agriculture

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Ivy Geranium (*Pelargonium peltatum* (L.) L'Hér.) Plant Growth and Flowering as Affected by Mineral or Biofertilizer with or without Compost Amendment

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Abstract: Sustainable agriculture aims to eliminate the excessive usage of chemical fertilizers and can be crucial for soil fertility. A factorial pot experiment in a randomized complete block design was carried out in King Khaled International Airport Nursery, Riyadh, Saudi Arabia, during 2019/2020, to evaluate the role of a biofertilizer (i.e., Bio-Fert, nitrogen-fixing microorganisms; Biot-Phos, phosphorus-released microorganism; and Bio-Potas, potassium-released microorganisms, either alone or in combinations) and slow-release compound chemical fertilizer (Osmocote), with or without compost, on *Pelargonium peltatum* plant growth, flowering, chlorophyll level, and ion percentage. Soil amendment with compost in general significantly increased plant growth and flowering attributes as well as chlorophyll level, nitrogen (N), phosphorous (P), and potassium (K) percentage over garden soil (without compost). All growth and flowering traits as well as ion percentage and chlorophyll level were significantly increased by biofertilizer treatments either alone or in combinations. The supreme treatment was the triple interaction over single or double interactions or untreated plants. Osmocote application increases chlorophyll levels, ions, flowering, and vegetative growth relative to untreated plants. Additionally, the data also revealed that all interactions between either osmocote or biofertilizers with compost significantly increased all studied attributes over each treatment alone or untreated control plants. Accordingly, it is recommended to add compost to the soil along with a triple mixture of biofertilizers for obtaining high plant growth and flowering attributes along with soil fertility.

Keywords: biofertilizer; chemical fertilizer; chlorophyll; ions; organic fertilizer; sustainable production

Citation: Altobaishi, S.F.; Almana, F.A.; Abd-ElGawad, A.M.; Al-Yafrsi, M.A.; Elhindi, K.M. Ivy Geranium (*Pelargonium peltatum* (L.) L'Hér.) Plant Growth and Flowering as Affected by Mineral or Biofertilizer with or without Compost Amendment. *Agriculture* **2023**, *13*, 1106. https://doi.org/10.3390/agriculture13051106

Academic Editors: Beata Janowska and Maciej Bosiacki

Received: 24 April 2023
Revised: 13 May 2023
Accepted: 17 May 2023
Published: 22 May 2023

1. Introduction

Urban areas can be varying anthropized; major cities frequently have very dense populations, higher levels of pollution, and few spaces to grow plants. Cities will need to find solutions to issues including intense urbanization (almost 70% of global inhabitants are expected to live in cities by 2050 [1]), climate changes, water shortage, contamination, and a decline in human welfare [2,3]. Ornamental plants are produced for decoration and beautification either in indoor or outdoor spaces and enhance the beauty and visual features of a constructed environment [4]. The quality of life is considerably improved by the usage of ornamental plants in landscaping and in various green spaces, i.e., roads, parks, and gardens. Despite ornamental plants being significant components of human environments, compared to other plants, less is known about them and how they affect the quality of life [5]. Recently, concerning the burden of environmental difficulties and climate change, ornamental plants have been studied for their visual features and their aptitude to preserve the environment and an excellent quality of life [6]. A total of 749.200 hectares worldwide are used for the commercial cultivation of plants, which began to become more valuable at

the beginning of the 20th century [7]. The genus *Pelargonium* is widely distributed in temperate and humid regions worldwide. With an annual production value of USD 2.5 billion, this species ranks third among flowering potted plants globally [8]. *Pelargonium* comes in a variety of types and cultivars with different heights, shapes, bloom densities, and colors [8,9]. Moreover, they can be cultivated in a harsh environment, such as salty and calcareous soil, in addition to furthering the bioremediation strategy [10]. The demand for ornamental plants in urban areas is rising quickly as a result of increased urbanization.

Speedy growth and flowering in potted plants mostly rely on nutrient accessibility either in growing media or in fertilizers [11,12]. Nitrogen (N), phosphorus (P), and potassium (K) play a very substantial role in altering plant establishment and productivity [13]. N represents a crucial ion for improving plant establishment and protein synthesis as well as the biosynthesis of protein, chlorophyll, and nucleic acids [13]. P performs an energetic function in decisive plant development, cell division, enzyme activation, and carbohydrate metabolism [13]. K has a satisfactory impact on the metabolism of nucleic acid, protein, vitamin energy transfer, phloem transport, ion balance, and inducing water-stress tolerance [13]. The extensive and prolonged application of chemical fertilizers at an extremely high rate has recently evoked environmental pollution and declined microbial activity and the constancy of soil organic matter. Typically, 60–90% of whole applied fertilizers are mislaid, with only the remaining part (10–40%) being absorbed by plants. Hence, in order to fulfill the growing demand and stop overusing chemical resources, new sustainable and environmentally friendly solutions based on organic and biofertilizer amendments are needed [7,14,15].

Sphagnum peat has been widely utilized as an imperative element of growing substrates for ornamental plants owing to its anticipated physico-chemical attributes [16]; however, peat continues to be a costly and nonrenewable resource [11]. High-quality and low-cost peat alternatives are logical replacements. Various agro-waste has long been deliberated as being of little value and is typically discarded. Research has shown, however, the practicability of utilizing this agro-waste, after composting, as a growing substrate for vegetables and ornamental plants for its nutrient-rich fertilization as a soil amendment [14,15,17]. The addition of compost to the soil has valuable impacts on plant establishment and productivity via increasing soil fertility and microbial activities [7,9]. Compost represents an important source of micro- and macro-nutrients [18,19] and maintains soil water- and nutrient-retention capacity [15]. Several kinds of research have shown that the usage of biofertilizers enhanced plant growth, flowering attributes, and productivity [14,15,17,19].

Biofertilizer is a gainful and renewable source of crop nutrients that can reduce and eliminate the use of chemical fertilizers by 50% without reducing yield; it can also improve soil fertility [7] and restore the environment through agriculture [7,20]. Biofertilizers are products having beneficial living microorganisms, i.e., nitrogen-fixing bacteria and phosphorus- and potassium-solubilizing bacteria, that have the capacity to transform imperative ions from unavailable to accessible forms via biological processes [7,21]. Biofertilizers can be applied in different ways, i.e., through seed, seedling, or soil inoculation, and can be used alone or in combinations. Several kinds of research have shown that the usage of biofertilizers enhanced plant growth, flowering attributes, and productivity [7,21,22]. The efficient usage of biofertilizers for plants not only profits growers financially but furthermore enhances and sustains soil fertility and ecosystem resilience. The positive roles of biofertilizers on plant growth are related to boosting nitrogen fixation by microorganisms, synthesizing antibiotics and plant growth regulators (PGRs), improving ion uptake, and enabling the formation of metabolites that encourage and enhance meristematic activity [7,21,22]. Additionally, studies have also synthesized several organic acids that accelerate P, magnesium (Mg), zinc (Zn), iron (Fe), and manganese (Mn) release in non-available forms in the soil [7,20].

The research aims to achieve the effect of using different types of biofertilizers individually or in mixtures, after adding them to the agricultural soil with or without compost, on the vegetative and flowering growth of *Pelargonium peltatum* plants.

2. Materials and Methods

2.1. Plant Materials and Study Site

The pot trial was conducted in a greenhouse of King Khaled International Airport Nursery, Riyadh, Kingdom of Saudi Arabia (KSA, longitude: 46°43′ E, latitude: 24°55′ N, and above mean sea level 625 m), with a temperature of 24/20 °C, relative humidity of 60–70%, and photoperiod of 11 h (Figure 1).

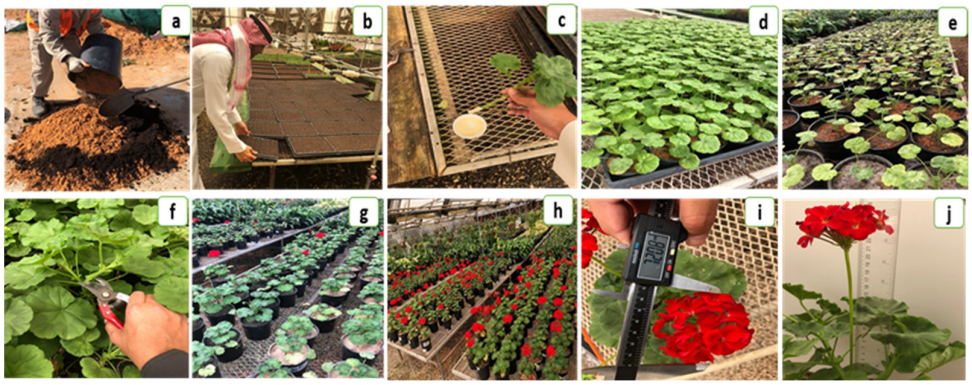

Figure 1. Experimental layout; (**a**) preparing soil mixture for cutting rooting; (**b**) preparing seedling tray for cutting rooting; (**c**) cutting bases dipped in indole-3- butyric acid (IBA) for indicating rooting formation; (**d**) cultivation of IBA treated cutting in seedling trays; (**e**) 30-day rooted cuttings were transplanted in 25 cm plastic pots (one plants/pot); (**f**) pinching plant shoot for improving branching capacity; (**g**) vegetative growth of *Pelargonium peltatum*; (**h**) flowering characteristics of plants; (**i**) estimation of inflorescence diameter; (**j**) estimation of plant height.

Terminal cuttings (10 cm in length) of ivy geranium (*Pelargonium peltatum* (L.) L'Hér.) 'Kim' from F1 mother plants were propagated from seeds (Blocompic, Holland) on 25 December 2019. The cuttings' bases were dipped in indole-3-butyric acid (IBA) (Rhizopona, 0.8%, Schutz company, Briogeton) as a plant growth regulator (PGR) from the auxin group that induces rooting capacity, and then, the planted seedling trays were filled with peat moss and perlite (1:1 v/v) within a mist propagation system for rooting.

2.2. Experimental Design

The experiment was laid out as a two-factorial experiment involving compost (with or without) as the first factor and fertilizers, i.e., biofertilizer (Bio-Fert, nitrogen-fixing microorganisms; Biot-Phos, phosphorus (P)-released microorganism; and Bio-Potas, potassium-released microorganisms, either alone or in combinations) or slow-release compound chemical fertilizer (Osmocote), as the second factor as well as their combination with 9×2 treatments and three replicates of 54 experimental units.

2.3. Experimental Layout

Plastic pots (25 cm in diameter) were divided into two sets, each consisting of 27 pots; the first set was filled with garden soil (GS, without compost), which is characterized as indicated in Table 1 following the protocol of Motsara and Roy [23]. Meanwhile, the second set was filled with a mixture of GS and compost (Klasmann Deilmam, Geeste, Germany) at the rate of 1:2 v/v. The chemical and physical features of the compost are indicated in Table 2.

Table 1. Physico-chemical attributes of the experimental soil.

Physical Attributes	Value	Chemical Attributes	Value
Silt (%)	88.22	pH	7.64
Clay (%)	8.78	EC (dSm^{-1})	1.47
Sand (%)	3.00	Cation Exchange Capacity (meq 100 g^{-1} soil)	35.94
Texture soil	Sandy	Organic matter (%)	1.82
Bulk density (g cm^{-3})	1.40	Available N (mg kg^{-1} soil)	57.24
		Available P (mg kg^{-1} soil)	7.93
		Available K (mg kg^{-1} soil)	120.16

Table 2. Physico-chemical attributes of the compost.

Characteristics	Value	Characteristics	Value
Moisture (%)	25–50	P (%)	0.5–0.75
EC (dSm^{-1})	3–4	K (%)	1.25–1.75
pH	7–7.5	Fe (mg kg^{-1})	50–70
Organic matter (%)	45.56	Mn (mg kg^{-1})	10–15
C/N ratio	14.2/1	Cu (mg kg^{-1})	5–10
Total N (%)	1.5–1.8	Zn (mg kg^{-1})	15–22

The homogenous rooted cuttings (30 days old) were transplanted into the pots (1 plant/pot) and irrigated regularly once every 3 days to the end of the experiment. To avoid fungal diseases and pest management, a fungicide and insecticide were applied to plants every 15 days from transplanting to the end of the experiments. Additionally, to avoid the defeat of vegetative growth, wholly flowering buds that appeared on the plant during the first month from transfer to the media were cut upon emergence.

The biofertilizers (Al-Maheliah company for trade and agriculture, Ltd., Riyadh, KSA) used were Bio-Fert© (*Bacillus polymyxa* at 2×10^8 active bacterial cells/mL); Bio-Phos© (*Azospirillium lipoferum* at 2×10^8 active bacterial cell/mL); and Bio-Potas© (*Streptomyces* spp. at 2×10^6 active bacterial cell/mL); they were added either individually or as a mixture to the pots at a rate of 2 mL liquid biofertilizer/liter of irrigation water in three stages: before planting and one month after and two months after transplanting [9]. The complex mineral fertilizer Osmocote (NPK: 13-13-13) was weighed and then added at a rate of 10 g/pot in one dose to the agricultural soil immediately after the transfer, as recommended by the producers. Pinching was also performed for all cultivated plants at a height of 15 cm and two weeks after planting seedlings.

2.4. Data Recorded

At 90 days from transplanting, the plant samples were collected for morpho-physiological and flowering attributes as well as leaf photosynthetic pigments and shoot ion percentage.

The plants were collected, and the plant growth attributes were measured, including plant height (cm), number of leaves and branches per plant, and shoot and root system/plant (g) once dried for 72 h in an oven at a temperature of 70 °C. In addition, the leaf area (cm^2) was measured using the leaf area estimator (LI-3000 COR, Walz Co., OR, USA).

As for flowering attributes, we recorded the time for flowering (day, by the number of days from planting until the appearance of the color at the first inflorescence on the plant); inflorescence age (from the beginning of the formation of flower buds until the stage of aging and the end of its life period); number of inflorescences per plant; the number of flowers in inflorescence; the diameter of the inflorescence per plant (cm) during the stage of full bloom; flower stock length (cm); and dry weight of the inflorescences per plant, weighed after drying in an oven at a temperature of 70 °C for 72 h.

Total chlorophyll concentrations (mg·g^{-1} FW) within the third fully upper leaf were extracted by methanol and quantified spectrophotometrically (T60 UV-Visible spectropho-

tometer, PG Instrument Limits, Lutterworth, UK), following the Lichtenthaler and Welburn [24] protocol.

For estimation of nitrogen (N), phosphorous (P), and potassium (K) percentage, two-hundred mg of shoot dry matter was digested with a sulfuric and perchloric acid mixture [25] and then diluted with bi-distilled water to the final volume (100 mL). Total N, P, and K were determined with micro-Kjeldahl protocol, stannous chloride plus ammonium molybdate method, and also flame-photometrically, respectively.

2.5. Statistical Analysis

The CoHort Software (CoHort software, 2006; Cary, NC, USA) statistical package was used to apply two-way-ANOVA. Tukey's HSD-MRT test at $p \leq 0.05$ was also used to separate the means. Values with the different letters were substantially different at $p \leq 0.05$. The data existing are represented as mean with standard error (SE).

3. Results

3.1. Growth and Flowering Attributes

The data in Table 3 show that the application of biofertilizer or Osmocote with or without compost supplementation significantly increased the growth attributes of *Pelargonium peltatum* plants. Soil supplementation with compost significantly ($p \leq 0.05$) boosted plant height, leaves number per plant, branches number per plant, leaf area, shoot dry weight, and root dry weight by 20.06, 6.01, 6.07, 28.65, 32.41, and 5.58% respectively, over garden soil (soil without compost).

Plants treated with either biofertilizer or Osmocote significantly ($p \leq 0.05$) increased all growth parameters relative to untreated plants. The greatest values of plant height (34.20 cm), leaves number per plant (50.16), branches number per plant (9.30), leaf area (133.6 cm^2), shoot dry mass (8.46 g), and root dry mass (2.50 g) were recorded for plants treated with Bio-Fert + Bio-Phos + Bio-Potas mixture over non-treated plants, which gave the lowest values (22.58, 35.33, 5.58, 88.58 cm^2, 4.03 g, and 1.45 g respectively (Table 3). Additionally, the data in the same table show that Osmocote typically gave superior values of shoot and root dry mass over each biofertilizer separately, and it also gave superior values of plant height and leaf area over single- or double-mixture application of biofertilizers.

The data in the Table 3 reveal that all interactions between compost and either biofertilizer or Osmocote significantly increased all studied characteristics compared to control plants. The use of a triple mixture of biofertilizer with compost significantly gave the highest values of plant height (36.69 cm), leaves number per plant (55.96), branches number per plant (9.80), leaf area per plant (146.4 cm^2), shoot dry mass (9.36 g), and root dry mass (2.69 g), with increasing rates of 71.52, 59.35, 76.25, 65.74, 138.7, and 86.80% over the untreated control plants.

The results in Table 4 show that the addition of compost significantly ($p \leq 0.05$) increased the number of days to flowering (44.48 days), flowering stock length (16.59 cm), inflorescence number per plant (2.67), flower number per plant (35.41), inflorescence diameter (5.61 cm), inflorescence age (34.35 days), and inflorescence dry weight (0.99 g) over garden soil (without compost addition).

Table 3. Effect of different biofertilizer treatments and chemical fertilizer (osmocote) with or without compost on the *Pelargonium peltatum* plant growth attributes.

Treatments	Plant Height (cm)	Leaves Number/Plant	Branches Number/Plant	Leaf Area (cm^2)	Shoot Dry Weight (g)	Root Dry Weight (g)
			Compost treatment			
− Comp (C1)	26.32 ± 1.98 b	41.05 ± 2.56 b	7.08 ± 0.97 b	95.29 ± 9.65 b	5.46 ± 1.06 b	1.79 ± 0.25 b
+ Comp (C2)	31.6 ± 2.32 a	43.52 ± 3.32 a	7.51 ± 1.43 a	122.6 ± 16.0 a	7.23 ± 1.43 a	1.89 ± 0.32 a
ANOVA *p*-values	***	***	***	***	***	***
			Fertilization treatments			
Control (without fertilization) (T1)	22.58 ± 0.54 f	35.33 ± 0.43 f	5.58 ± 0.34 e	88.58 ± 0.69 b	4.03 ± 0.22 e	1.45 ± 0.02 g
Osmocote (T2)	31.45 ± 0.50 b	39.02 ± 0.38 e	6.98 ± 0.13 cd	117.1 ± 20.0 b	6.83 ± 0.78 b	1.85 ± 0.03 cd
Bio-Fert (T3)	26.51 ± 0.98 c	42.38 ± 1.30 c	7.56 ± 0.48 b	103.8 ± 13.3 e	6.21 ± 1.26 c	1.58 ± 0.08 f
Bio-Phos (T4)	28.04 ± 1.06 d	41.96 ± 0.50 d	6.76 ± 0.42 d	101.8 ± 13.9 g	5.54 ± 0.89 d	1.68 ± 0.06 e
Bio-Potas (T5)	29.09 ± 0.81 e	42.01 ± 0.70 d	6.70 ± 0.41 d	102.0 ± 12.4 g	5.48 ± 1.09 d	1.79 ± 0.05 d
Bio-Fert + Bio-Phos (T6)	30.95 ± 0.94 b	43.74 ± 1.87 b	7.75 ± 0.35 b	112.4 ± 21.1 c	7.12 ± 1.33 b	1.89 ± 0.04 c
Bio-Fert + Bio-Potas (T7)	30.02 ± 0.92 c	43.05 ± 1.19 c	7.86 ± 0.19 b	111.1 ± 19.6 d	6.96 ± 1.01 b	1.88 ± 0.05 c
Bio-Phos + Bio-Potas (T8)	27.87 ± 0.97 c	42.47 ± 0.66 cd	7.20 ± 0.25 c	110.3 ± 20.1 e	6.45 ± 1.39 c	1.96 ± 0.09 b
Bio-Fert + Bio-Phos + Bio-Potas (T9)	34.20 ± 1.18 a	50.16 ± 3.38 a	9.30 ± 1.21 a	133.6 ± 14.0 a	8.46 ± 1.03 a	2.50 ± 0.22 a
ANOVA *p*-values	***	***	***	***	***	***
			Interaction Effects			
C1T1	21.39 ± 0.23 i	35.18 ± 0.03 i	5.56 ± 0.20 i	88.33 ± 0.46 m	3.92 ± 0.14 k	1.44 ± 0.01 h
C1T2	29.36 ± 0.20 jk	38.78 ± 0.16 h	6.93 ± 0.08 fg	98.86 ± 0.54 i	6.13 ± 0.10 ef	1.83 ± 0.01 de
C1T3	22.75 ± 0.21 g–i	42.01 ± 0.75 e–g	7.20 ± 0.05 ef	91.66 ± 0.31 k	5.07 ± 0.05 gh	1.51 ± 0.02 h
C1T4	24.85 ± 0.57 ij	41.62 ± 0.22 fg	6.40 ± 0.05 h	89.3 ± 0.29 m	4.74 ± 0.10 hi	1.63 ± 0.01 g
C1T5	25.66 ± 0.18 k	41.40 ± 0.08 g	6.50 ± 0.05 gh	90.6 ± 0.30 l	4.49 ± 0.09 ij	1.75 ± 0.01 c
C1T6	28.72 ± 0.11 d–f	42.09 ± 0.22 e–g	7.16 ± 0.08 de	93.1 ± 0.40 j	5.91 ± 0.13 f	1.88 ± 0.01 d
C1T7	26.65 ± 0.14 f–j	42.15 ± 0.51 e–g	7.76 ± 0.08 cd	93.16 ± 0.14 j	6.06 ± 0.20 ef	1.86 ± 0.03 de
C1T8	25.81 ± 0.43 f–h	41.92 ± 0.17 fg	7.20 ± 0.15 ef	91.96 ± 0.17 k	5.23 ± 0.20 g	1.90 ± 0.06 d
C1T9	31.71 ± 0.19 b	44.35 ± 0.43 c	8.70 ± 0.26 b	120.8 ± 0.36 e	7.57 ± 0.24 cd	2.32 ± 0.08 b
C2T1	23.77 ± 0.16 i	35.47 ± 0.37 i	5.60 ± 0.20 i	88.83 ± 0.34 m	4.14 ± 0.09 jk	1.47 ± 0.01 h
C2T2	33.53 ± 0.21 ij	39.26 ± 0.19 b	7.03 ± 0.06 ef	135.5 ± 0.37 b	7.53 ± 0.10 cd	1.87 ± 0.02 d
C2T3	30.26 ± 0.32 de	43.75 ± 0.29 cd	7.93 ± 0.08 c	116.0 ± 0.36 f	7.36 ± 0.13 d	1.65 ± 0.02 fg
C2T4	31.22 ± 0.29 e–g	42.30 ± 0.20 e–g	7.13 ± 0.12 ef	114.5 ± 0.17 g	6.33 ± 0.16 ef	1.73 ± 0.03 ef
C2T5	32.50 ± 0.41 h–j	42.62 ± 0.18 ef	6.90 ± 0.17 ef	113.4 ± 0.11 h	6.47 ± 0.09 e	1.83 ± 0.03 de
C2T6	33.17 ± 0.28 bc	45.39 ± 0.39 b	8.03 ± 0.12 c	131.7 ± 0.38 c	8.33 ± 0.06 b	1.91 ± 0.02 d
C2T7	33.38 ± 0.22 cd	43.96 ± 0.32 cd	7.96 ± 0.12 c	129.1 ± 0.36 d	7.86 ± 0.10 c	1.89 ± 0.02 d
C2T8	29.92 ± 0.59 de	43.01 ± 0.20 de	7.20 ± 0.17 ef	128.6 ± 0.46 d	7.67 ± 0.29 cd	2.03 ± 0.01 c
C2T9	36.69 ± 0.37 a	55.96 ± 0.20 a	9.80 ± 0.29 a	146.4 ± 0.63 a	9.36 ± 0.15 a	2.69 ± 0.03 a
ANOVA *p*-values	***	***	***	***	***	***

Levels of significance are represented by *** $p < 0.001$. For each parameter, different letters within the column show significant differences between the treatments and control according to Tukey's HSD test at $p < 0.05$.

Table 4. Effect of different biofertilizer treatments and chemical fertilizer (Osmocote) applied to agricultural soils with or without compost on the *Pelargonium peltatum* flowering attributes.

Treatments	Number of Days to Flowering	Flowering Stock Length (cm)	Inflorescence No/Plant	Flower Number /Plant	Inflorescence Diameter (cm)	Inflorescence Age (Day)	Inflorescence Dry Weight (g)
			Compost treatment (Comp, at a ratio of 1:2 *v*/*v* soil/compost)				
− Comp (C1)	43.09 ± 2.87 b	14.69 ± 2.96 b	2.11 ± 0.67 b	32.41 ± 3.94 b	5.18 ± 0.65 b	33.40 ± 4.36 b	0.36 ± 0.10 b
+ Comp (C2)	44.48 ± 3.65 a	16.59 ± 3.68 a	2.67 ± 0.85 a	35.41 ± 6.38 a	5.61 ± 0.11 a	34.35 ± 5.06 a	0.99 ± 0.62 a
ANOVA *p*-values	***	***	***	***	***	***	***
			Fertilization treatments				
Control (without fertilization) (T1)	38.57 ± 0.27 f	10.06 ± 0.22 b	1.40 ± 0.14 f	24.00 ± 0.37 g	4.10 ± 0.05 b	25.56 ± 0.65 g	0.22 ± 0.01 g
Osmocote (T2)	44.59 ± 0.57 c	15.83 ± 0.90 e	2.05 ± 0.28 de	36.75 ± 1.14 b	5.45 ± 0.08 c	37.71 ± 1.48 b	0.40 ± 0.01 e
Bio-Fert (T3)	42.48 ± 2.66 e	12.30 ± 1.30 g	2.20 ± 0.59 d	29.41 ± 1.04 f	4.89 ± 0.16 g	30.30 ± 1.46 f	0.31 ± 0.05 f
Bio-Phos (T4)	42.92 ± 2.16 e	12.86 ± 0.98 f	1.86 ± 0.37 e	31.81 ± 1.07 e	5.01 ± 0.18 f	30.13 ± 1.17 f	0.32 ± 0.05 f
Bio-Potas (T5)	43.39 ± 1.87 cd	15.31 ± 0.99 e	2.83 ± 0.50 b	34.41 ± 1.89 d	5.62 ± 0.15 b	33.38 ± 0.73 e	0.82 ± 0.44 d
Bio-Fert + Bio-Phos (T6)	44.66 ± 2.50 c	16.58 ± 1.26 d	1.88 ± 0.17 e	34.03 ± 0.77 d	5.25 ± 0.25 e	34.60 ± 1.01 d	0.79 ± 0.48 d
Bio-Fert + Bio-Potas (T7)	44.65 ± 2.80 c	18.06 ± 1.22 c	2.63 ± 0.28 c	36.90 ± 1.76 b	5.36 ± 0.10 d	35.01 ± 1.16 d	1.03 ± 0.64 c
Bio-Phos + Bio-Potas (T8)	45.26 ± 2.72 b	19.06 ± 1.39 b	2.66 ± 0.21 bc	35.16 ± 1.52 c	5.35 ± 0.19 d	36.53 ± 0.91 c	1.07 ± 0.69 b
Bio-Fert+Bio-Phos+Bio-Potas (T9)	47.82 ± 2.23 a	20.70 ± 1.94 a	4.03 ± 0.58 a	42.75 ± 6.30 a	7.56 ± 0.10 a	41.63 ± 2.81 a	1.19 ± 0.69 a
ANOVA *p*-values	***	***	***	***	***	***	***
			Interaction Effects				
C1T1	37.97 ± 0.12 hi	9.66 ± 0.12 n	1.30 ± 0.05 k	23.90 ± 0.20 l	4.10 ± 0.21 k	25.50 ± 0.45 j	0.21 ± 0.01 j
C1T2	43.58 ± 0.12 ef	15.10 ± 0.32 ij	1.80 ± 0.05 hi	35.73 ± 0.08 ef	5.38 ± 0.21 ef	36.16 ± 0.54 cd	0.38 ± 0.01 f–j
C1T3	41.54 ± 0.62 g	11.30 ± 0.63 m	1.66 ± 0.06 ij	28.66 ± 0.46 b	4.75 ± 0.32 j	29.30 ± 0.58 h	0.26 ± 0.01 j
C1T4	42.51 ± 0.31 fg	12.10 ± 0.36 l	1.53 ± 0.06 i–k	30.93 ± 0.24 j	4.84 ± 0.44 j	29.16 ± 0.14 h	0.26 ± 0.01 j
C1T5	42.76 ± 0.37 f	14.50 ± 0.17 j	2.40 ± 0.11 ef	32.80 ± 0.41 i	5.49 ± 0.35 de	32.93 ± 0.38 f	0.41 ± 0.01 fg
C1T6	43.30 ± 0.24 f	15.56 ± 0.53 hi	1.80 ± 0.05 hi	33.40 ± 0.11 hi	5.03 ± 0.49 i	35.23 ± 0.54 de	0.35 ± 0.01 i
C1T7	43.60 ± 0.05 e	16.96 ± 0.12 ef	2.46 ± 0.17 d–f	35.40 ± 0.11 ef	5.28 ± 0.42 fg	35.93 ± 0.43 cd	0.42 ± 0.01 fg
C1T8	44.83 ± 0.05 cd	17.80 ± 0.05 d	2.56 ± 0.14 c–e	33.90 ± 0.17 gh	5.18 ± 0.44 gh	37.30 ± 0.15 c	0.44 ± 0.01 f
C1T9	47.24 ± 0.38 b	18.93 ± 0.14 c	3.50 ± 0.05 b	37.03 ± 0.41 cd	6.60 ± 0.44 b	39.06 ± 0.08 b	0.56 ± 0.01 e
C2T1	39.17 ± 0.05 h	10.16 ± 0.13 n	1.50 ± 0.05 jk	24.10 ± 0.25 l	4.11 ± 0.40 k	25.63 ± 0.38 i	0.24 ± 0.01 j
C2T2	45.60 ± 0.38 c	16.56 ± 0.18 fg	2.30 ± 0.05 ef	37.76 ± 0.21 bc	5.52 ± 0.34 d	39.26 ± 0.38 b	0.41 ± 0.01 f–h
C2T3	43.43 ± 0.29 e	13.30 ± 0.10 k	2.73 ± 0.08 cd	30.16 ± 0.35 j	5.03 ± 0.49 i	31.30 ± 0.66 g	0.36 ± 0.01 hi
C2T4	43.34 ± 0.42 ef	13.63 ± 0.29 k	2.20 ± 0.05 fg	32.70 ± 0.36 i	5.16 ± 0.29 h	31.10 ± 0.45 g	0.37 ± 0.01 g–i
C2T5	44.03 ± 0.62 d	16.13 ± 0.34 gh	3.26 ± 0.12 b	36.03 ± 0.44 de	5.76 ± 0.29 c	32.83 ± 1.13 f	1.23 ± 0.01 d
C2T6	45.02 ± 0.20 c	17.60 ± 0.10 de	1.96 ± 0.12 gh	34.66 ± 0.29 fg	5.47 ± 0.45 de	33.83 ± 0.31 ef	1.24 ± 0.01 d
C2T7	45.71 ± 0.37 c	19.16 ± 0.14 c	2.80 ± 0.10 c	38.40 ± 0.58 a	5.43 ± 0.37 de	34.10 ± 0.32 ef	1.58 ± 0.03 c
C2T8	45.70 ± 0.59 c	20.33 ± 0.08 b	2.76 ± 0.08 c	36.43 ± 0.56 de	5.52 ± 0.50 d	35.76 ± 0.29 cd	1.70 ± 0.05 b
C2T9	48.40 ± 0.37 a	22.46 ± 0.08 a	4.56 ± 0.03 a	48.46 ± 0.52 a	8.52 ± 0.34 a	44.20 ± 0.00 a	1.83 ± 0.03 a
ANOVA *p*-values	***	***	***	***	***	***	***

Levels of significance are represented by *** $p < 0.001$. For each parameter, different letters within the column show significant differences between the treatments and control according to Tukey's HSD test at $p < 0.05$.

The results in Table 4 show that application of biofertilizer alone or in a mixture gave a significant ($p \leq 0.05$) increase in flower attributes over the untreated plants. The greatest values were found for the number of days to flowering (47.82 days), flowering stock length (20.70 cm), inflorescence number per plant (4.03), flower number per plant (42.75), inflorescences diameter (7.56 cm), and inflorescence dry weight (1.19 g), with increased rates of 23.98, 105.76, 187.85, 78.12 84.39, 62.87, and 440.90%, respectively, over the untreated plants. As for Osmocote effect, the same table shows that the application of Osmocote significantly increased all flowering attributes over untreated plants.

Application of either biofertilizer or Osmocote with compost significantly ($p \leq 0.05$) increased all flowering attributes over the untreated control plants (Table 4). The mixture of biofertilizer (Bio-Fert + Bio-Phos + Bio-Potas) with compost resulted in greater values in the number of days to flowering, flowering stock length, inflorescence number per plant, flower number per plant, inflorescence diameter, inflorescence age, and inflorescence dry weight by 21.09, 132.50, 250.76, 102.76, 107.80, 73.33, and 771.42%, respectively.

3.2. Ion Percentage and Chlorophyll Concentrations

The current outcomes (Table 5) indicate that the use of different types of fertilizers (organic, mineral, and biological) either individually or in a mixture have a significant effect on the ion percentage and chlorophyll concentration of geranium plants. Based on the results, it was found that there was a significant superiority in the ion percentage and chlorophyll concentration of geranium plants when compost was added to the soil compared to the plants growing in the soil without the addition of compost, where the percentages of the elements of nitrogen (N), phosphorus (P), potassium (P), and chlorophyll concentration were 2.13%, 0.25%, 1.46%, and 5.93 mg/g FW, respectively, and in different proportions, with an increase of 11.51, 47.05, 16.80, and 18.12%, respectively. It was also found that the use of biofertilizers, especially the mixture, contributed to a significant rise in geranium plants regarding the content percentages of major nutrients and chlorophyll. Treatment with the mixture of biofertilizers (Bio-Fert + Bio-Phos + Bio-Potas) recorded the highest percentages of each of N, P, K, and chlorophyll at 2.78%, 0.34%, 1.79%, and 7.89 mg·g^{-1} FW, respectively, with increased rates of 60.69, 183.33, 55.62, and 101.27%, respectively, compared to the control treatment. The results showed (Table 5) that the Osmocote mineral fertilizer application significantly ($p \leq 0.05$) increased the percentage of N, P, K, and chlorophyll concentration (2.2%, 0.19%, 1.76%, and 6.07 mg·g^{-1} FW), respectively, with increased rates of 27.16, 58.33, 53.04, and 54.84%, respectively, compared to the control treatment.

The results of the interaction between biofertilizers or chemical fertilizers (Osmocote) in the compost-added soil (Table 5) show that there are significant differences in the percentages of the major elements, as all interactions led to a significant increase in these elements and chlorophyll compared to the soil without the addition of compost. The highest values for the percentages obtained when using the biofertilizer mixture in the presence of compost were 2.85%, 0.44%, 1.92%, and 8.70 mg·g^{-1} FW, respectively, with increased rates of 87.50, 266.66, 68.42, and 125.38%, respectively, compared to the control treatment.

The findings also indicated that the addition of Osmocote in the presence of compost led to a significant rise in the plant levels of N, P, K, and chlorophyll (2.47%, 0.23%, 1.92%, and 6.39 mg·g^{-1} FW), respectively, with increased rates of 62.50, 91.66, 68.42, and 65.54%, respectively, compared to the control treatment. It was noted that the percentage of K resulting from the addition of mineral fertilizer to the compost-containing soil was similar to that when using the biofertilizer mixture.

Table 5. Effect of different biofertilizer treatments and chemical fertilizer (Osmocote) applied to agricultural soils with or without compost on the *Pelargonium peltatum* plant ion percentage and chlorophyll concentration.

Treatments	N (%)	P (%)	K (%)	Chlorophyll (mg·g^{-1} FW)
Compost treatment				
− Comp (C1)	1.91 ± 0.41 b	0.17 ± 0.04 b	1.25 ± 0.26 b	5.02 ± 0.27 b
+ Comp (C2)	2.13 ± 0.37 a	0.25 ± 0.08 a	1.46 ± 0.32 a	5.93 ± 0.13 a
ANOVA *p*-values	***	***	***	***
Fertilization treatments				
Control (without fertilization) (T1)	1.73 ± 0.24 ef	0.120.01 f	1.15 ± 0.03 f	3.92 ± 0.27 g
Osmocote (T2)	2.20 ± 0.31 bc	0.19 ± 0.04 d	1.76 ± 0.18 a	6.07 ± 0.18 b
Bio-Fert (T3)	2.31 ± 0.10 b	0.24 ± 0.05 c	1.08 ± 0.12 g	5.05 ± 0.19 e
Bio-Phos (T4)	1.79 ± 0.14 e	0.15 ± 0.03 e	0.98 ± 0.05 h	5.02 ± 0.21 e
Bio-Potas (T5)	1.57 ± 0.08 f	0.17 ± 0.05 d	1.59 ± 0.07 e	4.73 ± 0.23 f
Bio-Fert + Bio-Phos (T6)	2.07 ± 0.06 cd	0.25 ± 0.03 bc	1.03 ± 0.14 g	5.64 ± 0.17 cd
Bio-Fert + Bio-Potas (T7)	1.93 ± 0.45 de	0.27 ± 0.06 b	1.39 ± 0.17 e	5.80 ± 0.15 c
Bio-Phos + Bio-Potas (T8)	1.81 ± 0.08 e	0.18 ± 0.04 d	1.50 ± 0.09 d	5.14 ± 0.20 d
Bio-Fert + Bio-Phos + Bio-Potas (T9)	2.78 ± 0.15 a	0.34 ± 0.10 a	1.79 ± 0.24 b	7.89 ± 0.19 a
ANOVA *p*-values	***	***	***	***
Interaction Effects				
C1T1	1.52 ± 0.05 i	0.12 ± 0.01 h	1.14 ± 0.02 g	3.86 ± 0.51 hi
C1T2	1.94 ± 0.08 e–h	0.15 ± 0.01 g	1.60 ± 0.02 bc	5.74 ± 0.91 d
C1T3	2.22 ± 0.02 c–e	0.21 ± 0.01 d–f	0.97 ± 0.01 hi	4.70 ± 0.25 e
C1T4	1.71 ± 0.03 g–i	0.11 ± 0.01 b	0.93 ± 0.01 i	4.55 ± 0.10 f
C1T5	1.52 ± 0.04 f	0.13 ± 0.01 gh	1.53 ± 0.01 cd	4.34 ± 0.50 g
C1T6	2.05 ± 0.04 e–g	0.22 ± 0.01 de	0.91 ± 0.02 i	4.88 ± 0.21 e
C1T7	1.75 ± 0.37 f–i	0.21 ± 0.01 ef	1.24 ± 0.01 f	5.48 ± 0.24 d
C1T8	1.78 ± 0.06 f–i	0.14 ± 0.01 gh	1.43 ± 0.02 e	4.55 ± 0.58 f
C1T9	2.70 ± 0.03 ab	0.24 ± 0.01 d	1.48 ± 0.03 de	7.08 ± 0.72 b
C2T1	1.95 ± 0.03 e–h	0.120.01 gh	1.17 ± 0.01 fg	3.98 ± 0.09 h
C2T2	2.47 ± 0.07 bc	0.23 ± 0.01 de	1.92 ± 0.04 a	6.39 ± 0.21 c
C2T3	2.40 ± 0.10 b–d	0.28 ± 0.02 c	1.20 ± 0.01 fg	5.39 ± 0.42 de
C2T4	1.88 ± 0.09 e–h	0.18 ± 0.01 f	1.03 ± 0.01 h	5.50 ± 0.81 d
C2T5	1.62 ± 0.04 hi	0.22 ± 0.01 de	1.66 ± 0.01 b	5.13 ± 0.61 de
C2T6	2.10 ± 0.01 df	0.28 ± 0.01 c	1.16 ± 0.01 fg	6.40 ± 0.80 c
C2T7	2.10 ± 0.05 d–f	0.33 ± 0.01 b	1.55 ± 0.04 cd	6.13 ± 0.22 cd
C2T8	1.85 ± 0.01 f–i	0.22 ± 0.01 de	1.58 ± 0.03 c	5.73 ± 0.34 d
C2T9	2.85 ± 0.04 a	0.44 ± 0.01 a	1.92 ± 0.01 a	8.70 ± 0.62 a
ANOVA *p*-values	***	***	***	***

Levels of significance are represented by *** $p < 0.001$. For each parameter, different letters within the column show significant differences between the treatments and control according to Tukey's HSD test at $p < 0.05$.

4. Discussion

The microbial population and quantity of organic matter in soil have a key role in improving its health, fertility, and productivity. The former plays a vital role in sustaining soil structure that is favorable for nutrient and water maintenance as well as providing carbon and energy for the microorganisms to function [26]. In addition to carrying out a variety of other tasks in the soil, microorganisms that live at the expense of organic matter either from exogenous sources or from plant roots act as agents of nutrient release and mobilization [27]. The current finding proved that geranium plant growth, flowering attributes, ion percentage, and chlorophyll concentration significantly increased by application of either biofertilizer or chemical fertilizer with or without compost addition. These findings are in line with earlier studies that indicate the effects of the application of chemical fertilizer [28,29], compost [14,15,17], and biofertilizers [7,14].

The direct, positive effects of chemical fertilizer (i.e., Osmocote) on plant growth and flowering may be due to the content and rapid availability of nitrogen (N), phosphorus

(P), and potassium (K) needed for plant growth. It was found that N is necessary for protein and nucleic acid assimilation needed for chlorophyll synthesis and cell division, which accelerate several biochemical pathways and increase plant growth and flowering capacity [30]. Additionally, N is essential for tryptophan synthesis, which is the basic material for indole-3-acetic acid (IAA) assimilation, which is responsible for cell division and elongation and activation of meristematic peaks [13]. Moreover, N plays a prime role in accelerating and activating several proteins responsible for the unfolding of floral primordial development [31]. Additionally, a larger N concentration may have sped up protein synthesis, encouraging the early development of the floral primordium [32]. The findings of Acharya and Dashora [33] on *Tagetes erecta* reported that an increase in P was implicated at the beginning of floral primordial creation, which resulted in an increase in the size and quantity of flowers. The Osmocote also provides P in an easy way for the plant, which is a principal compound of energy compounds, phospholipids, and co-enzymes for the synthesis of a large group of proteins, and it enhances ion uptake and motivates flowering [13]. Sufficient quantities of K play multiple physiological roles in plants' life cycles. In addition to playing a crucial role in expanding the number of leaves, K is engaged in the formation of peptide bonds as well as the metabolism of proteins and carbohydrates [34]. Additionally, K performances a crucial role in photosynthetic effectiveness and the proper ratio of carbohydrates and protein, which shortens the time for flower bud appearance [35]. Accordingly, Gaber [28] found that the application of compound chemical fertilizer (20:20:20) significantly increased *Pelargonium* plant growth (plant height, number of branches/plant, number of leaves/plant, leaf area, and shoot dry weight) and flowering (number of inflorescence/plant, number of floret/inflorescence, and inflorescence duration) attributes as well as increased the percentage of N, P, and K and chlorophyll content. Recently, Nofal et al. [29], in their study on *Tagetes*, found that the application of compound chemical fertilizer (19:19:19) significantly increased plant growth and flowering attributes.

The remarkable effect of compost improvement on plant development may be attributed to improving the soil's physical, chemical, and biological properties via increasing organic matter [15], which in turn improves soil aeration, cation exchange capacity, soil water-holding capacity, root development stimulation, and their capacity to absorb more nutrients from the soil solution [36], which is reflected in increased plant growth and flowering as well as increasing ion % and chlorophyll concentration [15]. Moreover, compost application activates rhizosphere microorganisms with the liberation of several organic acids and lowering soil pH, leading to increasing ion availability and accumulation in plant tissues, improving plant growth and flowering ability as well as chlorophyll assimilation [37]. In this regard, Bi and Evans [38] and Chand et al. [39] found that the amendment of compost increased the ion content and plant growth and flowering of *Tagets patula* and *Pelargonium* plants, respectively. Due to its chelation capabilities, compost application also maintains soil nutrients' availability, prevents their loss, and improves nutrient usage efficiency [40] and also induces the excessive production of carbon dioxide (CO_2), which is dissolved in the soil solution and forms carbonic acid (H_2CO_3), leading to a lowered soil pH and the solubility of several ions such as K and P [41]. The high K also works to increase the numbers of cells and plastids of the leaf, which leads to a rise in chlorophyll level [42].

The current outcomes prove that the application of single or mixed biofertilizers significantly increased plant growth and flowering attributes. In a study on *Anthurium andreanum* plants, Bordoloi and Talukdar [43] found that the addition of biofertilizer to the soil resulted in a substantial rise in all flowering attributes of plants over the non-treated plants. Attia et al. [44] also showed that the use of different biofertilizers planted with *Polianthes tuberosa* plants led to an improvement in the characteristics of flowering growth, represented by the number of flowers per inflorescence, the length of the inflorescence, the dry weight of the inflorescence, and the diameter of the flower. Hassan and Abd El-Azeim [14] also found that the application of biofertilizers resulted in a significant increase

in the characteristics of inflorescence length, inflorescence wet and dry weight, number of flowers/inflorescence, and flower diameter of *Gladiolus* plants. These encouraging effects may result from increasing nutrient availability [45]; accelerating cell expansion and division via the synthesis and action of auxin, cytokinin (CK), and gibberellin (GA) [46]; and accelerating atmospheric N fixation, which is required for nucleic acid, protein, and chlorophyll synthesis along with enhancement of the photosynthetic rate and plant biomass accumulation and flowering attributes [47]. Additionally, the superior influence of biofertilizer application may be related to improving root system development and function due to auxin assimilation along with increasing plant water absorption [48,49]. Biofertilizer induces revitalization and accelerates the formation of the lateral root and surface area of absorption as well as the formation of auxin, which boosts the transfer of photoassimilates to the growing area, which is reflected in the weight of the flower and the flowering time of *Gladiolus* [50]. Moreover, inoculation with biofertilizer accelerates the generation of antagonistic substances or indirectly induces resistance to pathogens, and the indirect routes of plant growth promotion include antagonism against phytopathogens via the assembly of siderophores, antibiotics, and cyanide [51,52]. Likewise, biofertilization improves soil biodiversity [53] and prompt flowering, and a rise in florets number per spike is dependent on the photoassimilates' accumulation [54]. Carbohydrates are the foremost nutrient participating in the flower's development and may cause a rise in the number of flowers per plant [54]. Several studies have interpreted the role of phosphate-solubilizing bacteria in terms of increased soil availability; this may be due to the secretion of phosphatase that converts organic P to soluble forms [55]. Moreover, strong acids such as tartaric, malic, and oxalic acids are produced in the rhizosphere, and this takes place through acidification, chelation, and exchange reactions. These acids lower soil pH followed by P accessibility [56,57]. As a result, more P builds up in plant tissues, and P absorption increases. Potassium-dissolved bacteria play an important role in the establishment and maintenance of water and stable soil aggregates [58]. Moreover, potassium-dissolved bacteria can produce organic acid to solubilize potassium in rock, bringing K into the soil solution [58]. There are several plant growth substances secreted by biofertilizers that prolong the development and function of chloroplasts and hence boost chlorophyll assimilation within the plastids [21]. Additionally, the enzymes required to assimilate chlorophyll were recorded to be activated by the biofertilizer, whereas the chlorophyllase, which breaks down chlorophyll, was shown to be inhibited [59].

As for the interaction effects between either biofertilizer or chemical fertilizer with or without compost, there is little information on *Pelargonium* plants. It was found that the application of biofertilizers with compost causes an improvement in availability. Accordingly, Abou El-Ghait et al. [60] found that biofertilizers and organic fertilizers improved leaf photosynthetic pigment concentration compared to non-treated plants. Compost provides the necessary N for microbe growth and increases its effectiveness in the secretion of several enzymes such as phosphatase, which increases the mineralization of organic phosphate [61]. The beneficial impact of these treatments on chlorophyll biosynthesis may result from enhancing the absorption of N and iron (Fe), which are elaborated in chloroplast development and could be attributed to the increasing impact of bio and organic fertilizer on chlorophyll levels in dragonhead leaves [13].

5. Conclusions

In the cultivation of *Pelargonium peltatum*, it is recommended to use a mixture of biofertilizers (nitrogen-fixing bacteria, potassium-facilitating bacteria, and phosphorus-facilitating bacteria) with compost in order to obtain high qualities of vegetative and flowering growth in addition to prolonging the number of days required for flowering and reducing dependence on mineral fertilizers.

Author Contributions: Conceptualization, S.F.A., F.A.A. and K.M.E.; methodology, S.F.A., F.A.A. and K.M.E.; experiment design, S.F.A., F.A.A., M.A.A.-Y. and K.M.E.; data analysis, K.M.E. and A.M.A.-E.; writing—original draft, S.F.A. and K.M.E.; writing—review and editing, F.A.A. and A.M.A.-E. All authors have read and agreed to the published version of the manuscript.

Funding: This work was financially supported by The Researchers Supporting Project number (RSPD2023R676), King Saud University, Riyadh, Saudi Arabia.

Institutional Review Board Statement: Not applicable.

Acknowledgments: The authors extend their appreciation to The Researchers Supporting Project number (RSPD2023R676), King Saud University, Riyadh, Saudi Arabia.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. UN (United Nations). *World Urbanization Prospects: The 2018 Revision*; United Nations, Department of Economic and Social Affairs, Population Division: New York, NY, USA, 2018; pp. 1–126.
2. IPCC (Intergovernmental Panel on Climate Change). *Urban Areas Climate Change 2014—Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects: Working Group II Contribution to the IPCC Fifth Assessment Report*; Cambridge University Press: Cambridge, UK, 2014; pp. 535–612.
3. WHO (World Health Organization); UN-Habitat. *Global Report on urban Health: Equitable Healthier Cities for Sustainable Development*; World Health Organization: Geneva, Switzerland, 2016; pp. 1–239. Available online: https://apps.who.int/iris/handle/10665/204715 (accessed on 4 October 2022).
4. Kendal, D.; Williams, N.S.; Williams, K.J. A cultivated environment: Exploring the global distribution of plants in gardens, parks and streetscapes. *Urban Ecosyst.* **2012**, *15*, 637–652. [CrossRef]
5. Wilson, A.; Kendal, D.; Moore, J.L. Humans and ornamental plants: A mutualism? *Ecopsychology* **2016**, *8*, 257–263. [CrossRef]
6. Savé, R. What is stress and how to deal with it in ornamental plants? *Acta Hortic.* **2009**, *13*, 241–254. [CrossRef]
7. Keles, B.; Ertürk, Y. Advantages of microorganism containing biological fertilizers and evaluation of their use in ornamental plants. *Int. J. Agric. For. Life Sci.* **2021**, *5*, 189–197.
8. Mamba, B.; Wahome, P.K. Propagation of geranium (*Pelargonium hortorum*) using different rooting medium components. *Am.-Eurasian J. Agric. Environ. Sci.* **2010**, *7*, 497–500. [CrossRef]
9. Abedini Aboksari, H.; Hashemabadi, D.; Kaviani, B. Application of biofertilizer for *Pelargonium peltatum* growth in new organic substrates. *J. Plant Nutr.* **2018**, *41*, 137–149. [CrossRef]
10. Krishnaraj, S.; Dan, T.; Saxena, P. A fragrant solution to soil remediation. *Int. J. Phytoremediation* **2000**, *2*, 117–132. [CrossRef]
11. De Lucia, B.; Cristiano, G.; Vecchietti, L.; Rea, E.; Russo, G. Nursery growing media: Agronomic and environmental quality assessment of sewage sludge-based compost. *Appl. Environ. Soil Sci.* **2013**, *10*, 565139. [CrossRef]
12. Merida, D.; Pivetta, K.F.L.; Mazzini-Guedes, R.B.; de Castro, C.E.F.; Purquerio, L.F.V. Effects of nitrogen fertilization on development, flowering, and mineral nutrition of potted *Costus productus* Gleason ex Maas. *J. Plant Nutr.* **2017**, *40*, 1045–1052. [CrossRef]
13. Bhatla, S.C.; Lal, M.A. *Plant Physiology, Development, and Metabolic*; Springer Nature Singapore Pte Ltd.: Singapore, 2018. [CrossRef]
14. Hassan, A.A.; Abd El-Azeim, M.M. Impacts of compost, biofertilizer and/or some antioxidant treatments on gladiolus (*Gladiolus grandifloras*). B. Corms and cormels production and some chemical constituents. *Sci. J. Flowers Ornam. Plants* **2020**, *7*, 285–301. [CrossRef]
15. Esringü, A.; Turan, M.; Sushkova, S.; Minkina, T.; Rajput, V.D.; Glinushkin, A.; Kalinitchenko, V. Influence of vermicompost application on the growth of *Vinca rosea* valiant, *Pelargonium peltatum* L. and *Pegasus patio* rose. *Horticulturae* **2022**, *8*, 534. [CrossRef]
16. Zhang, R.H.; Quan, Z.Q.; Li, Z.G. Use of spent mushroom substrate as growing media for tomato and cucumber seedling. *Pedosphere* **2012**, *22*, 333–342. [CrossRef]
17. Abdou, M.A.H.; Taha, R.A.; Gahory, A.M.O.; Hassan, A.A.A. Effect of compost and some natural growth promoting on chamomile. *Sci. J. Flowers Ornam. Plants* **2021**, *8*, 447–459. [CrossRef]
18. Ngo, P.T.; Rumpel, C.; Ngo, Q.A.; Alexis, M.; Vargas, G.V.; Gil, M.; Dang, D.K.; Jouquet, P. Biological and chemical reactivity and phosphorus forms of buffalo manure compost, vermicompost and their mixture with biochar. *Bioresour. Technol.* **2013**, *148*, 401–407. [CrossRef] [PubMed]
19. El-Naggar, A.H.; El-Kiey, T.M.; Koreish, E.; Zaid, N.M. Physiological response of gazania plants to growing media and organic compost. *Sci. J. Flowers Ornam. Plants* **2020**, *7*, 11–26. [CrossRef]
20. Yasin, M.; Ahmad, K.; Mussarat, W.; Tanveer, A. Bio-fertilizers, substitution of synthetic fertilizers in cereals for leveraging agriculture. *Crop Environ.* **2012**, *3*, 62–66.
21. Ghatas, Y.A.A.; Mohamed, Y.F.Y. Influence of some phosphorus source and biofertilizers (EM and phosphorein) on vegetative growth, fixed oil productivity and chemical constituents of *Oenothera biennis* L. plant. *Sci. J. Flowers Ornam. Plants* **2020**, *7*, 247–268. [CrossRef]

22. Pandey, D.K.; Singh, K.K.; Pandey, A. Effect of bio-fertilizer on various growth parameters of *Gladiolus* cv. American Beauty. *Ind. J. Pure App. Biosci.* **2020**, *8*, 737–741. [CrossRef]
23. Motsara, M.R.; Roy, R.N. *Guide to Laboratory Establishment for Plant Nutrient Analysis*; FAO fertilizer and plant Nutrition Bulletin No., 19; FAO: Rome, Italy, 2008.
24. Lichtenthaler, H.K.; Wellburn, A.R. Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. *Biochem. Soc. Trans.* **1983**, *11*, 591–592. [CrossRef]
25. Latimer, G.W. *Official Methods of Analysis of AOAC*, 15th ed.; Association of Official Analytical Chemists: Washington, DC, USA, 2019.
26. Hargreaves, J.C.; Adl, M.S.; Warman, P.R.A. Review of the use of composted municipal solid waste in agriculture. *Agric. Ecosyst. Environ.* **2008**, *123*, 1–14. [CrossRef]
27. Van Der Heijden, M.G.; Bardgett, R.D.; Straalen, N.M. The unseen majority: Soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems. *Ecol. Lett.* **2008**, *11*, 296–310. [CrossRef] [PubMed]
28. Gaber, M.K. Vegetative and flowering growth of geranium as affected by mineral fertilization and ascorbic acid foliar application. *Middle East J. Appl. Sci.* **2019**, *9*, 220–230.
29. Nofal, E.M.S.; EL-Mahrouk, M.E.; EL-Sayed, B.A.; Radwan, A.M.M. Effect of NPK fertilizer and some natural extract treatments on the vegetative growth and flowering of African marigold (*Tagetes erecta* L. var. Dwarf Chrysanthemum). *Appl. Ecol. Environ. Res.* **2021**, *19*, 3167–3179. [CrossRef]
30. Inugraha, I.; Maghfoer, M.D.; Widaryanto, E. Response of stevia (*Stevia rebaudiana* Bertonim) to nitrogen and potassium fertilization. *IOSR J. Agric. Veter. Sci.* **2014**, *7*, 47–55. [CrossRef]
31. Abdou, M.A.H.; Ibrahim, T.I.E. Effect of mineral and biofertilization treatments on: 1- Vegetative growth and flowering of gladiolus plants. *Sci. J. Flowers Ornam. Plants* **2016**, *3*, 1–8. [CrossRef]
32. Singh, L.; Gurjar, P.K.S.; Barholia, A.K.; Haldar, A.; Shrivastava, A. Effect of organic manures and inorganic fertilizers on growth and flower yield of marigold (*Tagetes erecta* L.) var. Pusa Narangi Gainda. *Plant Arch.* **2015**, *15*, 779–783.
33. Acharya, M.M.; Dashora, L.K. Response of graded level of N and P on vegetative growth and flowering in African marigold. *J. Ornam. Hortic.* **2004**, *7*, 179–183.
34. Csirzinsky, A.A. Yield response of herbs to N and K rates in multiple harvests on sand. *Proc. Fla. State Hort. Soc.* **1997**, *110*, 385–388.
35. Nayak, D.; Mandal, T.; Roychowdhury, N. Effect of NPK nutrition on growth and flowering of *Gerbera jamesonii* L. c.v. Constance Orissa. *J. Hortic.* **2005**, *33*, 11–15.
36. Sarkar, B.; Mondal, S.S.; Nayak, S.S.; Saha, M.; Biswas, S. Integrated nutrient management for the productivity and quality improvement of potato under irrigated condition. *Potato J.* **2007**, *34*, 99–100.
37. Hamid, N.S.; Siddique, M.A.A.; Fahmeeda, S.; Shameen, I.; Ahmad, W.M. Influence of different organic manures and biofertilizers on morphological, floral and bulb traits of Narcissus (Daffodil cv. "Salome"). *Int. J. Agric. Sci.* **2017**, *9*, 3989–3992.
38. Bi, G.; Evans, B.W.; Spiers, J.M.; Witcher, A.L. Effects of organic and inorganic fertilizers on marigold growth and flowering. *Hortic. Sci.* **2010**, *45*, 1373–1377. [CrossRef]
39. Chand, S.; Pande, P.; Prasad, A.; Anwar, M.; Patra, D.D. Influence of integrated supply of vermicompost and zinc-enriched compost with two graded levels of iron and zinc on the productivity of geranium. *Commun. Soil Sci. Plant Anal.* **2007**, *38*, 2581–2599. [CrossRef]
40. Singh, R.P.; Varshney, G. Effects of carbofuran on availability of macronutrients and growth of tomato plants in natural soils and soils amended with inorganic fertilizers and vermicompost. *Commun. Soil Sci. Plant Anal.* **2013**, *44*, 2571–2586. [CrossRef]
41. Herencia, J.F.; Ruiz-Porras, J.C.; Melero, S.; Garcia-Galavis, P.A.; Morillo, E.; Maqueda, C. Comparison between organic and mineral fertilization for soil fertility levels. *Crop Macronutr. Conc. J. Agron.* **2006**, *99*, 973–983.
42. Taha, R.A.; Hassan, A.H. Response of gladiolus plants to mineral bio-fertilization and bio-fertilization treatments. 2- Corm production and chemical constituents. *Alex. J. Agric. Res.* **2008**, *53*, 87–95.
43. Bordoloi, S.; Talukdar, M.C. Effect of GA_3 and biofertilizer on growth and yield parameters of Anthurium (*Anthurium andreanum* Lindex Ex Andre) cv. Tropical in Soilless culture. *Int. J. Curr. Microbiol. App. Sci.* **2019**, *8*, 1157–1165. [CrossRef]
44. Attia, K.E.; Elbohy, N.F.S.; Ashour, N.A.M. Response of tuberose plants (*Polianthes tuberosa* L.) to chemical and bio-fertilization and their effect on vegetative growth, flowering and chemical composition under sandy soil conditions. *Sci. J. Flowers Ornam. Plants* **2018**, *5*, 261–273. [CrossRef]
45. Castagno, L.N.; Estrella, M.J.; Sannazzaro, A.I.; Grassano, A.E.; Ruiz, O.A. Phosphate solubilization mechanism and in vitro plant growth promotion activity mediated by *Pantoea eucalypti* isolated from *Lotus tenuis* rhizosphere in the Salado River Basin (Argentina). *J. Appl. Microbiol.* **2011**, *110*, 1151–1165. [CrossRef]
46. Senthil-Kumar, T.; Swaminathan, V.; Kumar, S. Influence of nitrogen, phosphorus and biofertilizers on growth, yield and essential oil constituents in ratoon crop of davana (*Artemisia pallens* Wall.). *Electron. J. Environ. Agric. Food Chem.* **2009**, *8*, 86–95.
47. Qasim, M.; Younis, A.; Zahir, Z.A.; Riaz, A.; Raza, H.; Tariq, U. Microbial inoculation increases the nutrient uptake efficiency for quality production of *Gladiolus grandiflorus*. *Pak. J. Agric. Sci.* **2014**, *51*, 875–880.
48. Khan, S.M.; Zaidi, P.; Wani, A. Role of phosphate-solubilizing microorganisms in sustainable agriculture-A review. *Agron. Sustain. Dev.* **2007**, *27*, 29–43. [CrossRef]

49. Salman, N.D.; Ali, N.S.; Majeed, N.H. Effect of *Azotobacter* inoculation on potassium availability of two different soil texture cultivated with maize. *Basrah J. Agric. Sci.* **2008**, *21*, 167–185.
50. Pansuriya, P.B.; Varu, D.K.; Viradia, R.R. Effect of biostimulants and biofertilizers on growth, flowering and quality of gladiolus (*Gladiolus grandiflorus* L.) cv. American beauty under greenhouse conditions. *Int. J. Chem Stud.* **2018**, *6*, 2191–2196.
51. Scher, F.M.; Baker, R. Effect of Pseudomonas putida and a synthetic iron chelator on induction of soil suppressiveness to *Fusarium* wilt pathogens. *Phytopathology* **1982**, *72*, 1567–1573. [CrossRef]
52. Flaishman, M.A.; Eyal, Z.A.; Zilberstein, A.; Voisard, C.; Hass, D. Suppression of *Septoria tritci* blotch and leaf rust of wheat by recombinant cyanide producing strains of *Pseudomonas putida*. *Mol. Plant Microbes Interact.* **1996**, *9*, 642–645. [CrossRef]
53. Megali, L.; Glauser, G.; Rasmann, S. Fertilization with beneficial microorganisms decreases tomato defenses against insect pests. *Agron. Sustain. Dev.* **2013**, *34*, 649–656. [CrossRef]
54. Brijendra, S.; Singh, B. Foliar application of fertilizer mixtures for *Chrysanthemum*. *South Indian Hort.* **1986**, *34*, 367–369.
55. El-Ghandour, I.A.; Desouky, E.M.; Galal, Y.G.M.; Arafa, R.A.; Abou Seer, A.M.M. Effect of biofertilizers and organic phosphorus amendments on growth and essential oil of marjoram (*Majorana hortensis* L.). *Egypt Acad. J. Biol. Sci.* **2009**, *1*, 29–36. [CrossRef]
56. Puente, M.E.; Bashan, Y.; Lebsky, V.K. Microbial population and activities in rhizoplane of rockweathering desert plants, I. Root colonization and weathering of igneous rocks. *Plant Biol.* **2004**, *6*, 629–642. [CrossRef]
57. Parassana, A.; Deepa, V.; Murthy, P.B.; Deecaraman, M.; Sridhar, R.; Dhandapani, P. Insoluble phosphate solubilization by bacterial strains isolated from rice rhizosphere soils from Southern India. *Int. J. Soil Sci.* **2011**, *6*, 134–141. [CrossRef]
58. Zakaria, A.A.B. Growth Optimization of Potassium Solubilizing Bacteria Isolated from Biofertilizer. Bachelor's Thesis, Universiti Malaysia Pahang, Pahang, Malaysia, 2009. Available online: https://core.ac.uk/download/159177375.pdf (accessed on 23 April 2023).
59. Dubey, R.K.; Mishra, R.L. Response of chemical and bio-fertilizers on corm and cormel production in gladiolus. *Progress. Hortic. Today* **2005**, *5*, 36–40.
60. Abou El-Ghait, E.M.; Gomaa, A.O.; Youssef, A.S.M.; Atiea, E.M.; AbdAllah, W.H. Effect of sowing dates, bio, organic and chemical fertilization treatments on growth and production of Indian fennel under north Sinai conditions. *Bull. Fac. Cairo Univ.* **2012**, *63*, 52–68.
61. Balakrishnan, V.; Venkatesan, K.; Ravindran, K.C. The influence of halophytic compost, farmyard manure, and phosphor-bacteria on soil microflora and enzyme activities. *Plant Soil Environ.* **2007**, *53*, 186–192. [CrossRef]