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ORIGINAL ARTICLE / ORIGINALBEITRAG

Modifying the Growing Media and Bio Stimulants Supply for Healthy Gerbera (*Gerbera jamesonii*) Flowers

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Abstract

Gerbera (*Gerbera jamesonii*) cv. Jaguar Yellow is an ornamental plant of the *Asteraceae* family. Ordinarily, farmers use expensive materials such as peat moss as a media substrate in gerbera production, in addition to application high nitrogen fertilizers. Therefore, the current study was designed to assess the yield and quality changes of gerbera flowers owing to utilizing environment-friendly inputs under unheated plastic greenhouse conditions for two seasons of 2017/18 and 2018/19. The experiments were laid out in a randomized complete block design with 3 replicates, each replicate involved 5 pots per treatment. For preparing the soil substrate mixtures, four substances were used which involved peat moss (P), sand (S), vermicompost (V), and compost (C). P+S, P+S+V and P+S+C were assembled whether with or without *Azotobacter+Azospirillum* as bio stimulant (Bio) addition to obtain six combinations. Results showed that P+S+V+Bio was the effective practice for enhancing gerbera plant height, leaf width, root weight plant plant-1 and leaves weight plant-1. Also, P+S+V+Bio produced the maximum values of leaf chlorophyll, nitrogen, phosphorus, and potassium contents. The differences in flowering initiation between P+S and each of P+S+V, P+S+V+Bio, P+S+C and P+S+C+Bio were not significant. P+S+V+Bio (for flowering duration and flower yield), in addition to P+S+V (for flowering duration) recorded the highest values in both seasons.

Keywords Decorative plants · Flower vase life · Gerbera nutrient content · Organic materials · Soil rhizosphere

1 Introduction

The *Asteraceae* family is one of the largest families of flowering plants in the plant kingdom with over 1500 genera and close to 23,000 species (Bremer et al. 1994). As a prominent member of the *Asteraceae* family, gerbera (*Gerbera jamesonii*) is commonly known as Transvaal Daisy or African Daisy, with nearly 70 species (Norberto 2010). Gerbera is a very popular flower plant having double, semi-double, and single-structure flowers. Because of color variation, size of flowers, and long-lasting and wide adaptability for culture, gerbera is highly demanded for cultivation worldwide under protected conditions (Singh et al. 2017).

Soilless culture, a technique of growing plants without soil as a rooting medium, in which the inorganic nutrients needed for the plant are supplied via the irrigation water, to be absorbed by the roots, has rapidly increased around the world. The use of appropriate substrates, for growing medium, is essential to produce healthy horticultural plants. A good growing medium would provide comfortable anchorage or support to the plant, function as a reservoir for nutrients and water (El-Metwally et al. 2022; El-Bially et al. 2023). As well, the useful medium enables oxygen diffusion to the roots, and permit foamy exchange between the roots and atmosphere outside the foundation substrate (Abad et al. 2002). Therefore, supplying soil with different nutrients is a crucial action to improve soil properties (Salem et al. 2022; Saudy and El-Metwally 2023; Shaaban

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et al. 2023), hence, nutrient uptake (El-Metwally and Saudy 2021) as well as growth and yield of the crops (Saudy et al. 2023).

Although crop production requires nutrients, the overly large doses of fertilizers with chemically unbalanced NPK ratios have resulted in soil-related problems, such as acidification (Chen 2006; Saudy and Mubarak 2015). Mineral nutrition is one of the most important factors for plant growth and yield (Saudy et al. 2021a, 2022a; Abd El-Mageed et al. 2022; Abou El-Enin et al. 2023). Mineral fertilizers, particularly inorganic nitrogen, are important elements for plant nutrition (Noureldin et al. 2013; Saudy 2014, 2015); however, they are also potential source of environmental pollution (Hartman et al. 1988). Thus, developing and adopting environmentally friendly alternatives are needed to supplement and/or replace chemical fertilizers (Saudy et al. 2018, 2020a).

Peat moss is vastly exploited as a prime component of growing media in potted ornamental plants production. However, recently, owing to its ecological unsustainability (Carlile and Coules 2013), in addition to its high price (Gruda 2010) ornamental farms has been trying to reduce the application of peat as a media substrate. Consequently, several new plant substrates and mixtures have been inserted and evaluated worldwide (Gruda 2019). Compost prepared from various organic wastes has the beneficial effects not only in terms of its positive carbon footprint but also for its good impact to suppress some soil diseases and low cost (Raviv 2011; Saudy et al. 2021b).

Since vermi-compost has high potential to maintain soil fertility by improving aggregates and holding water, it is considered a promising organic fertilizer (Abul-Soud et al. 2014). Vermi-compost is a privileged material in available forms of various nutrients, i.e. nitrogen, potassium, calcium, magnesium and phosphorus (Hashem and Abd-Elrahman 2016). Therefore, vermi-compost is recommended in fertilization programs in different soil and crop cultivations (Frederickson et al. 2007; Amalraj et al. 2013; Yang et al. 2015; Abd-Elrahman et al. 2022).

There is no doubt that mineral nutrients application occurred distinctive prosperity in crop production. However, the ecosystems have been injured owing to continuous use of inorganic fertilizers. In this respect reducing the dependence on inorganic nutrients can be archived by exploiting the plant bio-stimulants via bio-fertilization (Rouphael and Colla 2020), maintain the efficient uptake by plants (Zulfiqar et al. 2020; Saudy et al. 2022b). Accordingly, the use of bio-stimulants is so significant in agricultural sustainability since they can boost crop production while reduce the possible environmental pollution (Ertani et al. 2015; Saudy et al. 2020b).

Little knowledges are available about the optimal growing substrate mixture for healthy status of gerbera plants. The current work hypothesized that substitution peat moss partially with compost or vermi-compost will possess better growth of gerbera inoculated by bio-stimulants. To combine the benefits of various organic materials while reducing costs, mixing peat moss, compost and vermi-compost with sand in the preparation of growth media substrate of gerbera plants was applied and evaluated in the current study. Furthermore, different structured substrate mixtures were supported by bio-stimulants bacteria (*Azotobacter* and *Azospirillum*) to assess their nutritional value.

2 Materials and Methods

2.1 Experimental Site and Treatments

Pot experiments were conducted at the Arid land Agriculture Research Institute (ALARI), Shobra Elkheima area, Qalyobia governorate, Egypt (30º07′01.6″N 31º14′37.6″E) under open plastic house in December-September period (25th December to 21st September for two seasons of 2017/18 and 2018/19).

The experiment included six packages of growth medium and bio stimulators as follows:

- T1 = Peat moss + sand (1:1 v/v), P + S
- T2 = Peat moss + sand (1:1 v/v) with (*Azotobacter+Azospirillum*), P + S + Bio
- T3 = Peat moss + sand + vermicompost (1:1:1v/v/v), P + S + V
- T4 = Peat moss + sand + vermicompost (1:1:1 v/v/v) with (*Azotobacter+Azospirillum*), P + S + V + Bio
- T5 = Peat moss + sand + compost (1:1:1 v/v/v), P + S + C
- T6 = Peat moss + sand + compost (1:1:1 v/v/v) with (*Azotobacter+Azospirillum*), P + S + C + Bio

The treatments were arranged in a randomized complete block design with 3 replicates, each replicate involved 5 pots per treatment.

Table 1 Chemical analysis of peat the used moss and sand

Growing Medium	Cations (meq L^{-1})				Anions (meq L^{-1})		
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	CO_3^{--}	HCO_3^{-}
Peat moss	9.6	10.4	337.5	224.8	108.2	Not detected	13.0
Sand	13.8	18.2	30.1	64.3	36.4	Not detected	8.0

Table 2 Physical and chemical properties of the used vermicompost and compost

Property	Vermicompost	Compost
pH	8.14	7.92
EC (ds m^{-1})	2.55	10.1
Organic matter (%)	21.2	40.4
Carbon (%)	10.6	20.2
Nitrogen (%)	10.6	2.11
Weight/kg	0.816	0.527
Phosphorus (%)	0.600	0.304
Potassium (%)	1.10	2.20
Calcium (%)	0.67	1.42
Magnesium (%)	1.16	0.73
Iron (mg L^{-1})	1.80	1.14
Manganese (mg L^{-1})	315.11	54.37
Zinc (mg L^{-1})	578.11	305.96
Cupper (mg L^{-1})	82.24	49.11

Peat moss used was obtained from Sab Syker Agrar Beratungs Company from Syke, Germany. Table 1 shows the chemical analysis of the peat moss and sand. Compost was obtained from Al-Nile Organic Fertilizer company, Egypt. While, vermi-compost is a product of decomposing compost by certain types of earthworms, usually red, white, and other earthworms in order to make a heterogeneous decomposed compound from vegetable or food waste, animal bedding material. Worms stools is the final result of the process of breaking down organic matter using the earthworm (10.6% N), obtained from Central Laboratory for Agriculture Climate Research Center (CLAC), Dokki, Giza governorate, Egypt.

The physical and chemical properties of the used vermicompost and compost are illustrated in Table 2. Furthermore, after preparing each mixture, physical properties of the pots growing medium were estimated (Table 3).

250 ml of *Azotobacter chroococcum* and *Azospirillum* spp. mixture was added one time, 15 days after planting, (Soil Application). Biofertilizer contained 103 cfu/ml of *Azotobacter chroococcum* and 103 cfu/ml of *Azospirillum* spp.

Table 3 Physical properties of the pots growing medium applied

Property	P + S	P + S + V	P + S + C
Particle density (g cm^{-3})	2.52	2.36	2.38
Bulk density (g cm^{-3})	1.49	1.21	1.25
WHC (% v/v)	3.27	42.51	40.00
Air at WHC (% v/v) 100g^{-1}	1.02	1.16	1.12
Total porosity (% v/v)	40.48	49.43	47.26
Organic matter %	22.40	13.65	13.55
pH	7.19	7.27	7.38
Organic carbon %	11.15	6.80	12.41
Weight/kg	1.086	0.909	0.858

P peat moss, *S* sand, *V* vermicompost, *C* compost, *WHC* water-holding capacity

2.2 Preparation of Greenhouse and Growing Place

The experiment was carried out in an unheated greenhouse with a plastic cover (25 m^2 length × 9 m width × 3.5 m height) covered with IR, UV, Anti-Fog reinforced plastic cover. Cultivation was carried out in the polyethylene pots 30 cm diameter and 15 height, filled with the experimental mediums. The pots were placed in a black & white 200-micron thickness polyethylene sheets. In the preparation of the cultivation areas, the greenhouse floor was first cleaned of weeds, stones, and clods, processed, and leveled with a rake, giving a fine structure. Later, a slope of 1% was given to the greenhouse floor in order to ensure the flow of water with different fertilization, and a smooth surface was obtained by rolling the ground. Fertilizer losses should be prevented in the experiment. For this reason, the necessity of collecting the drained water with different fertilizers has emerged and catchment tanks are placed end of the plastic sheets. A technique was adopted in that these catchment tanks used for the collection of the drained water with different fertilizers can be placed under the ground level by approximately 2 cm.

One month old, healthy, and uniform in shape, gerbera transplants (approximately 20 cm length) were purchased from a private nursery, Giza, Egypt. Each single transplant was cultivated in December in a plastic pot filled with experimental medium. The irrigation was regularly done 2–3 times a week after calculating the decrease in water-holding capacity using the weight method.

2.3 Measurements

2.3.1 Growth and Yield Attributes

At harvest (on 21st September), ten plants per treatment were taken randomly to measure plant height, leaf width, first flower bud appearance (flower initiation), and duration of flowering. Leaves and roots fresh weights, leaves and roots dry weights, and flower yield were estimated.

2.3.2 Chemical Analysis

Using micro-Kjeldahl apparatus, nitrogen % was determined in leaves according to Jackson (1973). Phosphorus (%) was assessed calorimetrically by the methods described by Trough and Meyer (1939). By flame photometric method (Brown and Lilliland 1946), potassium % was measured. Furthermore, four plants were randomly chosen for each treatment to measure leaf greenness (SPAD). The SPAD value of the leaf was determined by a chlorophyll meter (SPAD–502Plus) according to Süß et al. (2015).

2.3.3 Microbial Count

Samples from the growing medium were taken two months after each addition by withdrawing about 400 g of soil at a depth of 15 cm around the root of the plant. Total counts of bacterial (*Azotobacter chroococcum* and *Azospirullum* sp. mixture) were determined in these samples two times (April and July) using the plate count technique on nutrient agar according to the method of (Louw and Webley 1959). Plates were incubated at 30 °C for 3 days and cell concentration was calculated by counting the growing colonies.

2.4 Data Analysis

Results of the whole experiment were subjected to statistical analyses using the analysis of variance (ANOVA) method. Mean comparisons were carried out by Casella (2008) multiple range test at $p \leq 0.05$. Data were statistically analyzed using the analysis of variance adopting a SAS package.

Table 4 Plant height, leaf width, root weight and leaves weight of gerbera as affected by different soil substrate matures

Variable	Plant height (cm)	Leaf width (cm)	Root weight plant^{-1}(g)		Leaves weight plant^{-1} (g)	
			Fresh	Dry	Fresh	Dry
Season of 2017/18						
P + S	16.30b	9.90a	30.05bc	13.05dc	15.15bc	3.85c
P + S + Bio	16.30b	7.60ab	26.25bc	16.85c	12.45c	3.25c
P + S + V	14.50b	6.90b	40.75ab	26.15b	39.35a	9.15b
P + S + V + Bio	25.75a	9.60a	60.65a	32.20a	45.95a	11.95a
P + S + C	11.20c	8.50ab	16.90c	4.30e	20.80b	3.20c
P + S + C + Bio	11.70c	6.05b	18.80c	8.60de	10.90c	2.20c
Season of 2018/19						
P + S	24.80ab	9.90b	29.55bc	13.05dc	15.35bc	3.85c
P + S + Bio	17.75c	9.60bc	26.15bc	16.85c	12.65c	3.25c
P + S + V	21.50bc	8.05bcd	40.75ab	26.15b	39.5a	9.15b
P + S + V + Bio	29.50a	14.75a	60.70a	32.15a	45.95a	12.05a
P + S + C	17.00c	5.60cd	16.90c	4.30e	20.7b	3.20c
P + S + C + Bio	15.80c	4.75d	18.85c	8.65de	10.9c	2.20c

P peat moss, *S* sand, *V* vermicompost, *C* compost, *Bio* bio stimulants (*Azotobacter chroococcum* and *Azospirillum* spp.). Means not sharing the letters for each variable in each column vary significantly at $p \leq 0.05$ according to Duncan's multiple range

Table 5 Chlorophyll and nutrient contents of gerbera and biostimulants count as affected by different soil substrate matures

Variable	Chlorophyll	Nutrients content			Bio stimulant count
		Nitrogen	Phosphorus	Potassium	
Season of 2017/18					
P + S	33.56d	0.96c	0.126c	3.06c	0.000d
P + S + Bio	34.25d	1.05c	0.165c	3.25c	12.250b
P + S + V	58.65b	2.45a	0.258ab	5.26b	2.120c
P + S + V + Bio	64.65a	2.65a	0.310a	6.00a	23.550a
P + S + C	45.65c	1.45b	0.206b	3.52c	2.650c
P + S + C + Bio	48.65bc	1.56b	0.226b	3.62c	20.340a
Season of 2018/19					
P + S	34.25d	1.00c	0.135c	3.05c	0.000d
P + S + Bio	39.54cd	1.05c	0.175c	3.15c	13.825b
P + S + V	60.91b	2.51a	0.262ab	5.36b	2.554c
P + S + V + Bio	65.83a	2.51a	0.310a	6.10a	21.723a
P + S + C	44.75c	1.51b	0.217b	3.60c	3.520c
P + S + C + Bio	42.58c	1.65b	0.234b	3.46c	22.200a

P peat moss, *S* sand, *V* vermicompost, *C* compost, *Bio* bio stimulants (*Azotobacter chroococcum* and *Azospirillum* spp.). Means not sharing the letters for each variable in each column vary significantly at $p \leq 0.05$ according to Duncan's multiple range

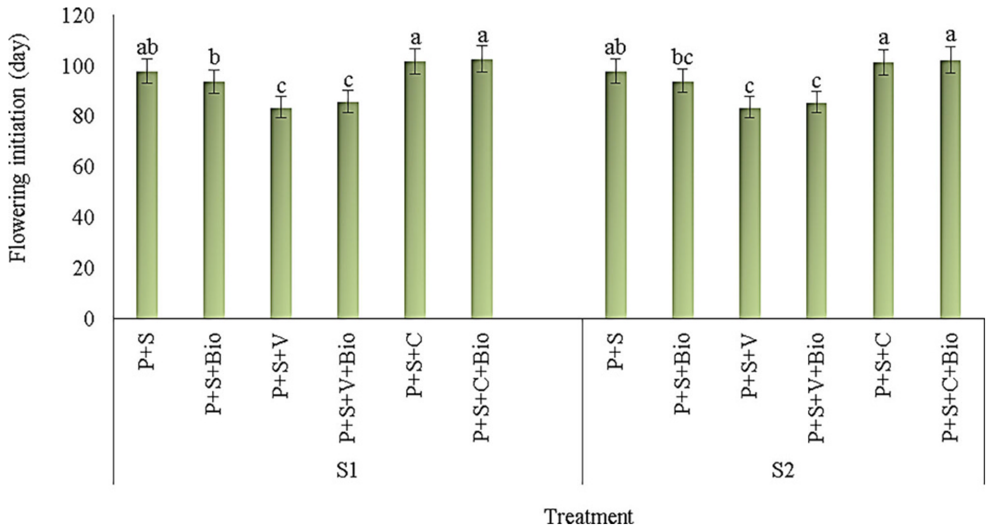

Fig. 1 Flowering initiation of gerbera as affected by different soil substrate mixtures in 2017/18 (S1) and 2018/19 (S2) seasons. P peat moss, S sand, V vermicompost, C compost, *Bio* bio stimulants (*Azotobacter chroococcum* and *Azospirillum* spp.). Means not sharing the letters for each variable in each bar vary significantly at $p \leq 0.05$ according to Duncan's multiple range

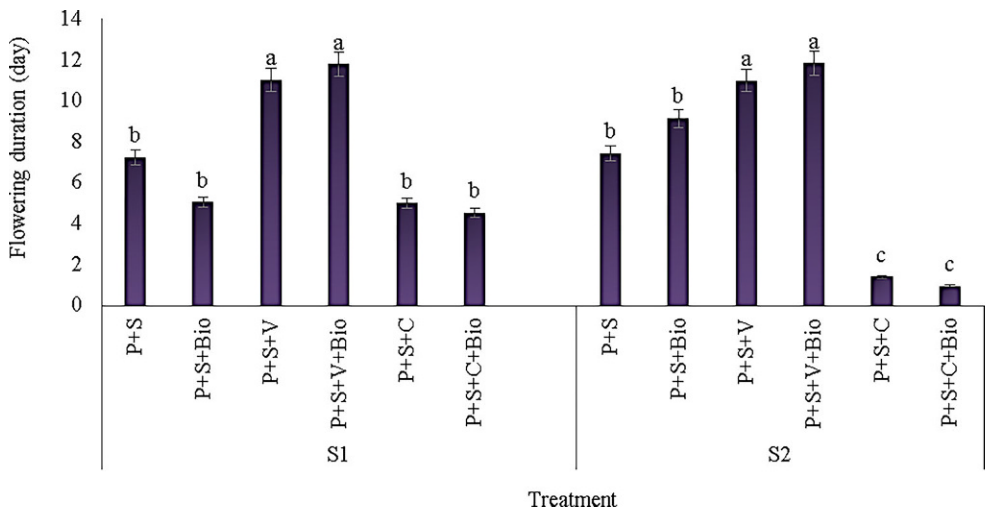

Fig. 2 Flowering duration of gerbera as affected by different soil mixtures in 2017/18 (S1) and 2018/19 (S2) seasons. P peat moss, S sand, V vermicompost, C compost, *Bio* bio stimulants (*Azotobacter chroococcum* and *Azospirillum* spp.). Means not sharing the letters for each variable in each bar vary significantly at $p \leq 0.05$ according to Duncan's multiple range

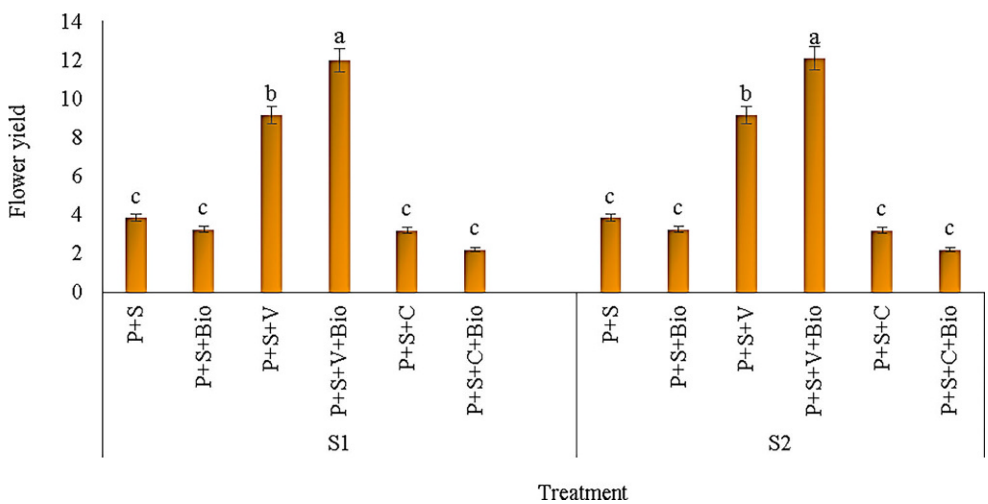

Fig. 3 Flowering yield (number of flowers per plant) of gerbera as affected by different soil substrate mixtures in 2017/18 (S1) and 2018/19 (S2) seasons. P peat moss, S sand, V vermicompost, C compost, *Bio* bio stimulants (*Azotobacter chroococcum* and *Azospirillum* spp.). Means not sharing the letters for each variable in each bar vary significantly at $p \leq 0.05$ according to Duncan's multiple range

3 Results

Different combination treatments of soil substrates showed significant effects on gerbera growth parameters (plant height, leaf width, root weight plant^{-1} and leaves weight plant^{-1}) in both seasons of 2017/18 and 2018/19 (Table 4). P+S+V+Bio was an effective practice for enhancing all growth traits. Furthermore, P+S+V+Bio statistically leveled with P+S, P+S+Bio, and P+S+C (for leaf width in the first season) as well as P+S+V (for root fresh weight plant^{-1} in both seasons) and P+S (for plant height in the second season).

Chlorophyll content, nutrient content, and bio-stimulant count in gerbera significantly responded to the various soil substrate mixtures in the 2017/18 and 2018/19 seasons (Table 5). Along the two-growing season, P+S+V+Bio produced the maximum values of chlorophyll, nitrogen, phosphorus, and potassium, with increases amounted to 92.4, 163.3, 137.5, and 98.0%, respectively, compared to the control treatment (P+S). However, the differences were not significant between P+S+V+Bio and P+S+V for nitrogen and phosphorus as well as P+S+V+Bio and P+S+C+Bio for the bio-stimulant count in 2018/19 season.

Flowering initiation (Fig. 1), flowering duration (Fig. 2), and flower yield (Fig. 3) of gerbera were significantly influenced by different soil substrates. The flowering of gerbera began early in pots treated by P+S+V or P+S+V+Bio in both seasons, compared to the other treatments. While, the flowering delayed in pots treated with P+S+C and P+S+C+Bio. The differences in flowering initiation between P+S and each of P+S+V, P+S+V+Bio, P+S+C and P+S+C+Bio were not significant. Contrariwise, P+S+V+Bio (for flowering duration and flower yield), in addition to P+S+V (for flowering duration) recorded the highest values in both seasons. As averages of the two seasons, the increase percentages in flowering yield due to P+S+V+Bio were 3.12, 3.71, 1.32, 3.76 and 5.47 folds higher than each of P+S, P+S+Bio, P+S+V, P+S+C and P+S+C+Bio, respectively.

Discussion

Organic and natural sources of fertilizers represent continues providers for various plant nutrients and organic acids while adjusting the physicochemical and biological characteristics of the soil (Elgala et al. 2022). Accordingly, improvements in gerbera plant growth and nutritional status were gained (Moreira et al. 2014). In this respect, compost as an organic material of fertilization had the potential to manipulate the sandy soil traits, since it improves organic matter content, nutrient availability, porosity, and H_2O holding capacity, while reducing the bulk density of soil (Mostafa et al. 2019). Another organic fertilization source is vermicompost which has a distinctive role in augmenting the fertility, moisture retaining, and aggregation of the soils (Abul-Soud et al. 2014). Also, several minerals such as nitrogen, potassium, phosphorus, calcium and magnesium are present in vermicompost in a form available to plants (Hashem and Abd-Elrahman 2016).

Gerbera plants effectively grow in soil having low pH (Savvas et al. 2003). Accordingly, soil substrate constituents dramatically determine the cultivated soil acidity, hence the availability of nutrients (Khalaj et al. 2019). As shown in Table 3, the obtained substrate mixtures had pH values lower than the individual used substrate compound, i.e. compost and vermicompost (Table 2). High pH around the root system may disturb the physiological balance in plants via nutritional infirmity due to limitation of nutrients availability such as phosphorus, manganese and iron (Barker and Pilbeam 2007). Addition of compost lowered soil pH, enhancing the nutrient uptake by gerbera plants (Ahmad et al. 2012). Really, growing media included compost can prop the ornamental plant growth and development by saving nutrients (Massa et al. 2018), while releasing bioactive organic compounds that improve the nutrient use efficiency (Massa et al. 2019). The presence of organic compounds such as humic acid improved the plant physiological status ad nutrient homeostasis, hence yield and quality (Makhlouf et al. 2022; Ramadan et al. 2023).

Not only soil properties improved with organic soil substrates, but also gerbera growth and flower yield and nutrients content. Since the organic fertilizers positively affected physical characteristic and beneficial microbes' activity the soil (Cayuela et al. 2009; Lima et al. 2009), the promotion of crop growth performance is expected. Leachates reduction is obtained with organic fertilizers addition (Girotto et al. 2013), since such types of fertilizers had high potential to hold water (Li et al. 2018). Thus, greater yield was recorded due slow–release organic fertilizer comparatively the mineral fertilizers (Wassie 2012; Yeshiwas et al. 2018). Long–term supply of organic fertilizers can modify soil properties expressed in acidy and microbial activity, hence increasing the nutrients availability (Rutkowska et al. 2014). Moreover, different soil mixture substrates have diversified mineralization rates and carbon content, therefore there was variation between compost and vermicompost in releasing nitrogen, potassium and calcium in soil (Hernández et al. 2016). Thus, growing gerbera in different mixed substrates showed differences in growth and flower yield. Owing to the abundance of available mineral in vermicompost (Abd-Elrahman et al. 2022), soil quality and plant growth improved (Birkhofer et al. 2008; Yang et al. 2015). Using mixture of soil substrates showed improvements in plant growth and number of flowers per plants (Zheng et al. 2004; Shrikant and Jawaharlal 2014).

Being the organic fertilizers provide the soil rhizosphere with organic carbon, the growth and activity of soil microbes increase whereby they can prepare their own food. Inoculation of Azotobacter in gerbera exhibited beneficial effect by improving growth traits due to the increase of N-fixation efficiency (Lele et al. 2009). Fertilization program involved the use of biofertilizers, i.e. *Azotobacter* achieved increases in flowering duration, flowers yield and vase life (Singh et al. 2008). The mechanisms by which biofertilizers exert a positive effect on plant growth can be through the synthesis of phytohormones, N_2-fixation, and some enzymes (such as ACC deaminase) that modulate the level of plant hormones. Free living N-fixing bacteria, such as *Azotobacter* and *Azospirillum*, have the ability not only to fix nitrogen but also to release certain phytohormons, i.e. Gibberellins, Indole acetic acid, and cytokinins, which stimulate plant growth and increase the availability of nutrients for plant roots by increasing their dissolution, in addition to increasing photosynthesis (Abdel-Latif et al. 2001).

Conclusion

It could be concluded that the healthy status, and flower productivity and quality of gerbera dramatically influenced by the component of the growing media. Findings of the current research exhibited that the media substrate should involve a mixture of peat moss, sand and vermicompost inoculating with nitrogen fixer bacteria to gain high yield and quality flower of gerbera. In fact, for improving the growth of ornamental plants such as gerbera, mixtures of organic materials used as media substrates require further investigation at multiple mixing ratios.

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Conflict of interest I.A.A. Ali, S.E. Hassan, A.A. Abdelhafez, M. Hewidy, M.A. Nasser, H.S. Saudy, K.M. Hassan and A.F. Abou-Hadid declare that they have no competing interests.

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