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RESEARCH PAPER

Evaluation of the effect of chemical fertilization and some natural extracts on the production of freesia (*Freesia refracta* L.) plants: a sustainable approach

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Abstract
Effects of different types of fertilizers; traditional NPK (1 g plant^{-1}), 2, 4, 6 and 8 gm L^{-1} of moringa leaves extract (MLE), 10, 20, 40 and 60 mL L^{-1} of aloe leaves extract (AL) on vegetative growth, flowering Corms production and chemical constituents of *Freesia refracta* L. were evaluated during two successive seasons (2020–2021 and 2021–2022). Treating plants with MLE caused increases in plant height, number if leaves and number of flowers by 35.2%, 8.2% and 16.3%, respectively, while treating plants with Al caused increases by 33.2%, 7.9% and 15.4% in the same parameters, respectively, averaged between different concentrations and growth seasons. The results revealed that, treating plants with 8 gm L^{-1} MLE caused a significant increase in the vegetative growth, flowering, and corms production. These improvement fits with the many goals of the 17 United Nation Sustainable Goals (UNSDGs); especially SDG2 (Zero hunger), SDG13 (climate action) and SDG15 (Life on land). Moreover, the chemical composition of plant was improved significantly.

Keywords *Freesia refract L.* · Chemical Fertilization · Moringa leaves extract · Aloe leaves extract · Growth

1 Introduction

Freesia (*Freesia refracta* L.) plants, family Iridaceae, are prominent annual bulb plant and a popular cut flower (Manning et al. 2010). They are important as sources of food, in the production of drugs and chemicals, their flowers are characterised by their longevity, bright and attractive colours, and a pleasant aromatic smell; therefore, they become the most remarkable picked flowers in the worldwide (Kalaf et al. 2020).

Plant extracts contain many nutrients that are important for the growth and production at other plants, as they participate in the metabolic processes (Jasman et al. 2019). The lack of essential nutrients, due to different factors, such as edaphic, and environmental, causes a physiological disturbance (Al-Samaraee and Al-Showily 2020; Hassan et al. 2021a, b; El Dakak et al. 2023).

Moringa *(Moringa oleifera* L.) plants (Family Moringaceue) are fast growing plants, especially in the tropical areas, and they are cultivated also near the Red Sea in Egypt (Leone et al. 2015; Gopalakrishnan et al. 2016).

Leaf extract of moringa (MLE) has the potential to be used as a plant biostimulant to improve product quality, its effectiveness is ascribed to its physiological traits (phytohormones, mineral composition, secondary metabolites, and other bioactive compounds) (Yuniati et al. 2022). Zaki and Radi (2015) stated that fresh leaves of moringa contain high levels of antioxidants, proline, tocopherol, soluble sugar, glutathione, amino acids (Desoky et al. 2019). These findings supported the earlier report of Fuglie (1999), who reported that MLE is rich in zeatin, and can be used as an available source of cytokinins. Moreover, leaves are rich in

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phenols, and carotenoids, as well as potassium and calcium; these components are used exogenously to promote plant growth and productivity. (Foidle and Beeker 2001).

Nactor and Foyer (1998), found high concentrations of antioxidants (ascorbic acid and glautathione) in the chloroplast of moringa leaves, which are crucial for plant defense against oxidative stress. This finding was supported later by the results of Ahmed (2016) who found that MLE contains variety of plant growth regulators.

Aloe vera L. (Family Alliaceae) is a succulent herb, that contains most of the essential amino acids (isoleucine, leucine, lysine, methionine, phenylalanine, threonine, valine and tryptophan), and some of non-essential ones (alanine, arginine, asparagin, cystenien, glutamic acid, glycine, histidine, proline, serine, tyrosine, glutamine and aspartic acid). Moreover, it contains monopolysaccharides (cellulose, glucose, mannose, aldopentose), lignin, macro and micro nutrients (N, P, K, Zn, Fe, Mn, Cu, Mg, and Ca) (Sahu et al. 2013; Raman-Rao et al. 2013).

It is well-known that fertilizers (natural or chemical) can increase productivity of plants (Hassan et al. 2015; 2021a, b). There are many nutritional media that help in improving plant response and increase yield. The most important one is Kristalon, its effectiveness in improving quality of various plants was documented, due to its richness in macro and micro elements (Salisburg and Ross 1992). Moreover, it is well-known that its contents of N, P, and K elements play a major role in growth and development of plants. N is the main constituent of proteins and nucleic acid, while K plays a vital role in stomatal movement, photosynthesis, respiration, sugars translocation (Yoenhee et al. 2000; Csirzinsky 2019).

The aim of the present investigation was to assess and evaluate the magnitude of applying extracts of moringa (*Moringa oleifera* L.) (MLE) and aloe (*Aloe vera* L.) leaves in improving and enhancing the quality and quantity of *Freesia refracta* L. plants, in terms of vegetative growth, flowering, corms and cormlets productivity as well as chemical constituents, to increase its productivity to meet the increasing demand this plant.

2 Materials and methods

Corms of *Fvreesia refrecta* L. were obtained from local nursery in Egypt, they were about 8 cm in diameter. They were planted under open field conditions during two successive seasons on 28 October 2021 and 2022, respectively.

Corms were grown in 50 plastic pots (one corm/pot) filled with sandy loam soil. Physiochemical properties of the soil are shown in Table 1.

On 28th Nov 2021 (i.e., 1 month after planting).plants were received different types of fertilizers and extracts twice a month during the entire course of the experiment in the two seasons. It is a worth mentioning that regular agricultural practice were carried out normally (watering, weeding, etc.) (Desoky et al. 2019).

Table 1 Physical and chemical properties of the soil

Properties	Composition
Physical properties	
Sand (%)	3.40
Silt (%)	29.10
Clay (%)	67.50
pH	7.80
E.C. (dsm^{-1})	1.84
Chemical properties	
N	132.70
K	22.50
P	380.0
Cations (meql)	
Ca^{+}	3.23
Mg^{+}	1.55
Na^{+}	4.60
K^{+}	2.21
Anions (meql)	
HCO_3^{-}	3.88
Cl^{-}	4.36
SO_4^{-}	3.46
Micronutrients	
(PPM)	5.15
Fe	3.72
Cu	5.25
Zn	9.12
Mn	5.15

The traditional chemical fertilizer (Kristalon) was purchased form OSM Agric. Specialized Co., Holland. (NPK, 1:1:1, and it contains 0.0017% Cu, 0.25% B, and 0.001% Mo), while Moringa and aloe extract were obtained from Al samatec Company for Agricultural service (20st), Alexandria, Egypt.

Minerals in Moringa leaf and Aloe vera extract are shown in Tables 2 and 3, respectively.

NP, was added at a rate of 19 m/Pot, while there were four different levels of Moringa leaves extract (MLE) (2, 4, 6, and 8 gL^{-1}) and four different levels of Aloe leaves extract (AL) (10, 20, 40, and 60 ml L^{-1}). There were three replicates, each replicate contained three corms.

2.1 Vegetative measurements

At the end of each season, plants were destructively harvested and different parameters were measured (number of leaves, plant height (cm), spike stem length (cm), total

Table 2 Concentrations of minerals (mg\100 g FW) in moringa leaf extract

N	P	K	Fe	Ca	Mg	Zn	Cu	Mn	B
21.5	6.1	11.5	1.0	32.0	1.8	28.63	14.56	52.13	39.18

Table 3 Concentrations of minerals (mg\100 g FW) in Aloe extract

N	P	K	Fe	Ca	Mg	Zn	Mn	Na
75.14	4.68	54.32	6.223	82.0	11.17	0.021	0.025	46.18

number of flowers/plant, duration of flowering, fresh weight of corms (gm), and number of the produced cormels).

2.2 Chemical constituents

Carbohydrates in corms (%) was determined using colorimetric method (Hassan et al. 2018).

Pigments content (Chlorophyll a, b and Carotenoids mg g^{-1} FW of fresh leaves were determined (El Maghraby and Hassan 2021).

Nitrogen, phosphorus and potassium (% DW) were determined in the new formed corms. Nitrogen % was determined by micro-kjeldahl apparatus, phosphorus was determined calorimetrically determined, while potassium was determined using Flame Photometer (John 1997; Dewis and Freius 1990).

2.3 Statistical analysis

Data were analyzed using statistical analysis systems, and Tukey multiple Comparison test with 0.05 probability was used to compare means (Costat 1989).

3 Results

A- Vegetative growth

1. Plant height (cm) and number of leaves

Treatment plants with different extracts caused significant variation in the plant height in both seasons (Table 4). Supplying plants with 8 gm L^{-1} MLE significantly gave the highest stem length in both seasons, (40.41 cm and 40.82 cm in the first and second seasons, respectively). Similarly, 8gm L^{-1} MLE produced the highest number of leaves in first (9.18) and second seasons (9.06), respectively (Table 4).

B- Flowering parameters

1. Number of days from planting to flowering and Spike stem length (cm)

Table 5 shows the effects of different treatments on flowering parameters. It was found that treatment plants with 8gm L^{-1} MLE significantly reduced the duration of flowering. It resulted in the shortest flowering time (154.51 and 154.06, for the first and second seasons, respectively).

Spike stem length followed the same pattern, as exposure of plants to 8gm L^{-1} MLE gave the highest spike stem length in both seasons (30.15 and 29.37 cm in the first

Table 4 Effect of kristalon, MLE and AL extracts treatments on vegetative growth of *freesia refracta* L. during the two seasons

Treatments	Plant height (cm)		Number of leaves	
	1st season	2nd season	1st season	2nd season
Kristalon (NPK)	37.1^{bc}	37.07^{cd}	8.41^{d}	8.62^{b}
MLE1	29.66^{e}	29.74^{g}	7.28^{f}	7.32^{d}
MLE2	32.92^{d}	33.08^{e}	7.74^{e}	7.90^{c}
MLE3	37.14^{bc}	36.78^{d}	8.65^{c}	8.64^{b}
MLE4	40.41^{a}	$40.\ 82^{a}$	9.18^{a}	9.06^{a}
AL1	26.42^{f}	26.45^{h}	6.94^{g}	6.88^{e}
AL2	35.15^{c}	31.47^{f}	7.48^{f}	7.14^{d}
AL3	37.09^{bc}	37.31^{c}	8.67^{bc}	8.56^{b}
AL4	37.91^{b}	37.96^{b}	8.88^{b}	8.89^{a}

Means not followed by the same letter(s) are significantly different from each other at $P \geq 0.05$

Table 5 Effect of kristalon, MLE and AL extracts treatments on flowering characteristic of *Freesia refractal*

Treatments	Number of days from planting to flowering		Spike stem length (cm)	
	1st season	2nd season	1st season	2nd season
Kristalon	160.58^{e}	160.88^{e}	27.48^{c}	27.53^{c}
MLE1	168.20^{b}	168.40^{b}	21.15^{f}	21.51^{e}
MLE2	163.81^{d}	164.20^{d}	24.89^{d}	24.51^{d}
MLE3	158.68^{f}	158.11^{f}	27.58^{c}	27.58^{bc}
MLE4	154.51^{h}	154.06^{h}	30.15^{a}	29.37a
AL1	173.47^{a}	173.34^{a}	19.19^{g}	19.00^{f}
AL2	165.97^{c}	166.33^{c}	22.82^{e}	22.62^{e}
AL3	161.63^{e}	160.60^{e}	27.72^{c}	26.61^{c}
AL4	157.08^{g}	156.33^{g}	28.69^{b}	29.91^{ab}

Legends as Table. 4

season and second seasons, respectively), compared with other treatments (Table 5).

2. Total number of flowers/plant and vase life day

It could be noticed from data averaged in Table 6 that all treatments increased number of flowers/plant. In this connection, supplying plants with MLE at 8 gm/L significantly gave the highest number of flowers/plant as recorded 19.05 in the first season and 18.97 in the second season, respectively. Moreover, the results indicated that treatment of plants with 8 gm L^{-1} MLE gave longest vase life in both seasons. All treatments have significant effect on flowering age.

C- Corms and cormels parameters

1. Fresh weight, the percentage of carbohydrates in corms, and number of produced cormels

Table 7 shows insignificant difference between most treatments in the first season on comes fresh weight. MLE at 8 gm L^{-1} increased fresh weight of corms than all treatments recorded 3.13 g in the first season and 3.11 g in the second season. Against mean, while the lowest values were obtained by AL at 10 ml L^{-1}, 1.95 g in both seasons.

Data presented in Table 6 show that although the application of MLE at 8 gm L^{-1} resulted in the highest values in terms of total carbohydrates percentage. Al at 10 ml L^{-1} produced the lowest values in this regard (10.82, 1054% in both seasons, respectively).

It could be noticed from data averaged in Table 6 supplying plants with MLE at 8 gm L^{-1} and Kristalon gave the highest number of cormels without significant differences between them as recorded (6.20 and 5.97) in the first season. While in the second season supplying plants with MLE at 8 gm L^{-1} gave the highest number of cormels.

D- Chemical constituents

1. Chlorophyll *a* and Chlorophyll *b* contents

The highest Chl *a* content was recorded in plants treated by 8 gm L^{-1} MLE (0.966 mg g^{-1} FW) followed by those treated with kristalon (NPK) at 1 gm $plant^{-1}$ and 60 ml L^{-1} AL extract (0.883, and 0.883 mg g^{-1} FW, respectively) (Table 8). On the other hand, plants treated with 10 ml L^{-1} Al extract produced the lowest Chl *a* content (0.423 and 0.436 mg g^{-1} FW) in first and second seasons, respectively.

Regarding Chl *b,* it was increased significantly after application of 8 gm L^{-1} MLE (0.373, and 0.386 mgg^{-1} F.W), 60 ml L^{-1} AL extract (0.326 and 0.343 mgg^{-1} FW) and 1 gm $plant^{-1}$ kristalon fertilizer (NPK) (0.316 and 0.32 mg g^{-1} FW, in the first and second growing seasons, respectively (Table 8).

2. Total carotenoids

Its content was significantly increased ($P \leq 0.05$) due to application of different treatments, except those treated with 10 ml L^{-1} Al extract. The highest content

Table 6 Effect of kristalon, MLE and AL extracts treatments on number of flowers and vase life day of *Freesia refractal*

Treatments	Total number of flowers\ plant		Vase life day	
Kristalon	16.68^{c}	16.62^{d}	8.18^{bc}	8.27^{b}
MLE1	13.26^{e}	13.15^{f}	7.24^{d}	7.26^{e}
MLE2	14.90^{d}	14.89^{e}	7.87^{c}	7.75^{d}
MLE3	17.79^{b}	17.47^{bc}	8.11^{bc}	8.11^{bc}
MLE4	19.05^{a}	18.97^{a}	9.16^{a}	9.05^{a}
AL1	12.00^{f}	12.18^{g}	6.42^{e}	6.50^{f}
AL2	14.69^{d}	14.77^{e}	7.48^{d}	7.66^{d}
AL3	16.96^{c}	16.97^{ed}	7.94^{bc}	7.99^{c}
AL4	17.85^{b}	17.94^{b}	8.26^{b}	8.30^{b}

Legends as Fig. 4

Table 7 Effect of kristalon, MLE and Al extracts treatments on corms and cormels parameters

Treatments	Corms fresh weight (gm)		Carbohydrate (%)		No. of cormels	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Kristalon	2.99^{a}	2.97^{b}	14.82^{b}	4.83^{b}	5.97^{ab}	6.07^{b}
MLE1	2.06^{d}	2.04^{g}	11.48^{f}	11.48^{f}	4.13^{cd}	4.55^{f}
MLE2	2.44^{b}	2.42^{e}	12.83^{e}	12.93^{e}	4.72^{c}	4.72^{e}
MLE3	2.48^{b}	2.68^{c}	14.24^{c}	14.27^{c}	5.04^{bc}	5.02^{d}
MLE4	3.13^{a}	3.11^{a}	15.43^{a}	15.45^{a}	6.20^{a}	6.23^{a}
AL1	1.59^{d}	1.59^{g}	10.82^{g}	10.54^{g}	3.41^{d}	3.46^{h}
AL2	2.27^{c}	2.27^{f}	11.43^{f}	11.33^{f}	4.46^{c}	4.55^{f}
AL3	2.54^{b}	2.55^{d}	13.81^{d}	13.81^{d}	4.97^{bc}	4.97^{d}
AL4	3.03^{a}	2.99^{b}	14.82^{b}	14.87^{b}	5.42^{b}	5.47^{c}

Legends as Table 4

Table 8 Effect of kristalon, MLE and AL extracts on chemical constituents of *Freesla refrata* L.

Treatments	Chl *a* (mg g^{-1} FW)		Chl *b* (mgg^{-1} FW)		Total cartenoids (mg g^{-1} FW)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Kristalon	0.896^{ab}	0.88^{ab}	0.316^{b}	0.32^{bc}	0.86^{b}	0.89^{ab}
MLE1	0.61^{f}	0.61^{d}	0.166^{e}	0.17^{f}	0.65^{e}	0.64^{f}
MLE2	0.72^{de}	0.73^{c}	0.226^{d}	0.24^{d}	0.72^{d}	0.73^{de}
MLE3	0.82^{bc}	0.81^{bc}	0.31^{bc}	0.31^{bc}	0.81^{c}	0.82^{c}
MLE4	0.97^{a}	0.95^{a}	0.37^{a}	0.39^{a}	0.94^{a}	0.93^{a}
AL1	0.423^{g}	0.44e	0.11^{f}	0.13^{f}	0.54^{f}	0.55^{g}
AL2	0.64^{ef}	0.65^{d}	0.65^{d}	0.20^{e}	0.63^{e}	0.68^{ef}
AL3	0.75^{cd}	0.77^{c}	0.28^{c}	0.29^{c}	0.77^{d}	0.77^{d}
AL4	0.89^{ab}	0.88^{ab}	0.33^{b}	0.34^{b}	0.86^{bc}	0.86^{b}
	N% in the corms		K% in the corms		P% in the corms	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Kristalon	4.75^{b}	4.81^{b}	2.82^{bc}	2.99^{b}	0.68^{b}	0.71^{b}
MLE1	3.38^{f}	3.38^{f}	1.85^{g}	1.82^{f}	0.37^{e}	0.39^{e}
MLE2	3.94^{d}	3.99^{d}	2.47^{e}	2.52^{d}	0.46^{d}	0.46^{d}
MLE3	4.34^{c}	4.39^{c}	2.70^{cd}	2.72^{c}	0.69^{b}	0.69^{b}
MLE4	5.04^{a}	5.09^{a}	3.05^{a}	3.06^{a}	0.78^{a}	0.79^{a}
AL1	2.96^{g}	3.07^{g}	1.53^{h}	1.59^{g}	0.27^{f}	0.28^{f}
AL2	3.70^{e}	3.73^{e}	2.15^{f}	2.16^{e}	0.40^{e}	0.413^{e}
AL3	3.88d^{e}	3.90^{d}	2.65^{d}	2.66^{c}	0.57^{c}	0.58^{e}
AL4	4.77^{b}	4.87^{b}	2.92^{b}	2.90^{b}	0.70^{b}	0.70^{b}

Legends as Table 4

recorded when plants were treated with 8 gm L^{-1} MLE (0.936 and 0.933 mg g^{-1} F.W, in first and second seasons, respectively).

3. Nitrogen in newly formed corms

The highest percentage of nitrogen was observed when plants were treated with 8 gm L^{-1} (5.09%, in both seasons), while plants treated with 10 ml L^{-1} AL extract had the lowest nitrogen content compared with other treatments (3.07%, in both season) (Table 8).

4. Potassium and phosphorus in newly formed corms

The highest concentration of K was recorded in plants treated with 8 gm L^{-1} MLE (3.05% and 3.06% in both seasons, respectively) (Table 8).

Similarly, P content was increased significantly in plants treated with 8 gm L^{-1} MLE (0.783% and 0.79% in both seasons, respectively). On contrary, plants treated with 10 ml L^{-1} had the lowest concentrations of P (0.273% and 0.28% in both seasons, respectively) (Table 8).

4 Discussion

Using natural products to promote growth and productivity is a must for better and healthier environment (Basahi et al. 2016). There are many studies reporting the importance of applying moringa leaves extract and chemical NPK fertilization on growth and development of many species, such as *Euonymus japonica*, *Narcissus tazetta*, *Hymenocallis speciosa*, *Gladiolus grandiflorus*, *Codiaeum variegation* (Abdel-Wahed et al. 2006; EL-ghazaly 2016; Taha et al. 2015; Fakhria and Fatima 2019; Faisal et al. 2020; Sarhan et al. 2022). Very little is known about the response of *Freesia sp.* to theses extracts (Atowa 2012).

It is well-documented that N, P and K nutrients play a vital role in enhancing plant growth and development (Weaam et al. 2018).

Extract of Aloe vera leaves (AL) is known to activate growth and development of on growth and development basil, Ggranium, *Abelmaschus esculentus* L., *salvia officinalis* L., and *Oenothera biennis* L. (Salim 2006; El Shayeb 2009).

Azara et al. (2012) stated that Moringa leaves extract is very rich in K, Ca, Fe, amino acids, vitamins, cytokinins (zeatin), antioxidants, and auxin-like growth substances which caused an increase by about 25% in the yield of wheat plants. This finding was supported recently with the results of Abdel Rahman and Abdle Kader (2021), who reported that moringa leaf extract contains active growth enhancing substances, such as Zeatin, dihydrozeatin and isopenty ladenine which are natural (endogenous) cytokinins. In early days, Nactor and Foyer (1998) found plenty of caroteniods, phenols, ascorbates, minerals (Ca and K), and they stated that these constituents could be used as exogenous plant growth promoters. Moreover, Foidle and Beeker (2001) indicated that richness of moringa extracts in antioxidants (ascorbic acid and glutathione) is an important issue as it could help in alleviation of oxidative stress, and he recommended using MLE as a promising and an environmentally friendly tool for enhancing growth and yield of many plants due to abundance of secondary metabolites total phenols, and cytokinin (zeatin). Therefore, it could be used as a neutral and potential stimulus for productivity instead of fertilizers to increase growth and yield and minimize side effect of chemical fertilizers (Gsirzinsky 2009).

Nitrogen, phosphorus and potassium are are essential ones for the structural and non-structural components of all living organisms.

Nitrogen is a main constituent of proteins, nucleic acids, it helps in tissue repairing. Potassium is a very effective macro-element for growth and development of different plants; it helps in controlling respiration and photosynthesis through controlling movement of stomata, as well as controlling translocation of sugars and carbohydrates. Phosphorus is an important element for structural integrity of plasma membranes, coenzymes that speed up the metabolic reactions and hence reduces energy Loss (Mazrou 2019).

Marschner (2005) ascribed the positive effect of NPK fertilizer to its simulative effect on the different vegetative growth parameters, which could be reflected in higher flowering rate and, consequently, higher production (Hassan et al. 2015).

In summary, the present investigation highlighted the positive roles of plant extracts (aloe leaves extract "AL", moringa leaf extract "MLE") in the sustainable development. They are vital in alleviation of poverty and hunger as well as maintaining life on earth due to presence of high concentrations nutrients (N, P, K, Zn, Fe, Mn, Cu, Mg, and Ca), amino acids, polysaccharide, and vitamins.

5 Conclusions

Moring leaf extract (MLE) is a good growth promoter, especially when applied at a concentration of 8 gm L^{-1} several times during the entire course of the vegetative growth of the plant. It stimulate a vigorous growth of the canopy, thus absorbing more CO_2 from the environment and reducing the temperature, this helps in achieving SDG13 (Climate action), increasing the productivity and thus achieves SDG2 (Zero hunger) and finally it improves quality of plants and this achieve SDG15 (Life and Land). Moreover, it is advised to cultivate more moringa trees to stabilize soils, stop desertification to confront climate change and use its extracts to promote growth of crops to feed the rapidly growing populations.

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Declarations

Conflict of interest The authors declare no conflict of interest among them.

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