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Effects of Some Mineral Substrates on Qualitative and Quantitative Traits of Tuberose (*Plianthes tuberosa* L.)

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Abstract
Tuberose is one of the most important aromatic cut flower among ornamental plants that its growth and quality is influenced by the type and percentage of mineral compounds in the substrate. This study was carried out on the basis of a randomized complete design to explore the impact of feldspar, talc, dolomite and tuff minerals at the rate of 10, 20 and 40% incorporated with garden soil and manure on some quantitative and qualitative traits of Tuberose plants. The results showed that the highest stem diameter, floret number, root fresh and dry weight were obtained from plants grown in garden soil + dolomite + manure at the ratios of 40:40:20% and 60:20:20%. The highest stem length, floret fresh weight, content of chlorophyll b and total chlorophyll were detected in the plants treated with garden soil + talc and manure (40:40:20%). Highest daughter bulb perimeter, total bulb weight, and floret dry weight were obtained from plants treated with garden soil + feldspar + manure (40:40:20%). Highest floret length and width were seen in plants grown in garden soil + tuff + manure (70:10:20%) and garden soil + talc + manure (60:20:20%). Plants that were grown in garden soil + feldspar + manure at the ratios of 70:10:20% and 60:20:20% had the highest chlorophyll a content and the lowest daughter bulb perimeter, stem length and width, floret dry weight, width and number of floret, chlorophyll b, and total chlorophyll content respectively. Highest root dry weight was measured in control (garden soil + manure 80:20%) and the lowest root fresh and dry weights and volume were recorded for plants grown in garden soil + tuff mineral soil + manure (40:40:20%). Overall, the use of talc, dolomite, and feldspar at the ratio of 40% as Mg and K supplying minerals can improve growth and biochemical parameters of the Tuberose plant.

Keywords: Dolomite, Feldspar, Silicon, Talc, Tuff.

Abbreviations: CV, Coefficient of variation; **OM**, Organic matter; **EC,** Electrical conductivity; **CEC**, Cation Exchange Capacity. **N,** Nitrogen; **P,** Phosphorus; **K,** Potassium; **Mg,** Magnesium; **Ca,** Calcium; **Chl a,** Chlorophyll a; **Chl b,** Chlorophyll b; **Total Chl,** Total Chlorophyll; **SD**, Stem diameter; **LFS,** Length of the flowering stem; **FW**, Fresh weight; **FWF**, Fresh weight of the florets; **DWF**, Dry weight of the florets; **FWR**, Fresh weight of root; **DWR**, Dry weight of root; **NF**, Number of florets; **FFW**, Fresh weight of floret; **DFW**, Dry weight of floret; **FL**, Floret length; **DBP**, Daughter bulb perimeter; **TBW**, Total bulb weight**; P,** Phosphorous; **EC,** Electrical conductivity.

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Introduction

Tuberose (*Polianthes tuberosa* L.), from the Agavaceae family and one of the most important cut flowers in tropical and subtropical areas (Bahadoran et al., 2015) especially Iran (Afifipour and Khosh-Khui, 2015), is an herbaceous, perennial, monocot, bulbous plant that is native to Mexico (Benschop, 1993). This plant is one of the most important commercial and aromatic species that is widely used in perfume production, floral industry, decoration and wreaths (Amin et al., 2017). Growing of this species in some region of the world such as Iran is increasing due to the very favorable climate and the global markets for its export (Bahadoran et al., 2015; Anjali et al., 2012). Tuberose needs adequate light and nutrient in the substrate medium (Ghort Tappeh and Ghalavand, 2006; Ikram et al., 2012) and given that the physical and chemical characteristics of substrates influence plant growth, development, yield and crop quality directly and/or indirectly (Ghasemi et al., 2017). Suitable substrate should contain adequate reserve of nutrients for all growth stages of the plant (Dilmaghani and Hemmaty Emmaty, 2011; Marschner, 2011). Bahadoran et al., (2012) conducted an experiment to investigate the effects of various concentrations of natural zeolite (control, 5, 10, 15, 20, 25 and 30 g zeolite/kg soil) on growth and flowering of Tuberose plants. The results of their study showed that addition of zeolite to soil had beneficial effects on vegetative and physiological parameters of Tuberose plants. In their experiment addition of zeolite to the soil caused increase in the height of flowering stem, flower diameter, leaf area and chlorophyll content of Tuberose plants.

In recent years, natural minerals such as feldspar, dolomite, talc and silicon have been used to improve the fertility of different soils for plant cultivation, as well as to modify the physical and chemical structure of the soils (Ahmadi Azar et al., 2015; Damrongrak et al., 2015; Ibrahim et al., 2015; Mousavi et al., 2014; Wroblewska and Debicz, 2011). By investigating the effects of aforementioned minerals on some crops and ornamental plants, Marschner et al. (1990), Sacala, (2009) and Wroblewska and Debicz, (2011) showed that silicon has a positive effect on plant development and resistance against some abiotic stresses and play an important role in osmoregulation, holding water capacity and provide the sufficient nutrients and minerals in plants. In another study, Sivanesan and Park, (2014) used silicon in plant tissue culture and found that silicon is beneficial for plant growth and development, also improves morphological, anatomical and physiological characteristics and yield of various plants. It helps plants to cope with environmental stresses such as salinity and oxidative stresses and metal toxicity. Artyszak (2018) stated that foliar application of silicon can be used as a standard method for managing the agronomy of many crop and ornamental plants, and it can help to increase the yield of cultivated crops. Pati et al., (2016) showed that application of silicon increases plant height, number of tillers, number of panicle, and 1000-grain weight in rice plant. Furthermore, Rogerio and Crusciol (2008) investigated the effect of different levels of Dolomite (0, 1100, 2700, and 4300 kg ha^{-1}) and Phosphogypsum (0 and 2100 kg ha^{-1}) applications on some of the annual crop species such as rice and common bean and they showed that above-mentioned treatments increase shoot dry matter, grain yield and some minerals content such as N, P, K, Ca, S, Cu, Fe and Mn. Chutichude et al., (2010) investigated the effects of different concentrations of dolomite (0, 50, 100 and 150 ppm) in three times (25, 40 and 55 days after planting) on lettuce plants. They found that dolomite application in all studied times had no effect on morphological, physiological and biochemical traits (e.g. stem diameter, plant height, fresh weight, biomass, content of chlorophyll, the content of phenolic, Quinone, total soluble solids, pH and ascorbic acid content). However, in their study it was shown that application of 150 ppm dolomite at 55 days after planting increased the brightness of the leaves.

Given the economic significance of Tuberose in ornamental industry and due to the following reasons: 1) supplying some minerals such as silicon, magnesium and calcium by the mineral substrates for the plants, 2) impact of mineral substrates in regulation of the soil pH, 3) availability of mineral substrates in some region soils (in the current study Iran's soils) the present study aimed to explore the effect of mineral substrates on growth and biochemical characteristics of Tuberose plants.

Materials and Methods

Experimental location

The present study was carried in 2016-2017 growing seasons as a randomized complete design in three replications in the research greenhouses (with a daily temperature of 25±2 °C, a nightly temperature of 18±2 °C and relative humidity with average value of 60±5%) of Islamic Azad University Isfahan (Khorasgan) Branch, Isfahan, Iran.

Plant materials

The uniform bulbs of Tuberose (cv. double), with 9-11 cm diameter, were prepared from a flower producer institute in Dezful, and they were planted in 4-L pots containing the mineral treatments.

Mineral substrate media

In the present study the effects of different levels of mineral substrate treatments on some qualitative, quantitative and flowering traits of Tuberose were investigated. The treatments in this study were 13 mineral substrates including 10, 20 and 40% feldspar, talc, dolomite, or tuff mineral soil as well as 20% decayed manure mixed with garden soil. The treatment of 80% garden soil + 20% rotten manure was regarded as the control treatment. In each pot, a Tuberose bulb was planted at a depth of 1-1.5 times of the bulb length. To do the experiment, the pots were irrigated at one-week intervals and then, it was reduced to once per 10 days in November until February. At vegetative phase after emergence, the pots were fed with NPK (20:20:20) fertilizers at the rate of 1:1000. The substrate was disinfected with the Carbendazim fungicide (1:1000 w/w) every week to avoid the fungal diseases. Before doing the test, to determine the physicochemical characteristics of the treatments, samples were transferred to the specialized laboratory of water, soil, plant and fertilizer of “Sahand Azma” located in Isfahan province, Iran. The characteristics of the studied substrates are presented in Table 1.

Measurements

Growth parameters such as the length and diameter of flowering stem were measured at harvest time from the soil surface to the stem end with a ruler and the diameter of flowering stem was measured by precision caliper. Number of floret were counted at

Table 1. Physical and chemical characteristics of the studied mineral compounds

Substrate ingredients	pH	OM (%)	Lime (%)	EC ($dS.m^{-1}$)	CEC ($meq.100g^{-1}$)	Available N (%)	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)	Mg ($meq.l^{-1}$)	Ca ($meq.l^{-1}$)
Feldspar	8.26	0.17	5	5.94	2.08	0	25.57	0.366	4	2.2
Talc	7.57	0.65	19	5.21	8.17	0	29.51	0.23	27.6	6.4
Dolomite	7.88	0.17	48	1.76	0.97	0	23.78	0.351	16.3	18.1
Tuff	9.78	0.11	23	16.02	76.52	0.01	19.24	0.21	4.3	1.8
Garden soil	7.76	1.2	28	1.63	15.82	0.168	45.13	0.16	4	3

OM, Organic matter; EC, Electrical conductivity; CEC, Cation Exchange Capacity. N, Nitrogen; P, Phosphorus; K, Potassium; Mg, Magnesium; Ca, Calcium.

the end of the experiment by counting the number of each floret in the plants and floret length was measured from the floret stem to the end of the biggest petal and its width was calculate based on the widest blade of floret. Fresh and dry weights of the florets and roots were determined at harvest time with a precision scale of 0.001 g so that after harvesting the plants, the florets and roots in each treatment were placed one by one in oven and were dried at 75 °C for 48 hours. The bulbs and roots were taken out of the substrate, were completely rinsed, and were dried in the open air to determine their weight on a digital scale. To measure the perimeter of the daughter bulb, the biggest bulb that had grown at the tip of the maternal bulb was selected. Root volume of the treatments was separately determined in 250 mL graduated cylinders by measuring the volume increase in the cylinder content following placing the roots in them.

Apart from the morphological measurements, in the present study the effects of treatments on biochemical characteristics of the Tuberose plant were also investigated. To do that, following complete growth of the plants, the fresh tissues of the plants were harvested and sent to the laboratory to assess their biochemical characteristics. Chl *a*, Chl *b* and total Chl contents were determined by using the Arnon (1967) method in mg g^{-1} FW of leaf. For Chl determination, after adding acetone (80%) in a mortar, 0.1 g of fresh tissue was weighed and eroded in the acetone until a scum was obtained. The obtained scum was isolated by filter paper. Then, the extract volume was reached to 10 ml by the acetone (80%).Thereafter, some of the extract was immediately transferred to the cuvette and their absorbed was recorded at 645, 663, and 470 nm wavelengths by a spectrophotometer (model D6320). Acetone (80%) was used as the Blanc solution.

Statistical analysis

The study was carried out on the basis of a randomized complete design in three replications. The data were analyzed by SAS software (ver 9.4) and the Duncan's Multiple Range test was used to compare the mean of data at $p < 0.05$.

Results

Stem diameter and stem length

The results of analysis of variance (ANOVA) showed that the effect of the substrate was significant at $p< 0.01$ on stem diameter and length.

Highest stem diameter (with average value of 5.94 mm) was obtained from the garden soil + dolomite + rotten manure (40:40:20%) treatment and the lowest stem diameter (with average value of 4.642 mm) was obtained from the garden soil + feldspar + rotten manure (70:10:20%) treatment. Based on the results of Table 3 it can be observed that the SD in the garden soil + dolomite + rotten manure treatment has an increase of approximately 7.03 % compared with the SD of the control. In other words, this treatment had a positive effect on stem diameter than the control treatment but garden soil + feldspar + rotten manure treatment did not improve this trait than the control treatment (Table 3).

Table 2. Results of analysis of variance for the effect of mineral substrate on some traits of Tuberose plants

Sources of Variation	df	Means of squares						
		SD	Total stem length	NF	FFW	DFW	Floret width	FL
Substrate	12	0.69^{**}	292.23^{**}	18.54^{**}	0.70^{**}	0.003^{**}	0.15^{*}	0.33^{**}
Error	65	0.17	17.62	2.10	0.04	0.0003	0.07	0.06
C.V. (%)		7.58	7.55	9.60	10.54	4.43	5.89	4.43

* and ** show significance at the $p < 0.05$ and $p < 0.01$ levels, respectively.
SD, Stem diameter; NF, Number of florets; FFW, Fresh weight of floret; DFW, Dry weight of floret; FL, Floret length

Table 3. Mean comparisons for SD, Total stem length, NF, FFW, DFW, Floret width, FL of Tuberose as influenced by different substrate treatments

Substrates	SD (mm)	Total stem length (cm)	NF	FFW (g)	DFW (g)	FL (cm)	Floret width (cm)
Garden soil + feldspar + manure (70:10:20)	4.64^{d}	43.54^{g}	11^{f}	2.23^{b}	0.14^{ab}	5.48^{b-e}	4.66^{ab}
Garden soil + feldspar + manure (60:20:20)	5.23^{bc}	48.62^{f}	13.60^{e}	1.86^{cd}	0.07^{e}	5.38^{c-f}	4.29^{c}
Garden soil + feldspar + manure (40:140:20)	5.56^{abc}	51.90^{ef}	16.66^{ab}	1.89^{cd}	0.15^{a}	5.41^{b-f}	4.76^{ab}
Garden soil + talc + manure (70:10:20)	5.26^{bc}	52.40^{ef}	14^{e}	2^{bc}	0.15^{a}	5.36^{c-f}	4.62^{abc}
Garden soil + talc + manure (60:20:20)	5.17^{bc}	52.92d^{ef}	15.20^{b-e}	1.81^{cd}	0.14^{ab}	5.43^{b-f}	4.88^{a}
Garden soil + talc + manure (40:140:20)	5.72^{ab}	71.08^{a}	16^{a-d}	2.76^{a}	0.13^{bc}	5.68^{abc}	4.68^{ab}
Garden soil + dolomite + manure (70:10:20)	5.44^{abc}	56.74^{cde}	14.40^{de}	2.17^{b}	0.11^{cd}	5.56^{a-d}	4.67^{ab}
Garden soil + dolomite + manure (60:20:20)	5.67^{ab}	60.04^{bc}	17.60^{a}	1.66^{de}	0.13^{ab}	5.72^{ab}	4.48^{bc}
Garden soil + dolomite + manure (40:140:20)	5.94^{a}	59.10^{bc}	16.40^{abc}	1.90^{cd}	0.13^{bc}	5.23^{efg}	4.42^{bc}
Garden soil + tuff + manure (70:10:20)	5.51^{abc}	56.30^{cde}	14.40^{de}	2.18^{b}	0.13^{ab}	5.79^{a}	4.78^{ab}
Garden soil + tuff + manure (60:20:20)	5.17^{bc}	57.88^{bcd}	17.20^{a}	1.89^{cd}	0.10^{d}	5.28^{def}	4.67^{ab}
Garden soil + tuff + manure (40:140:20)	5.02^{cd}	49.70^{f}	15^{b-e}	1.51^{e}	0.10^{d}	5.12^{fg}	4.57^{abc}
Control (garden soil + manure) (80:20)	5.55^{abc}	62.36^{b}	14.66^{cde}	1.45^{e}	0.10^{d}	4.96^{g}	4.60^{abc}

Mean of each variable fallowed by the non-similar letters have significantly difference at $p<0.05$ by Duncan's Multiple Range Test
SD, Stem diameter; NF, Number of florets; FFW, Fresh weight of floret; DFW, Dry weight of floret; FL, Floret length

Longest and shortest stem length (with average values of 71.08 and 43.54 cm, respectively) were observed in plants that were treated with garden soil + talc + rotten manure (40:40:20%) and those treated with garden soil + feldspar + rotten manure (70:10:20%), respectively. Application of garden soil + talc + rotten manure (40:40:20%) significantly increased stem length (approximately 13.98%) compared with the control plants (Table 3).

Number of floret

According to the analysis of the obtained results, FN per plant was significant influenced by mineral fertilizers at $p< 0.01$ (Table 2). Means comparison of the results of the present study (Table 3) showed that plants grown in garden soil + dolomite + rotten manure and in garden soil + tuff mineral soil + rotten manure, both at the ratio of 60:20:20%, produced 17.6 and 17.2 florets per each treatment, respectively. There was about 20.06% increases in NF trait in garden soil + dolomite + rotten manure and control treatments (with average value of NF 14.66 numbers). On the other hands, the lowest NF per plant (with average value of 11 florets) was observed in plants treated with garden soil + feldspar + rotten manure (70:10:20%) (Table 3).

Floret fresh and dry weights

Analysis of variance of the effects of present treatments on FFW and DFW showed that substrate materials has significant effect on both mentioned traits at $p<0.01$ (Table 2).

Regarding the mean comparison of FFW trait, the highest value of FFW (with average value of 2.76 g) was obtained in garden soil + talc + rotten manure (40:40:20%) treatment and the lowest value (with average value of 1.45 g) was obtained in control treatment (garden soil + rotten manure, 80:20%). In general, application of the garden soil + talc + rotten manure treatment was better than the other treatments. Furthermore, we found significant increase in amount of FFW at garden soil + talc + rotten manure treatment (40:40:20%) when compared to its amount in control treatment (Table 3).

In studying the effects of treatments on FDW, the highest value for FDW (with average value of 0.15 g) was observed in both treatments of garden soil + feldspar + rotten manure (40:40:20%) and garden soil + talc + rotten manure (70:10:20%) and the lowest value in FDW (with average value 0.07 g) was obtained from the plants treated with garden soil + feldspar + rotten soil (60:20:20%). There was a significant increase in the FDW in comparison with control treatment (with average value of 50%) (Table 3).

Floret length and width

Analysis variance in Table 2 showed that substrate materials had significant effects on FL and floret width at $p<0.01$ and $p< 0.05$, respectively. The results of mean comparison of Table 3 showed that the plants that were treated with garden soil + tuff mineral soil + rotten manure (70:20:20%) had the longest FL (with average value of 5.79 cm) and the plants that were treated with garden soil + rotten manure (80:20%) as a control treatment produced the shortest FL (with average value 4.96 cm). Highest and lowest floret width (with average value of 4.88 and 4.29 cm, respectively) were obtained from the plants treated with garden soil + talc + rotten manure and garden soil + feldspar + rotten manure respectively, both at the ratio of 60:20:20% (Table 3).

Daughter bulb perimeter and total bulb weight

Analysis of variance showed that the effect of the mineral substrates was significant ($p < 0.01$) for DBP and TBW (Table 4).

The highest and the lowest DBP (with average values of 8.34 and 4.63 cm, respectively) were obtained in plants treated with garden soil + feldspar + rotten manure (40:40:20%) and garden soil + feldspar+ rotten manure (70:10:20%) treatments, respectively. Highest TBW that had a significant difference compared with the other treatments (with average value of 58.588 g) was achieved in plants grown in garden soil + feldspar + rotten manure (40:40:20%) and the lowest value of TBW (with average value of 30.26 g) that had a significant difference than the other treatments was obtained in plants grown in garden soil + tuff mineral soil + rotten manure treatment (40:40:20%) (Table 5).

Table 4. Results of analysis of variance for the effect of mineral substrate on TBW, DBP, Chl a, Chl b, Total Chl, FWR, DWR and Root Volume of Tuberose plants

S.O.V.	df	Means of squares							
		TBW	DBP	Chl *a*	Chl *b*	Total chl	FWR	DWR	Root volume
Substrate	12	250.16**	5.81**	0.018**	0.003**	0.027**	30.08**	0.29**	33.04**
Error	65	27.65	0.38	0.001	0.0003	0.002	2.21	0.015	1.54
C.V. (%)		12.12	8.96	14.11	12.75	10.91	12.75	12.64	10.19

* and ** show significance at the $p < 0.05$ and $p < 0.01$ levels, respectively.
TBW, Total bulb weight; DBP, Daughter bulb perimeter; FWR, Fresh weight of root; DWR, Dry weight of root

Table 5. Mean comparisons for TBW, DBP, Chl a, Chl b, Total Chl, FWR, DWR, Root Volume of Tuberose as influenced by different mineral substrates

Substrates	TBW (g)	DBP (cm)	Chl *a* (mg g^{-1} FW)	Chl *b* (mg g^{-1} FW)	Total Chl (mg g^{-1} FW)	FWR (g)	DWR (g)	Root volume (cm^3)
Garden soil + feldspar + manure (70:10:20)	41.40^{bc}	4.63^{f}	0.33^{a}	0.13^{c}	0.47^{a}	13.06^{bc}	1.01^{cd}	13.50^{bc}
Garden soil + feldspar + manure (60:20:20)	43.71^{bc}	6.70^{cd}	0.16^{d}	0.06^{d}	0.23^{e}	11.91^{b-f}	1.03^{cd}	12.83^{cd}
Garden soil + feldspar + manure (40:140:20)	58.58^{a}	8.34^{a}	0.28^{ab}	0.16^{ab}	0.45^{a}	12.20^{b-e}	1.16^{bc}	12.80^{cd}
Garden soil + talc + manure (70:10:20)	42.30^{bc}	6.68^{cd}	0.33^{a}	0.12^{c}	0.45^{ab}	10.70^{f}	0.74^{d}	10.00^{e}
Garden soil + talc + manure (60:20:20)	47.64^{b}	7.30^{bc}	0.23^{bc}	0.08^{d}	0.32^{cd}	11.01^{def}	0.94^{d}	11.40^{de}
Garden soil + talc + manure (40:140:20)	48.39^{b}	7.56^{ab}	0.32^{a}	0.17^{a}	0.50^{a}	10.83^{ef}	1.00^{d}	11.00^{e}
Garden soil + dolomite + manure (70:10:20)	39.74^{c}	5.53^{e}	0.25^{b}	0.12^{c}	0.37^{c}	11.71^{c-f}	0.98^{d}	12.83^{cd}
Garden soil + dolomite + manure (60:20:20)	44.24^{bc}	7.24^{bc}	0.14^{d}	0.13^{bc}	0.28^{de}	15.16^{a}	1.18^{b}	15.20^{a}
Garden soil + dolomite + manure (40:140:20)	39.72^{c}	7.63^{ab}	0.18^{cd}	0.14^{bc}	0.32^{cd}	12.87^{bcd}	0.97^{d}	13.33^{bc}
Garden soil + tuff + manure (70:10:20)	43.98^{bc}	7.02^{bcd}	0.14^{d}	0.13^{c}	0.27^{de}	10.16^{f}	0.92^{d}	11.00^{e}
Garden soil + tuff + manure (60:20:20)	38.96^{c}	7.82^{ab}	0.29^{ab}	0.08^{d}	0.38^{bc}	12.50^{b-e}	0.97^{d}	13.40^{bc}
Garden soil + tuff + manure (40:140:20)	30.26^{d}	6.33^{d}	0.33^{a}	0.16^{ab}	0.50^{a}	5.93^{g}	0.44^{d}	6.16^{f}
Control (garden soil + manure) (80:20)	44.87^{bc}	7.02^{bcd}	0.15^{d}	0.11^{c}	0.26^{de}	13.84^{ab}	1.38^{a}	14.80^{ab}

Mean of each variable fallowed by the non-similar letters have significantly difference at $p<0.05$ by Duncan's Multiple Range Test

Chlorophyll pigments

The analysis of the results of the present study revealed a significant difference at $p<0.01$ for the application of mineral substrates on Chl *a*, Chl *b* and total Chl contents of the leaves (Table 4). The highest Chl *a* content (with average value of 0.33 mg g^{-1} FW) was observed in plants that were grown in garden soil + feldspar + rotten manure treatment (70:10:20%) but it was not significantly different from the plants that were grown in garden soil + tuff mineral soil + rotten manure (40:40:20%) and in garden soil + talc + rotten soil (70:10:20 and 40:40:20%) treatments. The lowest Chl *a* content was observed in garden soil + tuff mineral soil + rotten manure (70:10:20%) and garden soil + domolite + rotten manure (60:20:20%) treatments (the amount of Chl *a* in both treatments was equal to 0.14 mg g^{-1} FW), (Table 5).

Highest and lowest Chl *b* contents (with average values of 0.17 and 0.16 mg g^{-1} FW, respectively) were observed in garden soil + talc + rotten manure (40:40:20%) and garden soil + feldspar + rotten manure (60:20:20%) treatments, respectively (Table 5). The plants that grown in garden soil + talc + rotten manure (40:40:20%), garden soil + tuff mineral soil + rotten manure (40:40:20%) and garden soil + feldspar + rotten manure (70:10:20%) exhibited the highest total Chl content (with average values of 0.50, 0.50, and 0.47 mg g^{-1} FW, respectively), while the lowest total Chl content (with average value of 0.23 mg g^{-1} FW) was obtained in plants that were grown in garden soil + feldspar + rotten manure treatment (60:20:20%) (Table 5).

Root characteristics

ANOVA indicated that FWR, DWR and root volume were significantly ($p < 0.01$) influenced by the mineral substrates (Table 4).

According to the mean comparisons in the Table 5, the highest FWR (with an average value of 15.16 g) was achieved in plants that were grown in garden soil + dolomite + rotten manure (60:20:20%) and the lowest FWR (with average value 5.93 g) was detected in garden soil + tuff mineral soil + rotten manure treatment (40:40:20%). Highest and lowest amounts of DWR (with average value of 1.38 and 0.44 g, respectively) were obtained in control treatment (garden soil + rotten manure, 80:20%) and garden soil + tuff mineral soil + rotten manure treatment (40:40:20%), respectively. Highest and lowest root volumes (with average values of 15.20 and 6.16 cm^3, respectively) were found in garden soil + dolomite + rotten manure (60:20:20%) and garden soil + tuff mineral soil + rotten manure (40:40:20%), respectively (Table 5).

Discussion

To have a marketable crop with long and strong stems and fresh flowers, it is imperative to consider vegetative parameters in addition to buds during the cultivation of the flowers. Quality loss in the plant's vegetative parameters would result in the loss of the economic value of the cut flowers (Nikrazm et al., 2011). Various minerals are employed as the substrate for growing different plant species. These minerals have their distinct characteristics. Since the nutrients of some kind of substrate will be gradually available for the plants, improvement in the physical and chemical characteristics of the substrates can enhance plant growth and development, extend the longevity, and decrease capital return (Kiuru et al., 2015). Our results revealed the significant effects of the type and amount of mineral substrates on the vegetative and biochemical characteristics of Tuberose plants. Among the studied treatments, the substrates containing dolomite and talc were more effective on stem diameter, root fresh weight and volume, floret number, chlorophyll *b*, and total chlorophyll contents. The physical and chemical characteristics of the substrates can profoundly influence the growth parameters of the plants. In addition to their nutritional value, the incorporation of different minerals improves the physical conditions, including the creation of porosity and the lightness of the substrate, thereby improving the growth of the plants (Ghasemi et al., 2017). The effect of dolomite- and talc-containing substrates on increasing the diameter of the flowering stem of Tuberose plants may be caused by the uptake of more nutrients and nutrient availability to capillary roots of the plant, as well as the high nutrient absorption properties of these substrates. Increase in flowering stem diameter may be related to elevated uptake of nitrogen (N) (Roosta et al., 2017; Tripathi et al., 2012). It has been shown that higher N content of substrate can make significant differences in stem diameter of azalea (Clark et al., 2003). Application of mineral compounds can increase the uptake of nutrients from the soil and the efficiency of the nutrients in plants, thereby contributing to the better growth of the plants, especially their roots, and increasing photosynthesis rate, nutrient uptake, leaf area, and plant biomass (Ghasemi et al., 2012; Bano Karim et al., 2017).

In advanced agriculture, leaf greenness is often regarded as a sign of N status, which is related to the chlorophyll content of the leaf (Kirkby and Zude, 2009). Leaf color, which is significantly correlated with chlorophyll content, is usually influenced by plant growth stage, nutrition, cultivar, leaf thickness, plant density, and climatic factors (Malassiotis et al., 2006). Given that nutrients are involved in chlorophyll construction and nitrogen directly occurs in chlorophyll structure, it seems that there exists a positive, significant relationship between the uptake of nutrients and chlorophyll content. These results can be related to the availability of nutrients in the substrates (Joshaghani et al., 2017). Increase in the amount of chlorophyll *b* and total chlorophyll in those substrates containing dolomite and talc may be associated with high Mg content of them. The main role of Mg in plants is regarded as its involvement in chlorophyll structure (Zad-Salehi et al., 2011). This is confirmed by the comparison of these results with the chemical decomposition of the substrates.

Since P plays a key role in the development of roots, increase in DWR in garden soil + rotten manure (80:20%) treatment may be attributed to the high P content of this substrate (Renau-Morata et al., 2012). P is involved in NADP structure that acts as an electron acceptor and provides the energy required for the reduction of carbon dioxide. As a result of these reactions, nutrients like carbon carbohydrates, proteins, and fats are produced and increase plant biomass and yield indirectly by accumulating materials in plants (Babadayi Samani, 2011). Furthermore, the increased level of dry matter production by high Mg content of garden soil treatment may be related to the increased level of photosynthesis and/or higher rate of sulfur uptake by the plants (Zad-Salehi et al., 2011).

According to the results of soil analysis, dolomite contains high amounts of calcium (Ca), magnesium (Mg), and potassium (K) and can contribute to the better growth of the plant by supplying the essential elements required by the plant, especially in acidic soils. K also plays a key role in osmotic regulation and the preservation of the turgor pressure of biotic plant cells, stomatal opening and closure, cell development, leaf movement and transpiration, photosynthesis, and enzymatic activities. It has been shown that K can increase the photosynthesis rate and the rate of assimilate mobilization through phloem to storage tissues, thereby improving yield and quality (Lester et al., 2010; Khayyat et al., 2007). K uptake from the substrate by the plant is influenced by factors such as soil moisture status, pH, texture, aeration, soil temperature, and the concentration of other nutrients. By increasing vacuole turgor pressure, K causes the enlargement of the cells and is also engaged in cell division (Jifon and Lester, 2011; Kabir et al., 2011).

Calcium (Ca) is another element that is involved in the integrity of the cell wall and the conservation of membrane structure and function and enhances water retention capacity of the cells. Ca directly plays a significant role in photosynthesis processes, the translocation of hydrocarbons, and the process of N uptake by the plants. Ca deficiency considerably reduces plant biomass by reducing the efficiency of carboxylation and photosynthesis (Kokabi and Tabatabaei, 2011; Khosravi Mashizi and Sarcheshmehpour, 2015). This explains why in substrates containing feldspar and tuff mineral soil that have a lower amount of Ca than talc and dolomite substrates, the fresh and dry weights of the plants were significantly reduced. Another likely reason for the decrease in growth and biochemical traits of Tuberose plants in substrates containing different ratios of tuff mineral soil is higher EC and pH of this soil than other mineral compounds, which impairs the growth of plants.

Feldspar at the rate of 40 and 10% incorporated into substrate influenced daughter bulb perimeter, total bulb weight, chlorophyll *a*, and floret dry weight. Since feldspar is a non-clay mineral, it could improve attributes such as lightness, drainage, and porosity of the substrate and make the medium more appropriate for bulb growth. Furthermore, it seems that substrates significantly affect the vegetative and biochemical traits of Tuberose plants by influencing the availability of water and nutrients as well as the amount of oxygen around the roots (Joshaghani et al., 2017), which is supported by the findings of the present study. On the other hands, the analysis of chemical compounds of substrates showed that feldspar had the highest K content. Plants require adequate K for rapid growth and development. K content is higher in meristem tissues than in other parts. P is an indispensable element activating a set of essential enzymes of the plants. This element activates the enzymes that contribute to accumulating macromolecules such as starch and protein. In case of potassium deficiency, cell division and plant growth are hindered. The effect of P content on plant growth is obvious because it plays an effective role in the construction of hydrocarbons and proteins and is involved in a lot of cell activities (Zadebagheri et al., 2011; Das et al., 2012), thereby influencing growth characteristics such as bulb perimeter and total weight as well as floret dry weight in Tuberose plants.

Conclusion

In conclusion, the result of present study confirms that application of mineral compounds of dolomite, talc and feldspar in substrate improves some growth and biochemical traits of Tuberose plants due to the availability of nutrients required by the plant and its optimal pH and EC. Threfore, any of these mineral compounds can be used in combination with the substrate to maximize the productivity of Tuberose plants.

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