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Full Length Article

Performance Evaluation of Freesia Genotype under Hyper-Arid Conditions of Pakistan

Shumaila Khan[1†], Muhammad Zafar Iqbal[2†], Bushra Iqbal[3], Khalida Hamid Abbasi[4], Riaz Ali Shah[5], Saeeda Khanum[4], Hamid Ali[6], Mahreen Khalid[7], Shahid Nadeem[8], Muhammad Ashfaq[9], Muhammad Ikhlaq[10], Muhammad Mohsin Waqas[1] and Ikram Ullah[11*]

[1]*Department of Agricultural Engineering, Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan 64200, Pakistan*
[2]*State key Laboratory for Conservation and Utilization of Bioresources in Yunnan, Yunnan Agricultural University, Kunming 650201, China*
[3]*Institute of Chemistry, Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan, Pakistan*
[4]*Barani Agricultural Research Institute, Chakwal 48800, Pakistan*
[5]*Horticultural Research Institute for Floriculture and Landscaping, Islamabad, Pakistan*
[6]*Department of Horticulture, Faculty of Crop Production Sciences, The University of Agriculture Peshawar, 25120, Pakistan*
[7]*Regional Agriculture Research Institute, Bahawalpur, Pakistan*
[8]*Horticulture Research Institute, National Agricultural Research Center, Park Road, Islamabad, Pakistan*
[9]*Cotton Research Station, Bahawalpur, Punjab, Pakistan*
[10]*Horticultural Research Station, Bahawalpur, Punjab, Pakistan*
[11]*College of Landscape and Horticulture, Yunnan Agricultural University, Kunming 650201, China*
[*]For correspondence: ikramkhan1800@gmail.com
[†]Contributed equally to this work and are co-first authors
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Abstract

Freesia is a popular cut flower, which has high demand all over the world's cut flower industry. Comparative study towards the freesia varietal response under a warm climate is scarce. This study was conducted to evaluate the best responding cultivar in the arid region of Punjab, Pakistan. Four different freesia cultivars were selected on a phenotypic basis named Valentino, Orlando, Jessica (Pink flowers), and Golden Wave. Results revealed that Jessica showed minimum sprouting time (4.60 days) with maximum sprouting percentage (27.3%), leaf number (18.07), Leaf area (33.92 cm^2) followed by Valentino and Golden wave which showed the least response. Orlando showed maximum flower quality (6.03) and golden wave showed minimum vase life (8.17 days), the least of all three compared genotypes. Therefore, it is suggested that Jessica (pink flower) genotype was the most responsive cultivar whereas the Golden wave was the least responsive when grown in the desert plus arid region of Pakistan.

Keywords: Cut flower; Genotypes; Freesia; Growth; Arid region

Introduction

Flowers are well-thought-out as a figure of classy, beauty and sophistication that delivers visual blowout to the viewer's eyes. The ritual of involving flowers in Asia all the back to hundreds of years on the basis of many references of garden and garden flowers in exemplary literature. Significance of gardens and garden-flowers since ages is being portrayed through antiquated portraits, canvases, coins etc. even nowadays the flowers are being utilized in different societal, educational, artistic and religious contributions. However, the marketable and commercial significance was not given before as the cultivation of flowers is viewed as a hobby, therapy and activity related with esthetic and artistic sense with tasteful mind and embellishment of the environment. In the present era, rapid urbanization and dynamic lifestyles has intensified the commercial importance of floriculture. Especially, during the last 50 years the gardening business is being valued and brought about improvement of commercial floriculture into a practical agro-business choice (Younis *et al*. 2010, 2012; Khan *et al*. 2015; 2016).

Although the production of cut flowers had been restricted to very few species of field flowers but it is a comparatively innovative sub-sector in Pakistan. In Pakistan, the most important floricultural crops for cut

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flower production are roses, gladiolus, tuberoses, iris, carnation, narcissus, lilies (Khan *et al*. 2015), freesia, statice, gerbera, marigold, etc. (Khan *et al*. 2016). Cut flower production is estimated to be in the range of 10–12 thousand tons per annum. Thus, floriculture is a money-market as well as fast-growing business for small farmers in Pakistan by contributing 45% of the marketing of the world floricultural products (Younis *et al*. 2010).

Freesia hybrida (high-worth crop) a member of the bulbous family Iridaceae is a popular cut flower with different attractive colors i.e., white, yellow, lavender, golden, pink, red, orange, and violet (Mushtaq *et al*. 2013; Sharma and Thakur 2020). Moreover, freesia extract is also used in candles, creams, and shampoos due to its fragrance and is included in the top ten selling cut flowers in several global markets with high demand in local markets. Though freesias are frequently defined as "sweet-smelling", a small number of cultivars are presently cultivated mostly for their scent (Ahmad *et al*. 2019). The freesia flower has very attractive shapes and a vast range and versatility making them ideal for the different types of flower arrangements. The freesia flowers are popularly used for decorations of events, bouquets, table arrangements, cosmetics, and body flavors (due to fragrance) and may also be used as a symbol of innocence and friendship (Sharma and Thakur 2020). Moreover, Freesias can easily propagate and are tolerant to harsh environments up to some extent, therefore can be used as a potted plant, easily cultivable in poly houses, sheath houses, cool houses, glass houses, and greenhouses.

The knowledge of different cultivars of freesia and freesia corms can support the selection and cultivation of freesia cultivars and their management. Furthermore, the development of new freesia genotypes suitable for domestic environmental conditions, especially salinity, is required (Kang *et al*. 2013; Mu *et al*. 2014). The agriculture all-over Punjab is characterized especially by its wheat-rice cycle, but recently many growers paid attention towards the cut flower industry for their production to increase their earning. In Punjab, the flowers are produced at an area of about 9000 acres including tuberoses, jasmine, roses, and gladiolus (Riaz *et al*. 2007). Under the agro-climatic conditions of Pakistan, very limited work has been conducted on the evaluation of different freesia cultivars for cut flower production. Many studies focused on bio-stimulants and postharvest quality and fertilizer effect on freesia but very few works of literature are found on the selection of cultivars for their best response under arid climatic conditions. The freesia responds differently to different environmental conditions. Both the genotype and environmental conditions strongly influence the phenotype development of a crop (Thakur *et al*. 2015). Therefore, the present study was designed to evaluate the vegetative and morphological response of different cultivars of freesia for cut flower production in arid region of Rahim Yar Khan, Punjab, Pakistan.

Materials and Methods

Plant material and growth conditions

Four freesia genotypes (Valentino, White Wings, Jessica, and Golden Wave) were purchased from a distributor of well-reputed company Sakata seeds, Lahore, Pakistan. This experiment was conducted at Agricultural research area, Department of Agricultural Engineering, Khawaja Fareed University of Engineering and Information Technology, Rahim Yar Khan, Pakistan at 27°56’ to 28°52’ N latitudes and 70°00’ to 70°32’ E longitudes, during the year 202021. Bulbs of phenotypically selected cultivars were propagated. Bulbs were treated with 1% solution of fungicide (Topsin-M®) for ten minutes followed by shade drying before planting into the soil.

Preparation of field

The experiment was laid out according to randomized complete block design (RCBD) with four treatments having three replications (18 plants in each replication) including control. The experimental plot was prepared thoroughly by ploughing and leveling. Plot size of 4.0 m × 4.0 m and ridges (40 cm row × row) were managed. Silt, leaf compost, and coco coir were adjusted at the rate of 1:1:1 (v/v) as a growing medium. All cultural practices including weeding, earthing up, stalking and plant protection measures, were adopted. For assessing the physicochemical properties (pH, EC, organic matter, texture) soil samples were collected randomly from the trial area. The average temperature was 22 to 27°C during the daytime and 15 to 18°C at night with 40% ± 10% relative humidity (RH). Other soil conditions were pH 8.1, electrical conductivity (EC) 1.5 dS m^{-1}, and organic matter 0.66%. Seedlings were transplanted on the raised beds of 45 cm in height with a bed width of 65 cm. and depth of 7-8 cm in soil with 15 cm plant × plant and row × row distance. Plants were allowed to grow and data on following growth and flowering parameters have been recorded using standard procedures.

Data collection and analysis

The comparisons of yield and quality parameters of freesia for cut flower production of different cultivars were carried out. It helps us to decide the best cultivar for commercial production of freesia in the Faisalabad areas. Data were collected on the following parameters using standard procedures given below.

Vegetative growth parameters

Days taken by corms to sprout 50% were recorded and the average was computed (Hussain *et al*. 2011; Younis *et al*.

2018). Sprouting %age was calculated with the formula:

$$\text{Sprouting \% age} = \frac{\text{Number of germinated corms}}{\text{Total number of corms}} \times 100$$

Plant height (cm) was measured with the help of a measuring scale (Yan *et al*. 2019). The length of the stem (cm) was recorded with the help of a measuring scale (Khan *et al.* 2019). Number of leaves per plant was counted and the average was computed (Wu *et al.* 2017). Two healthy and mature leaves from the center of the plant (10^{th} and 15^{th} leaves from the base) were selected and their area was calculated (Carleton and Foote 1965). Data of five plants in each replication were taken and the average was computed.

$$\text{Leaf area} = \text{Length} \times \text{Breadth} \times 0.68 \text{ (correction factor)}$$

Time to harvest was calculated by recording the number of days from sowing to harvest. Data were collected from six plants per replication and the average was computed (Abdulazeez *et al*. 2020). A number of florets per spike were counted and the average was computed (Younis *et al*. 2006; Abdulazeez *et al*. 2020). Days taken by complete emergence of spike were recorded and the average was computed (Zubair *et al*. 2006; Thakur *et al.* 2015). Spike length (cm) was recorded with the help of a measuring scale (Abdulazeez *et al*. 2020). The diameter of the spike (cm) was recorded with the help of a vernier caliper (Younis *et al*. 2006; Khan *et al*. 2012). The number of days to check the persistency of spikes was counted after the first flower opening to the senescence of the last flower (floret) (Khan *et al*. 2012).

Cormels traits

The number of cormels per clump was counted and the average was computed. After 30 days of harvest, bulbs were dug out and the diameter of six bulbs from each replication was measured with a digital caliper, and the average was worked out. cormels separated from each bulb/clump were weighed on an electric weighing balance and the average was computed. The weight of a single corm was weighed on an electric balance and the average was computed. The diameter of a floret (cm) was recorded with the help of a digital caliper from the middle of the lowermost floret when it was in full bloom (Chopde *et al*. 2015).

Three flowering stems were square-root transformed to normalize the error distribution before the analysis, as described (Khan *et al*. 2019) using an electronic balance (S = 0.1 g) (Acculab V-1200). The harvested floral stems were put into the brown paper bags, labeled according to the treatment number, and dried completely in an oven at 60–65°C to determine the dry weight of the floral stems. The following formulas were used to calculate the index of growth traits (Hunt 1982). The relative growth rate (RGR) was calculated by the following formula:

$$RGR = (InW2 - In\ W1)(t2 - t1)$$

Where, W_2 and W_1 denote the plant's dry mass (g) at times t_2 and t_1, respectively.

The net assimilation rate was calculated by the following formula:

$$NAR = dW/(A \times dt)$$

Where A is the area of assimilation organs (cm^2), dW is the dry mass increment (g), and dt is the time of cultivation (days) (Khan *et al*. 2019).

SPAD value

Two healthy and mature leaves were selected from the top of the plant per replication and leaf SPAD value were determined from three different points of a leaf (tip, middle, and base portion) and the average was computed (Khan *et al*. 2019).

Flower quality is an array of various characteristics including the development of bud, flower, form, size (diameter), leaf quality, and color. Flower quality was visually rated in numbers using a scale ranging from 1 to 9 (Very poor quality, poor quality, good quality, medium quality, best quality). Flower quality was rated after the approval of three different judges and average was worked out (Dest and Guillard 1987; Cooper and Spokas 1991).

Stems with 1-2 open florets were harvested and vase life was estimated by placing stems in distilled water after cutting stem end to avoid air embolism. In each treatment, 15 replicates were used. Stems were placed in a vase life evaluation room at 20 ± 2°C temperature and 60-80% relative humidity with a 12 h daily light period. Vase life was considered to be ended when stems had ≥ 50% of drooping, fading, wilting, or petal shedding on the stem. The number of days when stems were fresh was counted and the average was computed.

Statistical Analysis

Recorded data were subjected to analysis of variance (ANOVA) and fixed-factor models (Snedecor and Cochran 1980). Duncan's multiple range tests was used to assess the significance of treatment differences by means of IBM SPSS Statistics for Windows (version 26.0, IBM Corp., Armonk, NY, USA).

Results

Vegetative Growth Parameters

Golden Wave showed a maximum sprouting percentage (50%) and take more days (6.03 days) followed by Valentino (6 days) when compared to other cultivated genotypes. Orlando (5.57 days) and Jessica (pink flowers) showed minimum days (4.6 days) for 50% sprouting when compared to all other three cultivated genotypes in the experiment but there was no significant difference. Table 1 also shows that there was also no significant difference among all experimental genotypes Jessica, Valentino,

Orlando, and Golden Wave in terms of sprouting percentage (27.3, 24.3, 24.6 and 23.7%, respectively). Golden wave showed minimal plant height (28.82 cm) whereas Jessica, Valentino, and Orlando showed no significant difference in plant height (46.7, 44.72 and 42.88 cm) respectively. Leaf area was observed non-significance when compared between Jessica, Valentino, and Orlando whereas there was a significant difference when comparing golden wave with other cultivars of freesia i.e., showed a minimal number of leaves (13.27) and minimum leaf area (22.08 cm^2).

Physiological growth parameters

Chlorophyll contents showed a significant difference among Jessica (74.04) and Golden wave (69.81) cultivars (Table 1). The days was calculated and it was observed that Jessica took a minimum number of days to sprout (102 days) whereas the Golden wave showed maximum emergence time for spikes (104.43 days). Although the time of emergence showed no significant difference when compared to all experimental genotypes (Table 2). Table 2 showed that the Golden wave genotype of freesia showed minimum stem length (22.23 cm) whereas the other three genotypes Jessica (pink flowers) (40.54 cm), Valentino (38.59 cm), and Orlando (36.49 cm) showed non-significant difference when compared for stem length. Golden wave cultivar of freesia had a minimum spike length (7.93 cm), Spike diameter (2.88 cm), and floret diameter (30.76 cm), whereas there was non-significant difference observed among all other experimental genotypes (Table 2). Fresh weight of flower stem was minimum in Golden wave (9.30 g) followed by Valentino (10.87 g). However, Orlando and Jessica showed the maximum fresh weight of stem (11.13 and 11.21 g), respectively. Jessica showed maximum dry weight of stem (2.27 g). However, Golden Wave freesia showed the least response for all measured parameters when compared to Orlando, Valentino, and Jessica, respectively.

There was non-significant difference among all experimental genotypes when compared for relative water content percentage and net assimilation rate. Whereas Valentino freesia showed minimum values in terms of stem dry matter contents (0.17 g), Golden Wave showed a minimum fresh area of leaves (13.05 cm^2), and specific leaf area (7.68 cm^2), respectively. Orlando showed maximum SDMC (0.20 g) however there was non-significant difference between Jessica, Valentino, and Orlando when compared for fresh weight, dry weight, RWC and SMDC (Fig. 1), and for leaf are SLA and NAR (Fig. 2).

Quality measurements

Quality parameters were measured in terms of flower quality, vase life, the production time of flowers on spikes and spikelets, number of cormels per clump, corm diameter, corm weight, and cormels weight. Valentino showed a maximum cormels weight per plant (31.56 g) followed by Jessica (30.11 g), whereas Golden showed minimum weight of corms per plant (22.34 g). Golden Wave cultivar of freesia showed the least response when compared for vase life (8.17 days), the number of cormels per plant (8.43 cormels), corms diameter (26.96 cm), cormels weight per plant (22.34 g) and single corm weight (9.93 g) when compared to other genotypes. No significance ($P > 0.05$) difference was observed between Valentino and Orlando in terms of cormels weight (Table 3).

Discussion

Results revealed that based on growth, physiological and quality indicators, Jessica (Pink flower) genotype performed relatively better as compared to other genotypes. Plant height, days to sprouting, leaf number and leaf area was observed to be higher in Jessica genotype as compared to Valentino, Orlando, and Golden wave genotypes. This higher growth indicators might be due to the endogenous production of bio-stimulants, which can enhance different growth parameters under different growing conditions. Ahmad *et al*. (2019) also strongly affirmed that when *Fressia* × *hybrida* plants were treated with exogenous application of bio-stimulant such as moringa leaf extract, it significantly improved its growth performance such as plant height, leaf number and leaf area at less days as compared to other genotypes. Furthermore, quality of Fressia cut flowers are also observed to be increased due to the treatment with different preservative solution which makes certain changes in morphology and physiological responses under different growing conditions (Hajizadeh 2016). Among all growth parameters, plant height is one of the most key indicators for the healthier growth of plants which subsequently increased the spike length, stem length and spike diameter (Khan *et al*. 2019). Higher stem length was observed in Jessica genotype as compared to other Valentino, Orlando, and Golden Wave genotypes. This particularly increased number of stem length in Jessica genotype might be due to the endogenous production of cytokinin which ultimately increase the cell division, expansion, and proliferation process. Our assumption of increased stem length due to endogenous production of cytokinin. In this context, Maurya *et al*. (2020) showed that *LAP1*, which is a shoot promoting gene acts in a cytokinin dependent manner and stimulating the expression of cell cycle regulator *AIL1* and subsequently suppressing the *BRANCED1* expression to promote shooting in hybrid aspen cultivar.

Genotype Golden wave showed the least response in terms of sprouting percentage, plant height, stem length, specific leaf area, stem fresh and dry weight, spike length, floral diameter, SPAD value, leaf number per plant, corm diameter, number of corms, and vase life. This may be because of genetic response because all genotypes had different genetic makeup (Bhat *et al*. 2012; Gul *et al*. 2019). Overall, Jessica (pink flowers) cultivar of freesia showed a good response when compared with other studied cultivars

Table 1: Comparative effect of freesia cultivars on sprouting time, sprouting percentage, plant height, leaf number per plant, leaf area, and chlorophyll contents

Genotypes	Sprouting time (days)	Sprouting (%)	Plant height (cm)	Leaf number/plant	Leaf area (cm^2)	*SPAD value
Valentino	6.00	27.3a	44.72	17.60	35.61	73.57
Orlando	5.57	24.3b	42.88	17.87	31.51	73.56
Jessica	4.60	24.6b	46.70	18.07	33.92	74.07
Golden Wave	6.03	23.7b	28.82	13.27	22.08	69.81

*SPAD: Leaf greenness assumed as chlorophyll content

Table 2: Comparative effect of freesia cultivars on sprouting time, sprouting percentage, plant height, leaf number per plant, leaf area, and chlorophyll contents

Genotypes	Time to spike emergence (days)	Stem length (cm)	Spike length (cm)	Spike diameter (cm)	No of florets/spikes	Floret diameter (cm)
Valentino	102.50	38.59	11.09	3.29	9.97	33.40
Orlando	103.53	36.49	11.32	3.17	10.23	34.01
Jessica	102.00	40.54	11.90	3.24	10.37	33.28
Golden Wave	104.43	22.23	7.93	2.88	10.07	30.76

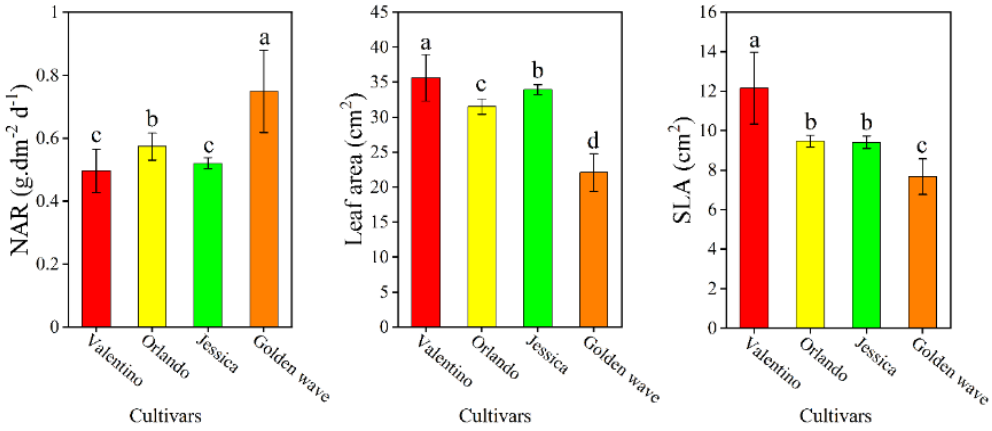

Fig. 1: Comparative growth analysis on (A) NAR (net assimilation rate) (B) Leaf area, (C) Specific leaf area; Means followed by the same lowercase letters do not differ significantly from each other according to Duncan's multiple range test ($p < 0.05$)

followed by Orlando and Valentino. Freesia can be considered a heat-tolerant flowering bulb and can be grown in a hot climate (Mansour 1968). The difference in response of different cultivars studied might be due to the genetic composition between the genotypes which can affect the interaction of climate and soil very differently in the arid areas (Riaz *et al*. 2013). The genetic makeup and constitution can be responsible for different variations and featured attributes of studied cultivars.

Chlorophyll contents affect the photosynthetic activity of plants, which may be the reason Golden wave was less responsive in other traits. A similar pattern was observed by (Ilyas 2007). Hussain *et al*. (2011) reported that quick sprouting in cultivar Jessica (pink flowers) and Orlando may be due to the genetic potential of these cultivars, which enable the plants to use nutrients efficiently and more adaptability in arid climatic condition of Pakistan. Moreover, higher value of chlorophyll content was observed in Jessica genotype which indicate healthier and well growth under different growing conditions. A higher chlorophyll content in Jessica genotype might be due to the upregulation of ammonium transporter genes which can improve the intensity of green pigments in leave portion of genotype. Higher level of chlorophyll content due to the accumulation of nitrate content was observed in walnut genotypes where the over-expression of ammonium transporter gene i.e., *JrAMT2* was observed during the stability of chlorophyll content (Liu *et al*. 2021). Besides higher accumulation of chlorophyll content in Jessica genotype, less rete of chlorophyll stability and accumulation was also observed in other genotypes such as Valentino, and Orlando, Golden wave. To this effect, He *et al*. (2018) who supported that CLH is a gene which is responsible for the degradation of chlorophyll content in citrus plants and over expression of this gene in different citrus cultivars results in the less accumulation of chlorophyll content as compared to other genotypes which highly accumulate the chlorophyll content due to the downregulation of genes.

Quality measurements of freesia flowers varied between different genotypes. It has been observed that flower quality and vase life was significantly higher in Orlando as compared to other genotypes such as Valentino, Jessica, and Golden wave. These quality attributes along

Table 3: Comparative effect of freesia cultivars on sprouting time, sprouting percentage, plant height, leaf number per plant, leaf area, and chlorophyll contents

Genotypes	Flower quality	Vase life (days)	Production time (days)	No. of cormels/clump	Corms diameter (cm)	Cormel weight (g)	Corms weight (g)
Valentino	5.70	10.13	120.00	11.40	32.57	31.56	14.99
Orlando	6.03	10.17	118.00	10.40	31.80	28.97	14.32
Jessica	5.90	9.90	116.00	10.60	32.65	30.11	15.18
Golden Wave	5.30	8.17	122.00	8.43	26.96	22.34	9.93

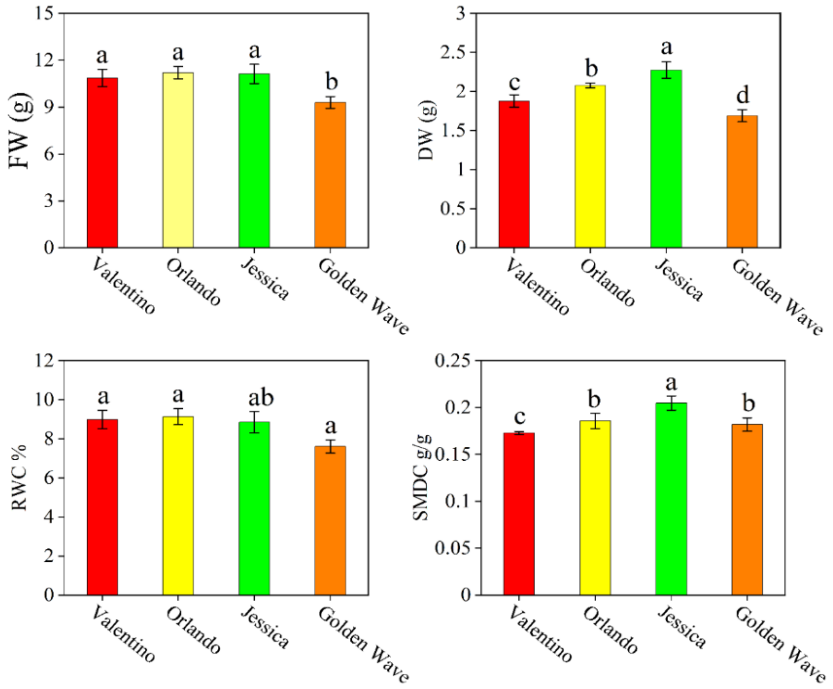

Fig. 2: Comparative growth analysis (A) Fresh weight of stems, (B) Relative water contents, (C) Stem dry matter contents, (D) Dry weight. Means followed by the same lowercase letters do not differ significantly from each other according to Duncan's multiple range test ($p < 0.05$)

with corm diameter, cormels and corms weight are driving key factors for the better development of flower scent characters. Flowers quality of Orlando genotype might be higher as compared to other genotypes due to the regulation of different transcriptomic factors which leads to the development of quality attributes. Huang *et al.* (2018) demonstrated that quality of *F. hybrida* was improved due to the over expression of *FhDXS2A*, *FhGPPs* and *FhTPSs* genes during the different growth and developmental stages of flowers. Moreover, it is also observed that during the developmental stages of F. hybrida flower, about 34 floral volatile compounds, and primarily volatile monoterpenes are produced which accounted for the better floral development. Corms attributes such as diameter and weight were enhanced in Jessica genotype when grown under different growing conditions. These characters are mostly attributed to the application of certain bio-stimulants, which improves their ability to gain more dry mass. In Jessica genotype higher corms attributes might be enhanced due to the endogenous accumulation of bio-stimulants which leads to the more corm diameter and weight. Corm attributes such as corms diameter, and weight of corms and comets were also increased due to the pre harvest application of moringa leaf extract which act as internal stimulants and ultimately enhance the growth and yield of cut flower *F.* × *hybrida* (Ahmad *et al.* 2019).

Conclusion

Jessica showed a better response in terms of vegetative growth traits, yield, and high-quality inflorescences and may be used as a cut flower and vase flower for more than a week without adding any vase solution as food/additives for flowers. However, Golden wave freesia is not recommended in hot climates due to its being less responsive in the cut flower industry. Further studies would be required to optimize freesia cultivars by adding different organic and inorganic growth promoters both in pre-harvest and post-harvest to check the best combination for use on individual flowering crops.

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Author Contributions

SK and MW designed the project, MZI, BI, SK, and KHA planned the experiments, RAS, SK, HA and MK interpreted the results and analyzed the data, SK, IU, and SN made the write up, MA, MI and MW did critical revision and editing. All authors have read and agreed to the published version of the article.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability

The data will be available on fair request to the corresponding author.

Ethical Approval

Not applicable to this paper.

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