitability of different soilless culture substrates for growth, flowering and quality of Gladiolus. Four types of soilless culture substrates were put under investigation as follow; mixture of sand and rice husk "SRh" (1:1 v/v), mixture of perlite and peat moss "PePr" (1:1 v/v), mixture of peat moss: rice husk "PeRh" (1:1 v/v) and finally perlite "Pr"100%. Different measurements were recorded during the experimental time such as: plant height, leaf width, fresh and dry weights of the remaining aerial parts, number of spikes per m^2, number of florets per spike, number of days from cultivation to flower bud initiation, number of days from cultivation to appearance of first color, number of days from cultivation to corm harvesting, number of corms and cormlets per m^2, spike length, spike base diameter, spike fresh weight, chlorophyll content in leaves and (nitrogen, phosphorus and potassium) percentages in leaves. The results indicated that the mixture of perlite and peat moss "PePr" (1:1 v/v) was the most appropriate substrate for producing Gladiolus with high yield and flower quality; Gladiolus plants grown in PePr gave the highest values regarding plant height, leaf width, fresh and dry weights of the remaining aerial parts, number of spikes per m^2, number of florets per spike, number of corms and cormlets per m^2, spike base diameter, spike fresh weight and chlorophyll content in leaves.

Keywords: Gladiolus, soilless, substrates, containers, perlite, peat moss, rice husk and sand.

Introduction

Flowers are prized as an object of great beauty and diversity and are commercially valuable (US$ 4.5 billion in international trade yearly), and are highly perishable (O'Donoghue, 2006).The interest in cut flower cultivation in many countries in Mediterranean region is increasing gradually because of increased internal market demand, climate advantages of the region and increase in the production of cut flower for export in recent years (Aydınşakir *et al.,* 2009). Gladiolus (*Gladiolus grandiflorus* L.) is one among the top ten elite cut flowers due to their different shapes, dazzling colors and varying sizes. It is highly demanded in both domestic and export markets. At the same time, Gladiolus is considered one of the most commonly cultivated and economically important flowering plants world-wide (Bose *et al*., 2003 and Ali *et al*., 2014), this economically important crop is very sensitive to soil-borne diseases; Gladiolus plants and corms are susceptible to diseases caused

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by fungi, bacteria and viruses. Pfleger and Gould, (2008) reported that one of the most destructive diseases of Gladiolus is Fusarium rot caused by *Fusarium oxysporium* f. sp *gladioli*, a soil-borne fungus. In case of failure to eliminate this disease well from soil before planting, plants growing from infected corms may develop arching of young stalks or premature yellowing of leaves and fading of flower colors. Plants are often stunted and fail to bloom. Furthermore, Gladiolus is severely affected by wilt disease caused by *Fusarium oxysporum* f. sp. gladioli leading to death of plant and rotting of corms. The pathogen was isolated from infected corms and on the basis of morphological and cultural studies, identified as *F. oxysporum* f. sp. gladioli. The fungus produced micro-conidia, macro-conidia and chlamydospores. Survival studies showed that the pathogen could survive for 42 weeks in sterile soil (Kulkarni, 2006). Therefore, producing Gladiolus flowers and corms in soilless culture is an alternative production method free of soil-borne diseases and pests. Soilless culture is defined as any method for growing plants without the use of soil as a rooting medium, in which the nutrients absorbed by the roots are supplied via the irrigation water. The fertilizers containing the nutrients to be supplied to the crop are dissolved in the appropriate concentration in the irrigation water and the resultant solution is referred to as “nutrient solution”. Substrate culture in solid medium (organic and inorganic substrates) is one of soilless culture methods (Savvas *et al.,* 2013). Soilless culture also offers an ideal alternative crop production method for traditional cultivation in soil when there is no soil available at all (Olympios, 2011). Stable and high quality production is the main advantage of soilless substrate culture, which has already been proven by many studies in various crop plants (Yashuba *et al*., 1995 and Veys, 1997). Moreover, Grillas *et al*. (2001) reported that soilless culture systems guarantee flexibility and intensification, provide high crop yield and high quality products, even in areas with adverse growing conditions. Furthermore, soilless cultivation represents a breakthrough and permit, achievement of high yield and a very standardized production (Burrage, 1992). Loana *et al.* (2013) reported that the limitation of water resources increased the importance of soilless culture. Moreover, soilless culture has proven to be a viable alternative for cut flower sector in many countries and regions all over the world (Yilmaz *et al*., 2006). About 25% transition rate from soil cultivation to soilless culture using substrates was applied to a number of flowering plants, where the use of substrate in production is possible such as calla, lilies, gerberas and carnations (UNEP, 2008). The term substrate or growing medium is used to describe the materials used to grow plants in containers (Blok and Verhagen, 2009; Schroeder and Sell, 2009). The good growing media should have some characteristics such as providing aeration and water, allowing maximum root growth and supporting the plant (Bilderback *et al.*, 2005). Moreover, Shylla *et al.* (2018) mentioned that the ideal rooting media or substrates combination can provide sufficient porosity, aeration and water holding capacity which can enhance crop growth and productivity but, soilless media combinations in particular, can also reduce the soil borne diseases and prevent the spread of nematode transmitted viruses. Various ingredients were used as growing media for vegetable production throughout the world. The raw materials used vary, being based on local availability (Schmilewski, 2009). Such materials can be inorganic or organic, but growing media are often formulated from a mixture of different materials or components in order to achieve the correct balance of air availability and water holding capacity for the plants to be grown well (Bilderback *et al*.,2005; Schroeder and Shell, 2009; Nair *et al*., 2011).

It was therefore very important to study the availability of producing Gladiolus flowers using soilless culture technology, and to evaluate the performance of Gladiolus in different types of soilless substrates consisting of different materials.

Material and methods

An experiment was conducted under greenhouse conditions in the experimental sites of Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt and Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center, Ministry of Agriculture and Land Reclamatio, Dokki, Giza, Egypt and Ornamental Horticulture Department, Faculty of agriculture, Cairo University, Giza, Egypt, during seasons of 2016 and 2017. The experiment was done to evaluate different types of soilless culture substrates for growth, flowering and quality of Gladiolus.

Treatments

Four types of soilless culture substrates have been put under investigation in this experiment as follow;

- Mixture of sand and rice husk "SRh" (1:1 v/v)
- Mixture of perlite and peat moss "PePr" (1:1 v/v)
- Mixture of peat moss: rice husk "PeRh" (1:1 v/v)
- Perlite "Pr" 100%.

These substrates were tested in concerning growth, flowering and quality of Gladiolus.

Plant materials

Imported Gladiolus corms "cv. Nova Lux” were used in this experiment. The planting depth was between 5- 6 cm at the four different substrates. The planting time was February 2016 for the first season and February 2017 for the second season. The corms were treated with a fungicide before planting. The planting density was 10 corms per m^2

System description

The container system was used in this experiment. The used container systems consisted of rectangular containers (150cm length × 50cm width and 25cm depth). The containers were made from a black polyethylene sheet (0.5mm thickness). Holes were made at the lowermost level in both sides and front of each container for drainage to release the excess nutrient solution and water. The containers were laid on a gully made of black and white polyethylene sheet (0.2mm thick) on a raised beds prepared with a slope of 1.0 %. The substrate depth in each container was 20 cm. Each bed had a catchment tank containing a submersible pump directing water and nutrient solution to plants through drip irrigation network. Excess water and nutrient solution returned back to the catchment tank by gravity and collecting gully in a recirculation close system.

The nutrient solution was described by El-Behairy, (1994) used in this experiment. The electrical conductivity (EC) was adjusted using digital EC meter at the range of 2 -2.5 $m.mhos^{-1}$ throughout the experimental time.

Harvesting

The experiment was extended from the beginning of February to the end of November in both 2016 and 2017. The Flowering spikes were harvested at the first floret loosening stage (opening stage) and the basal floret showing color. After harvesting, the rest of the plants were lifted in substrate to help forming the corms. The new corms were collected when the aerial parts of the plant turned yellow.

Measurements

The plant growth measurements:

- The plant height (cm)
- The leaf width (cm)
- The fresh and dry weights of remaining aerial parts (g).

The yield measurements (flowers – corms):

- The number of spikes per m^2
- The number of florets per spike.
- The number of days from cultivation to flower bud initiation.
- The number of days from cultivation to appearance of first color.
- The number of days from cultivation to corm collection.
- The number of corms and cormlets per m^2.

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The quality measurements:

- The spike length (cm)
- The spike base diameter (cm)
- The spike fresh weight (g)

The chemical measurements:

- The chlorophyll content in leaves
- The nitrogen percentage in leaves (N %)
- The phosphorus percentage in leaves (P %)
- The potassium percentage in leaves (K %)

Plant samples were collected for determining N, P and K % in leaves after 60 day after planting using methods described by A.O.A.C., (1975).

Experimental Design and Statistical analysis

The experiment was arranged in complete randomized blocks design with three replicates. The collected data were analyzed using ANOVA statistical analysis as described by Snedicor and Cochran, (1980) and the least significant difference (LSD) was used in comparison among means.

Result

Plant height

Data in Fig (1) illustrate the effect of different substrate types on the plant height of Gladiolus plants. Data collected from the first season showed that the highest plants were collected from the mixture of peat moss and perlite "PePr" (1:1 v/v) (71.87 cm) while the shortest ones were collected from perlite (64.33 cm). Differences among treatments were significant except the difference between PeRh and perlite. In the second season, data showed that the greatest plant height was recorded with PePr (89.33 cm) followed by PeRh (76 cm) then perlite (67.33 cm) and finally SRh recorded the lowest values (66.11 cm). The differences among treatments were found to be significant except for the difference between perlite and SRh.

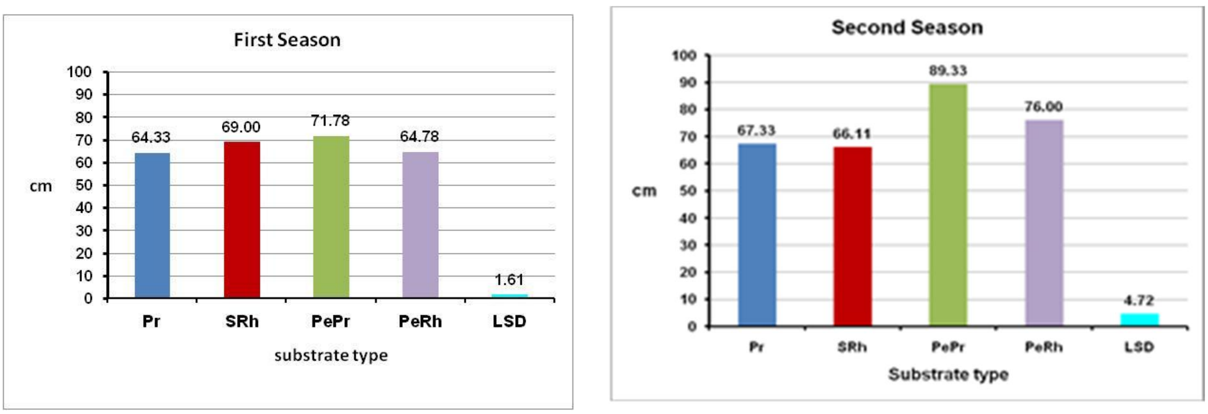


Fig. 1: Effect of different substrate types on plant height of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Leaf width

Data in Fig (2) illustrate the effect of different substrate types on the leaf width of Gladiolus. In the first season, data showed that the highest leaf width was recorded in PePr (4.99 cm) while the lowest value was recorded in SRh (2.54 cm). Moreover, PeRh recorded higher leaf width values (3.60 cm) than perlite (2.60 cm). Furthermore, data indicated that differences among treatments were significant except the difference between perlite and SRh. Similar trends were observed in the second season except for the difference between PePr and PeRh was not significant.

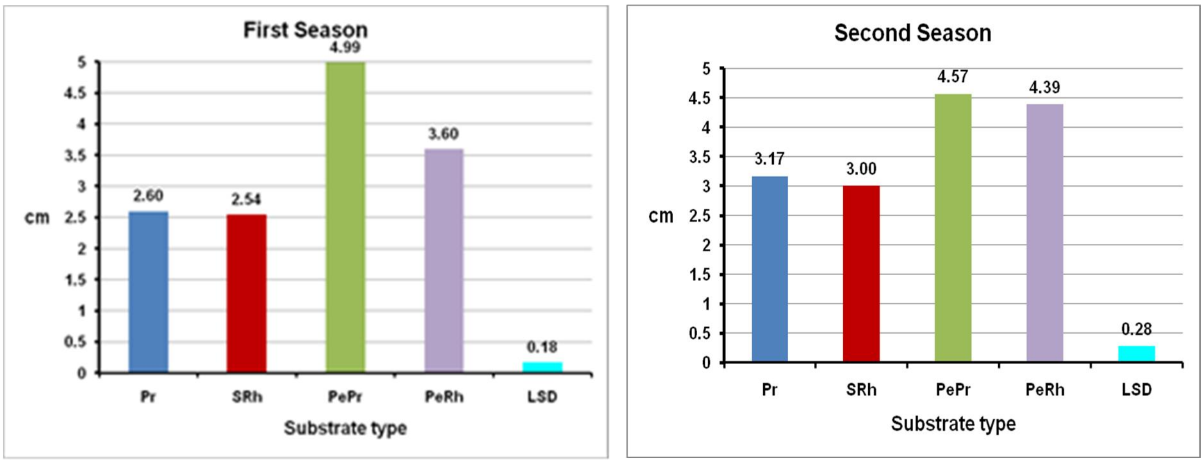


Fig. 2: Effect of different substrate types on leaf width of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Fresh weight of remaining aerial parts

Data in Fig (3) illustrate the effect of different substrate types on the fresh weight of the remaining aerial parts of Gladiolus. Data collected from the first season showed that the highest fresh weight values were recorded with PePr (100.56g), while the lowest values were recorded with SRh (63g). Also, the difference between PePr and all other tested substrates was significant. Moreover, PeRh recorded higher fresh weigh values (81.89g) than those recorded with perlite (63.37g). The difference between perlite and PePh was significant while the difference between perlite and SRh was not significant. Similar trends were observed in the second season except for the difference between PePr and PeRh was not significant. On contrary, the difference between perlite and SRh was significant.

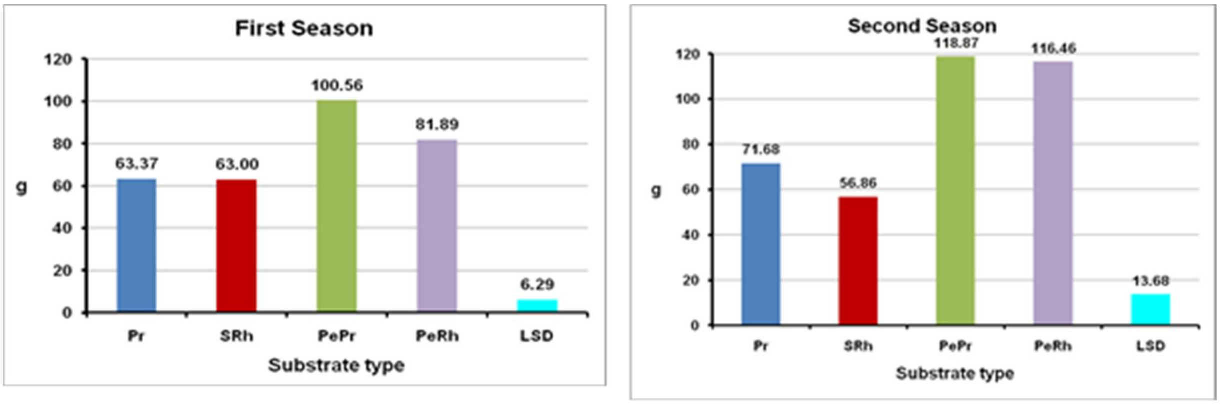
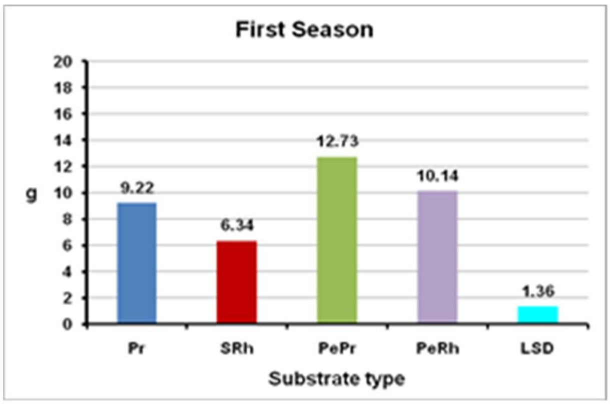


Fig. 3: Effect of different substrate types on the fresh weight of remaining aerial parts of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Dry weight of remaining aerial parts

Data in Fig (4) illustrate the effect of different substrate types on the dry weight of the remaining aerial parts of Gladiolus. Regarding the first season, data showed that the highest dry weight values were recorded in PePr followed by PeRh, then perlite and finally SRh gave the lowest values.

Furthermore, differences among treatments were significant. Similar trends were observed in the second season except for the difference between PePr and PeRh.



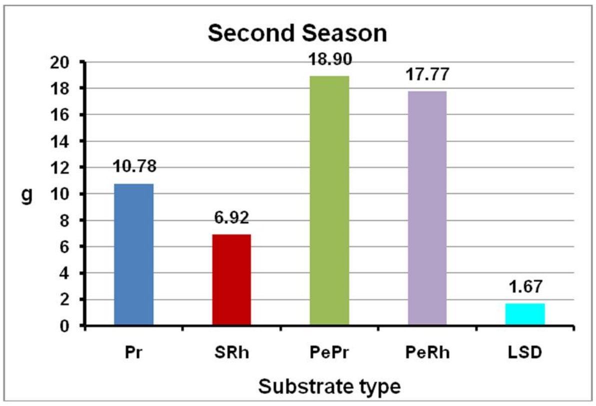
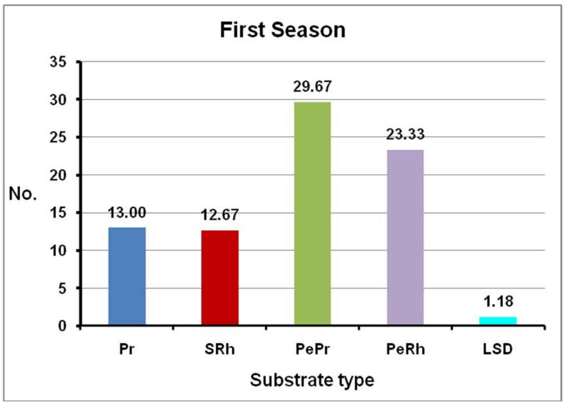


Fig. 4: Effect of different substrate types on dry weight of remaining aerial parts of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Number of spikes per m²

Data in Fig (5) illustrate the effect of different substrate types on the number of spikes per m^2 of Gladiolus. Data collected from the first season indicated that PePr (29.67) recorded the highest number of spikes per m^2 followed by PeRh (23.33), then perlite (13.00) and SRh (12.67) respectively. Furthermore, data indicated that differences among treatments were significant except for the difference between perlite and SRh. Similar trend was observed in the second season except for SRh (8.44) recorded higher number of spikes than perlite (8.22) but the difference between both of them still not significant.



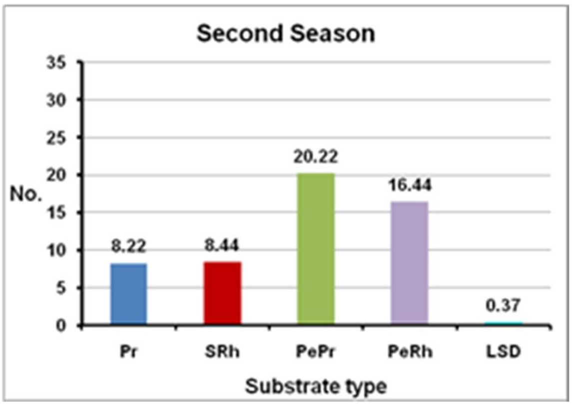


Fig. 5: Effect of different substrate types on number of spikes per m^2 of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Number of florets per spike

Data in Fig (6) illustrate the effect of different substrate types on the number of florets per spike of Gladiolus. Data collected from the first season showed that PePr produced more florets per spike than all other treatments (13.89) followed by PeRh (11.89) then perlite (11.22). On the other hand, SRh recorded the lowest number of florets (9.67). Furthermore, data showed that all differences among treatments were significant. Data showed a similar trend in the second season except for the difference between PePr and PeRh.

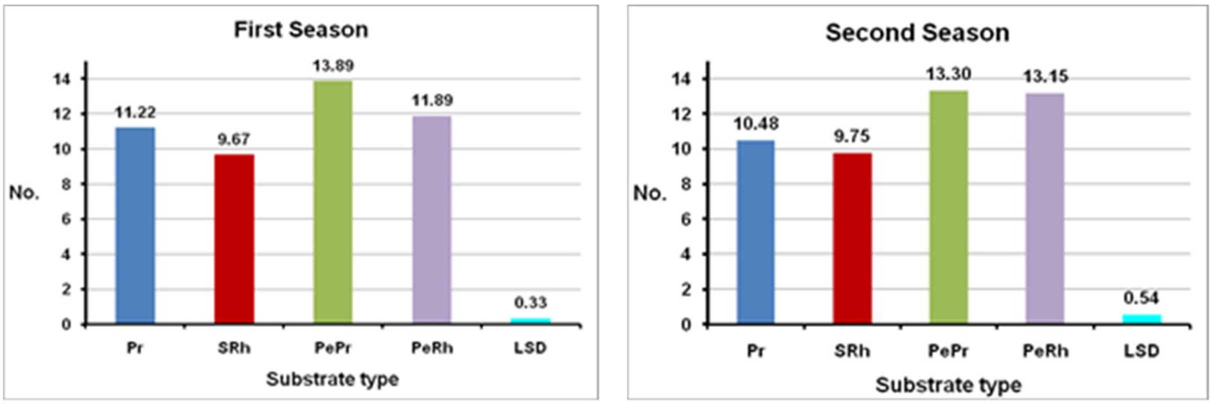


Fig. 6: Effect of different substrate types on number of florets per spike of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Number of days from cultivation to flower bud initiation

Data in Fig (7) illustrate the effect of different substrate types on the number of days from cultivation to flower bud initiation of Gladiolus. Data collected from the first season indicated that SRh recorded the shortest period from cultivation to flower bud initiation (67.33 days), followed by PeRh (70 days), PePr (71.33 days) and perlite (75.67 days) respectively. Data also showed significant difference among treatments. Similar trends were observed in the second season except for the difference between PeRh and PePr .

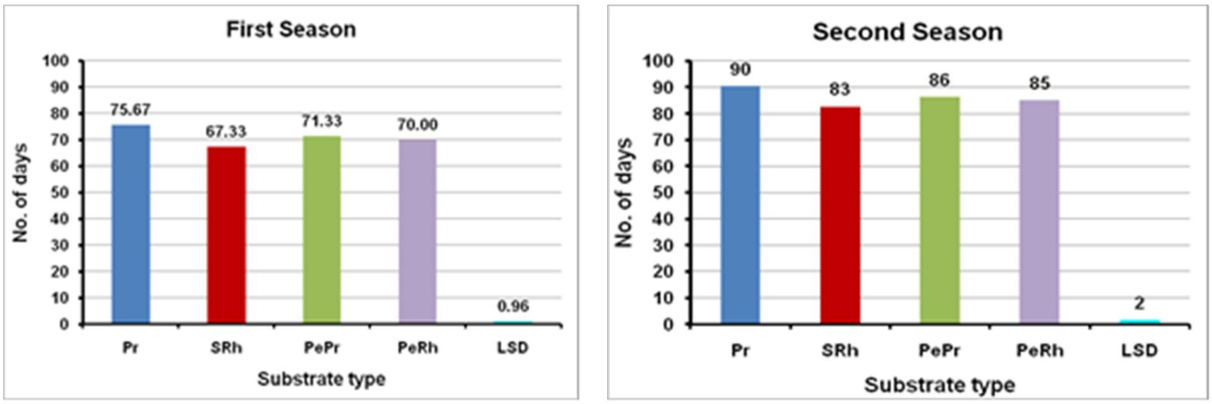


Fig. 7: Effect of different substrate types on number of days from cultivation to flower bud initiation of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Number of days from cultivation to appearance of first color

Data in Fig (8) illustrate the effect of different substrate types on the number of days from cultivation to appearance of first color on Gladiolus. Data collected from the first season indicated that the shortest period from cultivation to the appearance of first color was recorded with SRh (74 days) while the longest period was recorded with perlite (82.33 days). Data also showed that PePr recorded a longer period (77.67 days) than PeRh (75.67 days). Moreover, all differences among treatments were significant. Data showed similar trends in the second season except for the difference between PePr and PeRh . The difference between SRh and PeRh was not significant also.

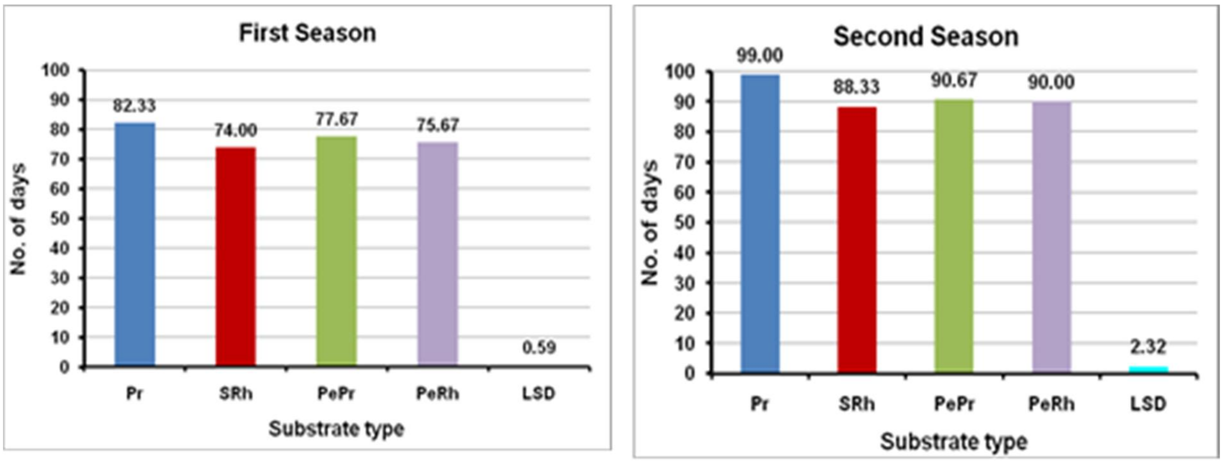


Fig. 8: Effect of different substrate types on number of days from cultivation to appearance of first color on Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Number of days from cultivation to corm harvesting

Data in Fig (9) illustrate the effect of different substrate types on the number of days from cultivation to corm harvesting of Gladiolus. Data collected from the first season showed that SRh produced corms ready to harvest in a shorter time than all other treatments (93.67 days). Data also showed that PeRh was earlier in producing corms (95.67 days) than PePr (100.33 days). On the contrary, perlite came at the last position (104 days). All differences among treatments were significant. A similar trend was observed in the second season except for the difference between perlite and PePr which was insignificant.

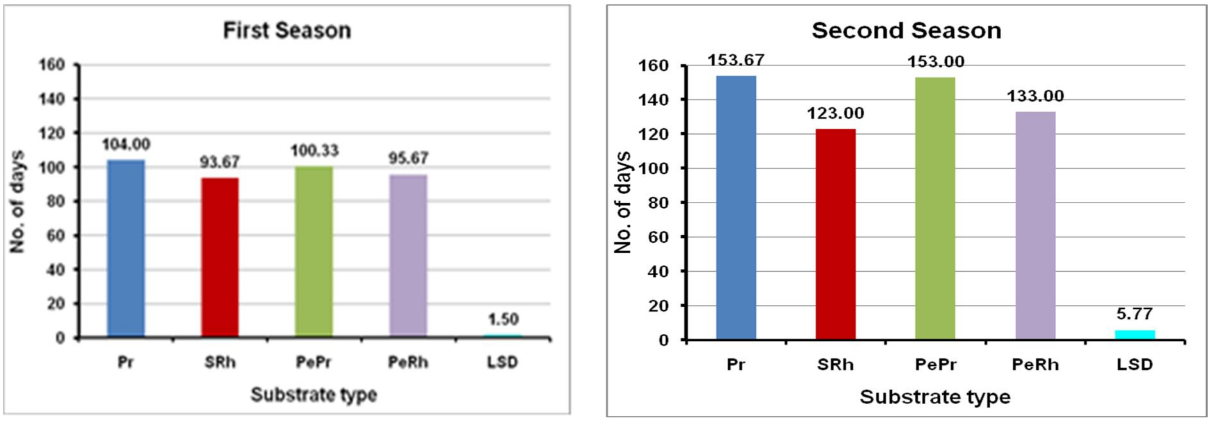
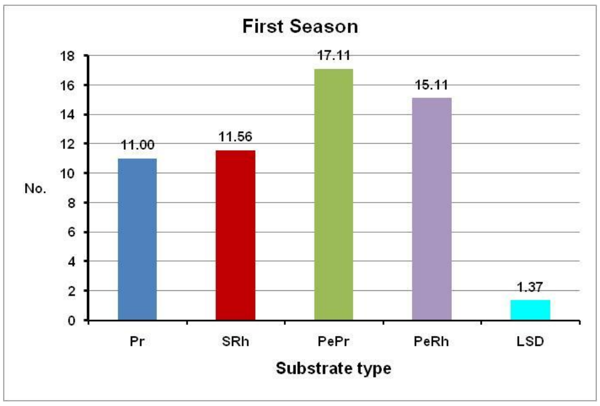


Fig. 9: Effect of different substrate types on number of days from cultivation to corm harvesting of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Number of corms and cormlets per m^2

Data in Fig (10) illustrate the effect of different substrate types on the number of corms and cormlets per m^2 of Gladiolus. Data collected from the first season showed that the highest number of corms and cormlets per m^2 was recorded in PePr (17.11) followed by PeRh (15.11) then SRh (11.56). The lowest values were recorded in perlite (11.00). Data also showed that differences among treatments were significant except for the difference between perlite and SRh. However, in the second season all differences were significant without exception.



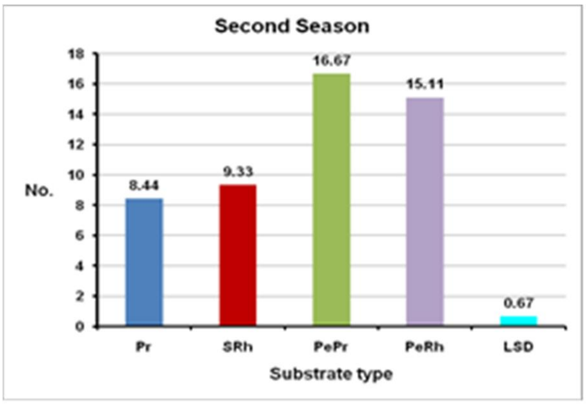
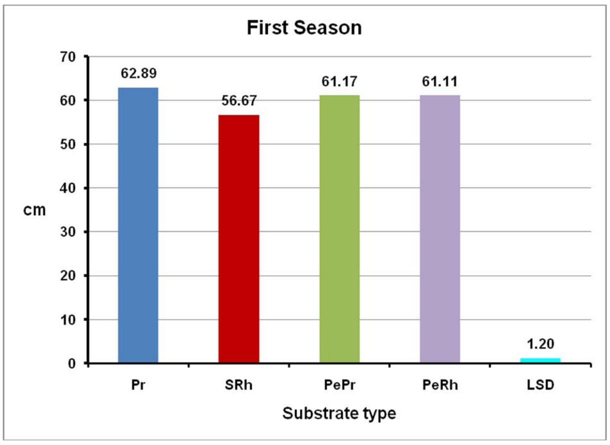


Fig. 10: Effect of different substrate types on number of corms and cormlets per m^2 of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Spike length

Data in Fig (11) illustrate the effect of different substrate types on the spike length of Gladiolus. Data collected from the first season illustrated that perlite produced the longest spikes (62.89 cm) followed by PePr (61.17 cm), PeRh (61.11 cm) then SRh (56.67 cm) respectively. Moreover, differences among treatments were significant except for the difference between PePr and PeRh. On the other hand, data collected from the second season indicated that the highest spike length value was recorded with PePr (61.98 cm) followed by perlite (59.97 cm), PeRh (57.57 cm), then SRh (40.60 cm) respectively. Moreover, data indicated that the difference between SRh and all other treatments were significant. On the contrary, the differences among perlite, PePr and PeRh were not significant.



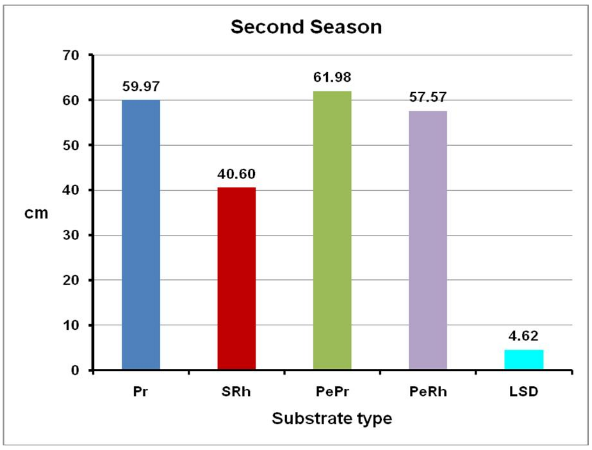


Fig. 11: Effect of different substrate types on spike length of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Spike base diameter

Data in Fig (12) illustrate the effect of different substrate types on the spike base diameter of Gladiolus. Regarding first season, data showed that plants grown in PePr recorded the highest value for the spike base diameter (0.43 cm) followed by PeRh (0.36 cm) SRh (0.32 cm) then Perlite (0.30 cm) respectively. Moreover, all the differences among treatments were significant. Similar trends were observed in the second season except for the lowest spike base diameter was recorded with SRh (0.29 cm).

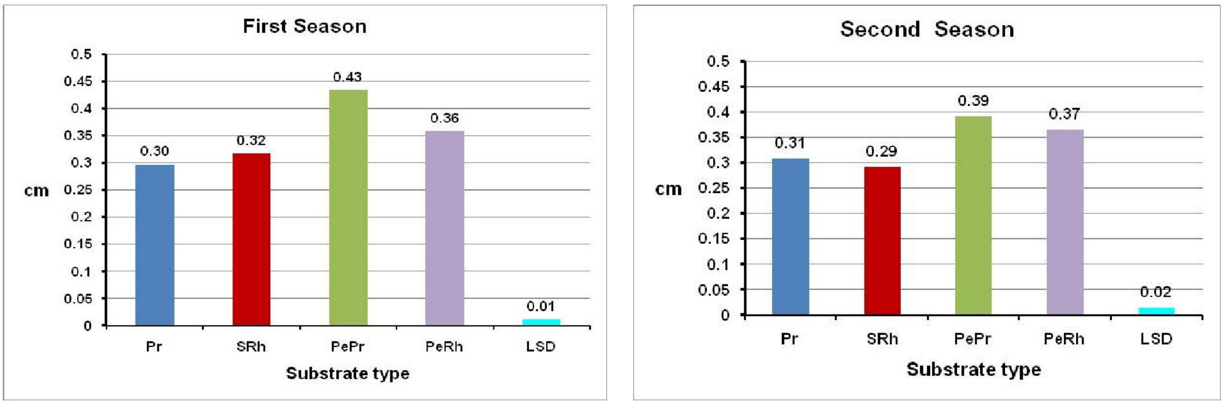


Fig. 12: Effect of different substrate types on spike base diameter of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Spike fresh weight

Data in Fig (13) illustrate the effect of different substrate types on the spike fresh weight of Gladiolus. Data collected from the first season illustrated that PePr showed the highest spike fresh weight value (60.63g) followed by PeRh (53.10g), then SRh (44.97g) and finally perlite (37.61g). Furthermore, all the differences among treatments were significant. Similar trend was observed in the second season except for the lowest value was recorded with SRh (25.23g).

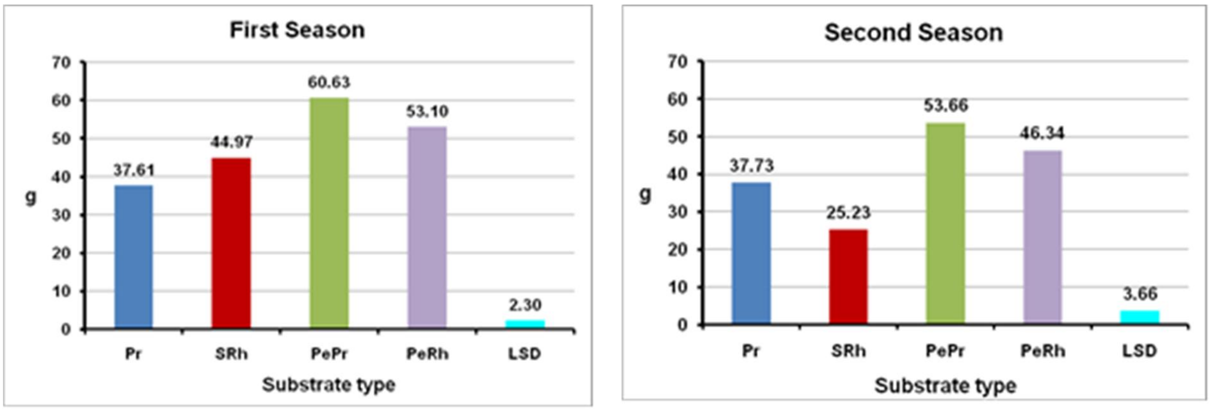


Fig. 13: Effect of different substrate types on spike fresh weight of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Chlorophyll content in leaves

Data in Fig (14) illustrate the effect of different substrate types on chlorophyll content in leaves of Gladiolus. Regarding the first season, data showed that the highest chlorophyll content was recorded with PePr substrate (58.32 nmol/cm^2) while the lowest value was recorded with SRh substrate (42.92 nmol/cm^2). The difference between PePr and all other tested substrates was significant. Moreover, PeRh recorded higher chlorophyll content (55.06 nmol/cm^2**)** than perlite (54.38 nmol/cm^2), but the difference was not significant. The same trend was observed in the second season.

Nitrogen percentage in leaves

Data in Fig (15) illustrate the effect of different substrate types on nitrogen percentage (N %) in leaves of Gladiolus. Data collected from both seasons indicated that there were no significant differences among treatments.

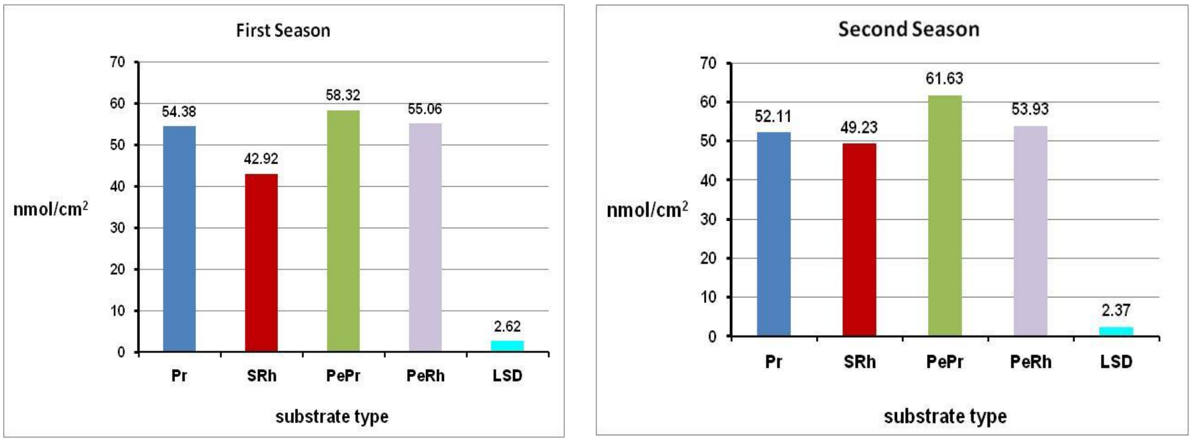


Fig. 14: Effect of different substrate types on chlorophyll content in leaves of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

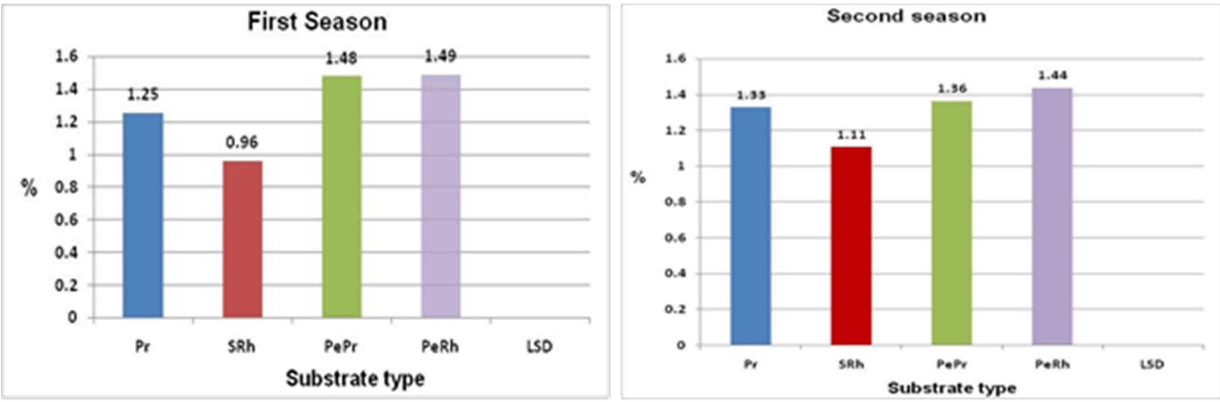


Fig 15: Effect of different substrate types on nitrogen percentage in leaves of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Phosphorus percentage in leaves

Data in Fig (16) illustrate the effect of different substrate types on phosphorus percentage (P%) in leaves of Gladiolus. Data collected from both seasons indicated that there were no significant differences among treatments.

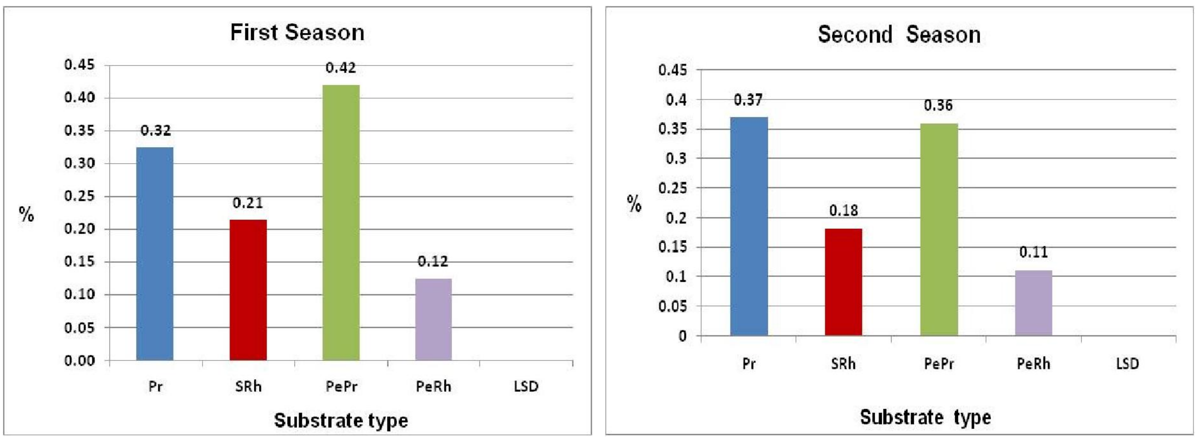
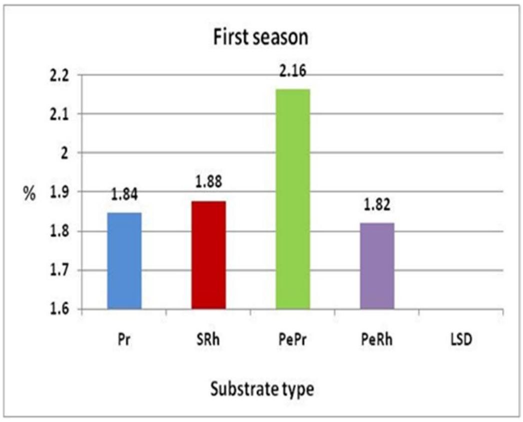


Fig. 16: Effect of different substrate types on phosphorus percentage in leaves of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Potassium percentage in leaves

Data in Fig (17) illustrate the effect of different substrate types on potassium percentage (K%) in leaves of Gladiolus. Data collected from both seasons indicated that there were no significant differences among treatments.



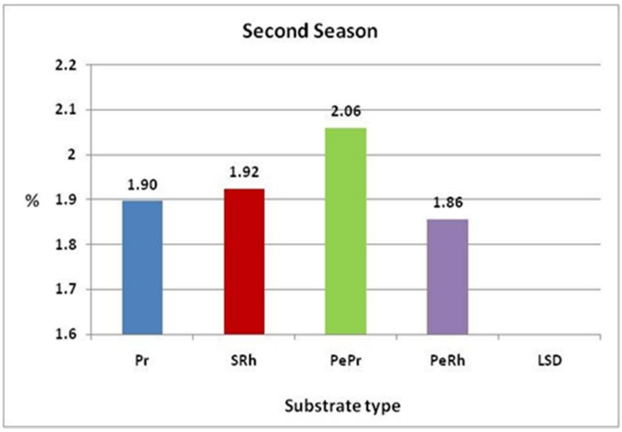


Fig. 17: Effect of different substrate types on potassium percentage in leaves of Gladiolus grown during seasons of 2016 and 2017 using soilless culture technology.

Discussion

From the overall results, it is clear that the mixture of perlite and peat moss "PePr" (1:1 v/v) is the most suitable substrate for producing Gladiolus than other tested substrates. Gladiolus grown in PePr recorded a higher number of spikes, corms & cormlets per m^2 and higher quality parameters (spike base diameter, spike fresh weight) in comparison to other treatments. This is attributed to enhanced vegetative growth of Gladiolus plants in PePr compared to other treatments. Gladiolus plants grown in PePr gave the highest values of plant height, leaf width, and fresh & dry weights of remaining aerial parts. Improvement of vegetative growth parameters means formation of a good canopy which is associated with better yield (higher numbers of spikes, corms & cormlets per m^2 and higher florets number per spike). These results reveal that substrate composition affects plant growth parameters. This agrees with the results of Lemaire, (1995) who concluded that one of the main factors affecting the physiological and productive performance of the plant in substrate culture is the type of substrate itself. On the other hand, Özcelik *et al.,* (1999) mentioned that flower yield of gerbera is significantly affected by growing media. Furthermore, Fakhri *et al.* (1995) studied the effect of three substrates (perlite – mixture of peat moss and perlite 1:1- pumice) on flower quality of three gerbera cultivars (Fame, Rosabella and Sunspot), They found that gerbera plants grown in mixture of peat moss and perlite gave the highest yield while the lowest number of flowers was recorded using perlite and pumice. In summary, adding peat moss to perlite (PePr) gave better results than using perlite alone as a substrate for producing Gladiolus. This can be due to better availability of plant water needs and reduction of air spaces attained by the addition of peat moss to perlite. Maloupa *et al.* (2001) found that mixed substrates can maintain favorable physical conditions over longer periods than the single substrate. Fakhri *et al.* (1995) mentioned that for optimum plant growth; the substrate must contain adequate easily available water and air. Easily available water is low in perlite, to solve this problem, it is recommended to increase the irrigation frequency, and in this case adding peat moss to perlite increases water availability around root zone. Also, if the aeration and the easily available water are maintained in the appropriate level, the roots grow fast. Vaughn *et al*. (2011) also reported that the interest in the use of mixtures of inorganic and organic materials as growing media in soilless culture is increasing. Adding inorganic substances to organic ones such as peat results a better plant growth and higher yield probably owing to increasing water-holding capacity of inorganic material and aeration of peat moss. Better aeration of peat promotes vigorous root growth, which allows better growth of foliage and therefore increases whole yield of plants. Furthermore, Metwally *et al*., (2013) studied the effect of using different growing media on the production and flower quality of carnation; they tested six growing media (perlite, perlite: peat moss 1:1 v/v, perlite: peat moss: sand 1:1:1 v/v/v, sand, sand: peat moss 1:1 v/v and coconut fibers). Their results indicated that carnation plants grown in peat moss: perlite mixture 1:1 v/v recorded the highest values in comparison to the other tested substrates regarding fresh and dry weights of the vegetative parts, flower yield and flower quality (flower stem length, flower head diameter, flower weight).

Conclusion

From the overall results, it can be concluded that the mixture of peat moss and perlite "PePr" (1:1 v/v) was the most appropriate substrate for producing Gladiolus with high yield and flower quality; Gladiolus plants grown in PePr gave the highest values regarding plant height, leaf width, fresh and dry weights of remaining aerial parts, number of spikes per m^2, number of florets per spike, number of corms & cormlets per m^2, spike base diameter, spike fresh weight and chlorophyll content in leaves.

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