

Bio- and synthetic fertilizers for reducing root rot and wilt and improving growth and flowering characteristics of rose

Gomaa A. ABDEL-WAHED¹, Reem M. SAID², Hamada F.A. AHMED¹,
Doaa A. IMARA¹, Mohamed A.M. BAIUOMY¹,
Mahmoud F. SELEIMAN^{3*}, Naeem KHAN⁴

¹Agricultural Research Center (ARC), Plant Pathology Research Institute, Department of Ornamental, Medicinal and Aromatic Plant Diseases, Giza P.O. Box 12619, Egypt; gomaaarafat@arc.sci.eg (G.A.A-W); dr.hamada.faa@gmail.com (H.F.A.A.); drdoaimara@arc.sci.eg (D.A.I.); drbauionymohamed@gmail.com (M.A.M.B.)

²Agricultural Research Center, Horticulture Research Institute, Department of Botanical Gardens, (ARC), Giza P.O. Box 12619, Egypt; alprinceibrahim565@gmail.com (R.M.S.)

³King Saud University, College of Food and Agriculture Sciences, Department of Plant Production, P.O. Box 2460, Riyadh 11451, Saudi Arabia; mseleiman@ksu.edu.sa (M.F.S.); (*corresponding author)

⁴University of Florida, Institute of Food and Agricultural Sciences, Department of Agronomy, Gainesville, FL 32611, USA; naeemkhan@ufl.edu (N.K.)

Abstract

Root rot and wilt diseases are among the most pressing obstacles to the production of rose flowers in Egypt. Isolation results showed that these diseases are mainly caused by seven soil-borne fungi. However, *Fusarium roseum*, *Verticillium dahlia*, and *Rhizoctonia solani* were the most pathogenic fungi against *Rosa gallica* and *R. chinensis* compared to other isolated fungi. The present study aimed to investigate the potential of some bio- and synthetic fertilizers, including seaweed extract, Rhizobacterin, NPK, and potassium silicate, as well as the chemical fungicide vitavax 200, to control root rot and wilt and improve growth and flowering traits of both *R. gallica* and *R. chinensis*. Under *in vitro* conditions, the highest linear growth inhibition of pathogenic fungi was achieved by seaweed extract followed by potassium silicate, at 400 ppm each. In addition, vitavax 200 at 400 ppm completely inhibited the linear growth of these fungi. The results also showed that all treatments applied *in vivo* significantly reduced the incidence of diseases on rose plants in both seasons, leading to an improvement in all growth and flowering parameters and an increase in the content of photosynthetic pigments, total carbohydrates, nitrogen, phosphorus, and potassium. In this regard, seaweed extract (4 and 2 g/L) and potassium silicate (4 g/L) were the most efficient, while Rhizobacterin (2 g/L) and NPK (2 g/plant) were the least effective. However, vitavax 200 was the most effective of all the treatments used. In conclusion, the results proved the possibility of increasing the tolerance of *R. gallica* and *R. chinensis* against root rot and wilt, while improving growth and flowering characteristics by using some bio- and synthetic fertilizers.

Keywords: bio and synthetic fertilizers; seaweed extract; Rhizobacterin; potassium silicate; root rot and wilt; *Rosa gallica*; *R. chinensis*

Received: 14 Sep 2023. Received in revised form: 04 Nov 2023. Accepted: 11 Dec 2023. Published online: 13 Feb 2024.

From Volume 49, Issue 1, 2021, Notulae Botanicae Horti Agrobotanici Cluj-Napoca journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

Introduction

Rose (*Rosa* spp.) is a major commercial cut flower that is widely cultivated in different countries of the world (Gudin, 2000). Among all cut flowers, rose is the most popular because of its beauty, fragrance variety, and long blooming season. It is commonly known as the queen of flowers because of its majestic fragrance, wonderful colors, attractive shapes, and various sizes (Sumangala *et al.*, 2019). Botanically, the rose is a woody perennial plant that belongs to the Rosaceae family with over 100 species and thousands of cultivated varieties (Horn, 1992; Kim *et al.*, 2004). Rose is the most important ornamental crop worldwide, being the highest produced worldwide among the 10 commercial cut flowers (Synge, 1971). Its importance is due to its many uses in ornamental (floral decoration), as cut flowers, and in the medicinal and cosmetic industries (Amita *et al.*, 2021). *Rosa gallica* L. or Gallic rose, French rose, or Provins rose, is the most widely used *Rosa* spp. for cosmetic, medicinal, and culinary purposes (Pires *et al.*, 2018). It is one of the first rose to be cultivated in central Europe, and is the parent of several important cultivars. *Rosa gallica* L. is a low shrub with broad runners and above-ground reed-like shoots, which are erect and branched, reaching 0.5 to 1 m in height (Gahukar, 2003). *Rosa chinensis* Jacq. or China rose, Chinese rose, or Bengal rose, is a perennial shrub up to 2 m high, native to southwestern China, widely used outdoors and indoors to improve the aesthetic value of landscapes and has important economic and nutritional values worldwide (Yan *et al.*, 2016).

Rose plants are susceptible to many fungal diseases during their vegetative and flowering stages of growth, including powdery mildew, black spot, rust, stem canker, downy mildew, and gray mold (Whitaker *et al.*, 2007; Williamson *et al.*, 2007; Gastelum *et al.*, 2014; Farr and Rossman, 2016; Sinha, 2017; Romero *et al.*, 2018). However, root rot and wilt are the most damaging diseases of rose worldwide (Hammett, 1971; Kageyama *et al.*, 2002; Li *et al.*, 2007; Armanious, 2016). Such diseases are a major limitation to crop production worldwide, causing poor crop performance, lower yield, and higher production costs (Panth *et al.*, 2020; Ahmed *et al.*, 2021). Soil-borne pathogenic fungi, including *Fusarium* spp., *Rhizoctonia* spp., *Verticillium* spp., *Sclerotinia* spp., *Phytophthora* spp., and *Pythium* spp. can cause a yield loss of 50 to 75% for many crops such as cotton, maize, wheat, vegetables, fruits, and ornamentals (Mihajlovic *et al.*, 2017; Baysal-Gurel and Kabir, 2018). Rose diseases are generally managed with heavy applications of fungicides. But in recent years, the use of fungicides has been associated with very serious problems such as the development of fungicide resistance in pathogenic fungi, the evolution of new strains of the pathogen, environmental risks and the deterioration of soil health (Apte and Kamble, 2008; Christopher *et al.*, 2010).

Seaweeds are among the most abundant sources of several bioactive compounds and have been widely used in agriculture as plant biostimulants and as inducers of plant defense against many pathogens (Shukla *et al.*, 2019; Leandro *et al.*, 2020). Seaweeds (or macroalgae) are multicellular marine algae that are an essential part of marine coastal ecosystems. Extracts derived from seaweeds contain a large number of bioactive compounds, including pigments, polysaccharides, phenolic compounds, proteins, peptides, phytohormones, and micro- and macronutrients (Khan *et al.*, 2009; El Boukhari *et al.*, 2020). This complex chemical composition could explain the multiple biological functions of these extracts. The potential of several seaweeds to reduce the progression of plant diseases and promote plant growth have been extensively reported. In this regard, De Borba *et al.*, 2019 found that foliar application of seaweed extract on bean plants significantly reduced the colonization of epicotyl xylem vessels by *F. oxysporum*. Similarly, Rekanovic *et al.*, 2010 reveal that seaweed extract was effective in controlling *Verticillium* wilt of pepper. Also, Esserti *et al.*, 2017 reported that foliar spraying with a brown seaweed extract was more effective against *V. dahliae* in tomato plants. In a similar vein, Ara *et al.*, 1996 concluded that soil amendment with dry powder of seaweeds (*Sargassum tenerrimum*, *S. wightii*, and *S. swartzii*) significantly reduced the progression of *M. phaseolina* and *F. solani*, the causative agents of sunflower root rot.

The foliar application of organic and inorganic materials on plants is an effective approach and has become an alternative technique in agriculture used to stimulate growth and mitigate the adverse impact of abiotic and biotic stresses (Gomaa *et al.*, 2021; Taha *et al.*, 2021; Ahmad *et al.*, 2023; Alhammad *et al.*, 2023; Ali *et al.*, 2023; Qureshi *et al.*, 2023; Seleiman *et al.*, 2023). Potassium silicate (K_2SiO_3) is used as a plant stimulant and a good source of potassium (K) and highly soluble silicon (Si) (Rodrigues *et al.*, 2009). Several reports have indicated the efficiency of potassium silicate in controlling fungal diseases. Among these reports, Ahmed *et al.*, 2023 who found that the application of potassium silicate at a rate of 4 g/L was the most effective in decreasing the incidence of roselle root rot and wilt caused by *M. phaseolina*, *F. solani*, and *F. oxysporum*. Similarly, Whan *et al.* (2016) found that spraying cotton with potassium silicate was effective against wilt disease caused by *F. oxysporum* f. sp. *vasinfectum*. Also, Chérif *et al.* (1994) reported that cucumber treated with potassium silicate significantly decreased the incidence of root rot caused by *Pythium* spp. The antifungal activity of potassium silicate probably results from the combined effect of both potassium and silicon. Silicon increases the activity of defense-related enzymes and antimicrobial compounds, such as phytoalexins, pathogenicity-related proteins, and phenols. Si also regulates resistance in host plants through signaling hormones, such as jasmonic acid, salicylic acid, and ethylene (Wang *et al.*, 2017). As for potassium, it improves the health and vitality of the plant, which reduces the possibility of infection and also helps in quick recovery (Perrenoud, 1993).

Balanced mineral nutrition using macronutrients, including nitrogen (N), phosphorus (P), and potassium (K) is significant in imparting disease resistance and healthy growth for plant (Datnoff *et al.*, 2007; Gupta *et al.*, 2017). These mineral elements can affect plant health either directly by activating enzymes involved in the synthesis of defense metabolites (phenols, phytoalexins, glucosinolates, callose, and lignin,) or indirectly by altering microbial populations and activity, composition of root exudates, and modulating pH in the rhizosphere (Datnoff *et al.*, 2007). Several studies have shown that various NPK-based fertilizers have a significant positive effect on growth, flowering, active components, and quality in different varieties of rose. These hypotheses have been documented on both *Rosa* sp. (Sumangala *et al.*, 2019), *R. hybrida* cv. 'Gladiator' (Patel *et al.*, 2017), *R. damascena* (Ali *et al.*, 2021), rose var. local (Kularathne *et al.*, 2021), and *Floribunda rose* cv. Charishma (Parinitha *et al.*, 2022). Biofertilizers are an environmentally sustainable and inexpensive alternative to synthetic fertilizers (Zheng *et al.*, 2011; Kawalekar, 2013). Biofertilizers are products containing live microorganisms or their natural compounds that regulate soil bio-properties, improve plant growth, restore soil fertility, and reduce plant diseases (Abdel-Raouf *et al.*, 2012; Mahanty *et al.*, 2017). Extensive reports have showed the potential of biofertilizers to provide nutrients to grown plants and thus enhance crop yield (Sevilla-Perea and Mingorance, 2015; Mukhtar *et al.*, 2017). Most commercial products of rhizobacteria act as bio-inoculants for plant disease resistance (Hermosa *et al.*, 2012). For example, Ahmed *et al.* (2023) found that the mixture of Mycorrhizae and Microbein was the most effective in reducing root rot and wilt diseases of roselle, followed by Mycorrhizae, each at 10 g/kg seeds.

The aims of this study were to: (1) Evaluate the inhibitory activity of seaweed extract, potassium silicate, and vitavax 200 against linear growth of rose root rot and wilt fungi, (2) Impact of bio- and synthetic fertilizers as foliar spraying and soil addition, on reducing root rot and wilt of *R. gallica* and *R. chinensis*, and (3) Efficiency of these controlling agents in improving the growth and flower yield characteristics of the two rose species.

Materials and Methods

Plant material, treatments, and experimental layout

The current study was conducted in the greenhouse and open field in the nursery of the Horticulture Research Institute, ARC, Egypt, and Plant Pathology Laboratory, Sids Agricultural Research Station, Beni-

Suef, Egypt during the 2021 and 2022 growing seasons. Experiments were performed to evaluate the potential of some bio- and synthetic fertilizers to increase the tolerance of two species of rose, including *Rosa gallica* L. and *R. chinensis* Jacq. to infection with root rot and wilt fungi, in addition to their effect on growth, flowering, and chemical composition of plants. The treatments included two biofertilizers (i.e., Rhizobacterin (*Azotobacter chroococcum*; 10^{10} cfu/g) and seaweed extract (macroalgae; *Cystoseira myrica*, *Padina boergesenii*, and *S. cinereum*)), two chemical fertilizers (i.e., NPK (Kristallon; 20:20:20 + microelements) and potassium silicate), and the chemical fungicide vitavax 200 75% WP (37.5% carboxin (5,6-dihydro-2 methyl-1,4-oxathin-3-carboxanilide) + 37.5% Thiram (tetramethyl thiuram disulfide)). Rose cuttings of *R. gallica* and *R. chinensis* were provided by the Horticulture Research Institute, ARC. Cuttings were planted on February, 1st of each season in plastic pots with a diameter of 25 cm filled with an equal mixture of sand, clay, and peat moss sterilized with 5% formalin solution. The soil was covered with plastic sheet for 15 days and then aerated for another 15 days with stirring to eliminate bacteria or fungi in the soil. Physicochemical properties of the sand, clay and peat moss used in this study were analysed according to Olsen and Sommers (1982), as shown in (Tables 1 and 2). One month after planting (on March, 1st), the plants received the following treatments:

- T1: Adding NPK to the soil at a rate of 2 g/plant.
 T2: Adding NPK to the soil at a rate of 4 g/plant.
 T3: Adding Rhizobacterin solution to the soil at a rate of 2 g/L.
 T4: Adding Rhizobacterin solution to the soil at a rate of 4 g/L.
 T5: Foliar spraying with seaweed extract at a rate of 2 g/L.
 T6: Foliar spraying with seaweed extract at a rate of 4 g/L.
 T7: Foliar spraying with potassium silicate solution at a rate of 2 g/L.
 T8: Foliar spraying with potassium silicate solution at a rate of 4 g/L.
 T9: Adding vitavax 200 solution to the soil at a rate of 3 g/L.
 T10: No fertilization, indicating control.

The previous treatments were applied monthly until the end of the experiment in October of each growing season. Experiments were arranged in a randomized complete block design (RCBD) with three replicates, each containing five plants (one cutting/pot). Irrigation and other agricultural practices were performed as recommended by the Ministry of Agriculture and Land Reclamation, Egypt.

Table 1. Physicochemical properties of sand and clay used in pot experiments during the 2021 and 2022 growing seasons

Soil Type	Particle Size Distribution %				S.P.	E.C. (dS/m)	pH	Cations (meq/L)				Anions (meq/L)		
	Coarse sand	Fine sand	Silt	Clay				Ca++	Mg++	Na+	K+	HCO ₃ ⁻	Cl-	SO ₄ ⁻⁻
Sand	84.21	6.28	1.51	7.47	21.89	3.76	7.80	15.64	8.13	7.22	1.72	3.18	16.90	12.63
Clay	7.80	22.56	29.30	35.70	52.28	2.32	8.00	13.33	2.61	15.97	1.69	6.50	17.70	9.40

Physicochemical analysis of sand and clay was carried out in the Laboratory of Soil and Water Analysis, Faculty of Agriculture, Fayoum University, Egypt.

Table 2. Physicochemical properties of peat moss used in pot experiments during the 2021 and 2022 growing seasons

Component	Value	Component	Value
Organic matter (%)	90-95	N (%)	1.09
Ash (%)	5-10	P (%)	0.23
Density (vol. dry)	80-90	K (%)	1.77
pH value	3.4	Fe (ppm)	421
Water relation capacity (%)	60-75	Mn (ppm)	72
Salinity (g/L)	0.30	Zn (ppm)	41

Physicochemical analysis of peat moss was carried out in the Laboratory of Soil and Water Analysis, Faculty of Agriculture, Fayoum University, Egypt

Sampling, isolation, and identification of rose root rot and wilt fungi

Rosa gallica and *R. chinensis* naturally infected with root rot and wilt were collected from many nurseries in Beni-Suef and Giza governorates, Egypt, during the season of 2021. Plant samples were taken separately to the laboratory for diagnosis and isolate pathogenic fungi as per the method mentioned by Sahi and Khalid, 2007. Samples were washed, rinsed in sterile distilled water, disinfected in 5% Clorox solution, and then cut into small fragments. Small parts were transferred to 9 cm Petri dishes containing sterile PDA media supplemented with chloramphenicol (0.19 g/L), and then dishes were incubated for 7 days at 25 ± 2 °C. The resulting fungi were purified by the technique of hyphal tip or single spore isolation as reported by Booth, 1977. The identification was made according to Reid *et al.* (1965), Barnett and Hunter (1986), and Leslie and Summerell (2006) and then confirmed by the Department of Plant Pathology, Faculty of Agriculture, Beni-Suef University, Egypt. Pure isolates were sub-cultured on fresh PDA, kept on PDA slants, and refrigerated at 5 °C as stock cultures for further studies. Fungal frequency was assessed according to the following formula;

$$\text{Frequency \%} = [(\text{No. of each isolated fungus colonies} / \text{Total no. of all isolates}) \times 100]$$

Pathogenicity, pathogenic inoculum preparation, and soil infestation

A pathogenicity test was carried out under greenhouse conditions to find out the potential of isolated fungi in causing root rot or wilt diseases in two rose species. Fungal inocula of *Fusarium moniliform*, *F. roseum*, *F. semitectum*, *F. solani*, *Macrophomina phaseolina*, *Rhizoctonia solani*, and *Verticillium dahliae* were prepared separately on sterile maize-meal-sand medium in 500 mL flasks. Flasks were inoculated separately with 5 discs (10 mm in diameter), taken from a 3-day-old culture and then incubated for 15 days at 25 ± 2 °C. An equal mixture of sand, clay, and peat moss was sterilized with a 5% formalin solution for 15 min, then covered with polyethylene for a week to retain gas and then left for 2 weeks to get rid of residual traces of formaldehyde (Whitehead, 1957). The prepared inocula were added individually to the soil at a rate of 3% and mixed well 7 days before planting. Infested soil was packed in formalin-sterilized pots (25 cm in diameter) and watered regularly three times 7 days before planting. Rose cuttings were disinfected in 2% sodium hypochlorite solution, washed with sterile water, dried between two sterile layers, and planted at the rate of one cutting per pot. Five pots were used as replicates. Pots containing un-infested soil were used as control. The diseases incidence was measured three times every 15 days, starting from 60 days after planting and surviving plants were calculated. Re-isolation from artificially diseased cuttings was done. Developing colonies were sub-cultured on fresh PDA and identification confirmed with the original isolates to fulfil Koch's postulations.

*Disease management**In vitro* experiments

The inhibitory effect of seaweed extract, potassium silicate, and vitavax 200 on the linear growth of *F. roseum*, *R. solani*, and *V. dahlia*, was tested using the food poisoning technique described by Adjou *et al.* (2012). Different weights of 5, 10, 20, 40 mg of each tested material were added separately to PDA medium (100 mL) before solidification (at 45 °C) in flasks, then shaken well to obtain 50, 100, 200, and 400 ppm, respectively. Streptomycin (0.2%) was added to the medium to prevent bacterial contamination. The medium poured into sterile Petri dishes (9 cm in diameter) at a rate of 25 mL/plate and left to solidify. The plates were inoculated individually in the center with equal discs (5 mm in diameter) taken from each fungal culture (7 days old). Plates inoculated with fungi without treatment were kept as a control. Each treatment included 5 replicate plates. All plates were incubated at 27 °C until the tested fungi reached full growth in the control. Linear growth was measured by averaging the two dimensions of the fungal colony. The inhibition in linear growth was assessed using the formula proposed by Pinto *et al.* (2009);

$$\text{Inhibition in linear growth \%} = [(dc - dt/dc) \times 100]$$

where, dc = linear growth (LG) in the control and dt = LG in the treatment.

In vivo experiments

Two successive trials were conducted during the 2021 and 2022 growing seasons to evaluate the potential of some bio- and synthetic fertilizers to reduce root rot and wilt of rose, consequently improving growth traits. The soil infested with the pathogenic inoculum was packed in formalin-sterilized pots as mentioned in the pathogenicity test. Cuttings were disinfected in 2% sodium hypochlorite solution and planted on February, 1st at a rate of one cutting/pot. The pots were transferred under open field conditions in the nursery of the Horticultural Research Institute, ARC, Egypt. The treatments were applied as mentioned before. Untreated plants were kept as control. Experiments were implemented in 3 replicates, each containing 5 plants (one cutting/pot). The percentage of disease incidence of rose root rot and wilt was recorded after every application.

Recording of measurements data

Disease assessment

The percentage of disease incidence of root rot and wilt of rose was assessed using the equation given by Gamliel *et al.* (1996);

$$\text{Disease incidence (DI) \%} = [(\text{No. of diseased plants} / \text{Total no. of plants}) \times 100]$$

Morphological characteristics

At the end of each season (on October, 30th), several morphological characteristics of the rose were recorded as follows: plant height (cm), stem diameter (cm), number of branches and leaves per plant, root length (cm), as well as fresh and dry weight of aerial parts and roots (g).

Flowering parameters

At the end of each month from April to October, rose flower parameters were recorded as follows: number of flowers per plant, flower fresh and dry weight (g), flower diameter (cm), flower stalk length (cm), and flower stalk fresh and dry weight (g). Results were expressed as the average of data measured from April to October.

Chemical analysis

In fresh rose leaf samples, photosynthetic pigments (mg/g FW) such as chlorophyll (a and b) and carotenoids were assessed as in the method presented by Sumanta *et al.* (2014). In addition, in dry leaves, total carbohydrates, nitrogen, phosphorus, and potassium were estimated using the methods described by Herbert *et al.* (1971), Blake (1956), John (1970), and Jackson (1973), respectively.

Statistical analysis

The obtained data analysed statistically by ANOVA, using WASP software (Web Agriculture Stat Package). The values presented are the means of all measurements taken. Combined analysis of data from the two growing seasons and Duncan's range test was used in comparison significant differences between the tested treatments at $p \leq 0.05$ according to Mead *et al.* (1993).

Results

Isolation and identification of rose root rot and wilt fungi

Data provided in Table 3 show that 7 soil-borne fungi belonging to 4 genera were isolated from rotted and wilted rose samples as follows: *Fusarium moniliform* (Sheld.) Snyd. & Hans., *F. roseum* Snyd. & Hans., *F. semitectum* Berk. & Rav., *F. solani* (Mart.) Sacc., *Macrophomina phaseolina* (Tassi) Goid., *Rhizoctonia solani*

Kühn, and *Verticillium dahliae* Kleb. The fungi isolated differed in frequency as follows: *R. solani* and *F. moniliforme* had the highest frequency (22.3 and 19.7%, respectively), followed by *V. dahliae* (14.5%), *F. semitectum* (14.5%), and *M. phaseolina* (13.3%). While *F. solani* (6.5%) and *F. roseum* (9.3%) least frequent. Inoculation of *R. gallica* and *R. chinensis* with the previous fungi showed the same symptoms of root rot or wilt as observed the first time. Re-isolation resulted in fungi that were morphologically identical to the original fungi.

Table 3. Frequency of seven fungi isolated from rotted root and wilted rose samples, collected from Beni-Suef and Giza governorates, Egypt during the 2021 summer season

Isolated fungi	Frequency %		
	Beni-Suef Governorate	Giza Governorate	Mean
<i>Fusarium moniliforme</i>	20.0	19.4	19.7
<i>Fusarium roseum</i>	7.5	11.1	9.3
<i>Fusarium semitectum</i>	15.0	13.9	14.5
<i>Fusarium solani</i>	7.5	5.6	6.5
<i>Macrophomina phaseolina</i>	10.0	16.7	13.3
<i>Rhizoctonia solani</i>	22.5	22.2	22.3
<i>Verticillium dahliae</i>	17.5	11.1	14.5
Total	100	100	100

Pathogenicity test of isolated fungi against R. gallica and R. chinensis

Data presented in Table 4 show that all tested fungi were pathogenic to the two tested rose species, especially to *R. gallica* L., as they significantly increased the disease incidence of root rot or wilt to varying degrees in contrast to the control. In both species, the highest disease incidence of root rot or wilt was recorded by *F. roseum*, followed by *V. dahliae* and *R. solani*. The corresponding values to the mean of disease incidence were 39.5, 34, and 29.4%, respectively. While *F. semitectum* (9.3%) followed by *F. moniliforme* (14%) recorded the lowest values. In general, *F. roseum*, *V. dahliae*, and *R. solani* were the most damaging fungi to the two rose species, recording 60.5, 66, and 70.6% of the surviving plants, respectively. Therefore, they were selected in the following studies.

Table 4. Pathogenicity test of seven isolated fungi against *R. gallica* and *R. chinensis* under greenhouse conditions

Fungi	Average of disease incidence %			Symptoms	Surviving plants %
	Rose species		Mean of infection %		
	<i>R. gallica</i>	<i>R. chinensis</i>			
<i>Fusarium moniliforme</i>	15.0 ^f	13.0 ^f	14.0	Root rot	86.0
<i>Fusarium roseum</i>	40.0 ^a	39.0 ^a	39.5	Root rot	60.5
<i>Fusarium semitectum</i>	10.0 ^g	8.7 ^g	9.3	Root rot	90.7
<i>Fusarium solani</i>	25.0 ^d	24.0 ^d	24.5	Root rot	75.5
<i>Macrophomina phaseolina</i>	20.0 ^c	18.8 ^c	19.4	Root rot	80.6
<i>Rhizoctonia solani</i>	30.0 ^c	28.9 ^c	29.4	Root rot	70.6
<i>Verticillium dahliae</i>	35.0 ^b	33.0 ^b	34.0	Wilt	66.0
Control (un-infested soil)	0.0 ^h	0.0 ^h	0.0	No symptoms	100

Inhibitory activity of seaweed extract, potassium silicate, and vitavax 200 against linear growth of pathogenic fungi

Data presented in Table 5 reveal that all treatments significantly inhibited the linear growth of tested fungi at all used concentrations. However, the highest inhibition was achieved by seaweed extract followed by potassium silicate, each at 400 ppm. The corresponding inhibition values were 96.6 and 94.4% for *V. dahlia*, 94.4 and 93.3% for *F. roseum*, 90 and 90% for *R. solani*, respectively. While potassium silicate at 50 ppm recorded the lowest inhibition by 12.2, 16.6, and 26.6% for *R. solani*, *F. roseum*, and *V. dahlia*, respectively. Treatment with vitavax 200 at 400 ppm completely inhibited the growth of pathogenic fungi, making it significantly more effective.

Table 5. *In vitro*, efficiency of seaweed extract, potassium silicate, and vitavax 200 in inhibiting the linear growth of pathogenic fungi

Treatments	Conc. (ppm)	<i>F. roseum</i>		<i>R. solani</i>		<i>V. dahliae</i>	
		Linear Growth (cm)	* Inhibition %	Linear Growth (cm)	* Inhibition %	Linear Growth (cm)	* Inhibition %
Potassium silicate	0.0	9.0 ^a	0.0	9.0 ^a	0.0	9.0 ^a	0.0
	50	7.5 ^b	16.6	7.9 ^b	12.2	6.6 ^b	26.6
	100	4.5 ^d	50.0	4.0 ^d	55.5	3.5 ^c	61.1
	200	2.8 ^g	68.8	2.8 ^c	68.8	2.7 ^f	70.0
	400	0.6 ⁱ	93.3	0.9 ^f	90.0	0.5 ^h	94.4
	Mean	4.8	46.6	4.9	45.5	4.5	50.0
Seaweed extract	0.0	9.0 ^a	0.0	9.0 ^a	0.0	9.0 ^a	0.0
	50	5.6 ^c	37.7	5.8 ^c	35.5	6.0 ^c	33.3
	100	3.9 ^e	56.6	4.0 ^d	55.5	4.5 ^d	50.0
	200	1.9 ^h	78.8	2.6 ^e	71.1	2.6 ^f	71.1
	400	0.5 ⁱ	94.4	0.9 ^f	90.0	0.3 ^h	96.6
	Mean	3.8	57.7	4.5	50.0	4.5	50.0
Vitavax 200	0.0	9.0 ^a	0.0	9.0 ^a	0.0	9.0 ^a	0.0
	50	3.5 ^f	61.1	4.2 ^d	53.3	4.6 ^d	48.8
	100	1.7 ^h	81.1	2.1 ^f	76.6	2.5 ^f	72.2
	200	0.8 ⁱ	91.1	0.9 ^f	90.0	1.0 ^g	88.8
	400	0.0 ^j	100	0.0 ^g	100	0.0 ⁱ	100
	Mean	3.0	66.6	3.2	64.4	3.4	62.2

* Inhibition values were assessed based on the control value. In the same column, values followed by the same letters do not differ significantly at the $p \leq 0.05$ statistical level, as per Duncan's multiple range test.

Management of root rot and wilt of R. gallica under in vivo conditions

Data in Table 6 show that all treatments significantly decreased the incidence of root rot and wilt of *R. gallica* compared to the control plants in both growing seasons. In the first season, the lowest disease incidence was recorded by seaweed extract (4 g/L), followed by seaweed extract (2 g/L), potassium silicate (4 g/L), and potassium silicate (2 g/L). The corresponding averages for disease incidence were 6.4, 7.6, 9.1, and 10.4%, respectively. While the highest averages of disease incidence (17, 15.6, and 14.7%) were recorded by Rhizobacterin (2 g/L), Rhizobacterin (4 g/L), and NPK (2 g/plant), respectively. In the second season, the lowest averages of disease incidence were achieved by seaweed extract (4 g/L), seaweed extract (2 g/L), potassium silicate (4 g/L), and potassium silicate (2 g/L). They recorded 7.6, 8.7, 10.7, and 11.9%, respectively. Conversely, the highest averages of disease incidence (18.6, 17.8, and 16.4%) were recorded by Rhizobacterin (2 g/L), Rhizobacterin (4 g/L), and NPK (2 g/plant), respectively. The treatment with the fungicide vitavax 200 (3 g/L) showed a significant superiority in reducing diseases compared to other treatments, as it recorded the lowest disease incidence 4.6 and 4.9% in both seasons, respectively.

Table 6. Efficacy of bio and synthetic fertilizers against root rot and wilt of *R. gallica* L. during the growing seasons 2021 and 2022 under *in vivo* conditions

Treatments	Conc. (g/L)	Average of disease incidence %							
		Season 2021				Season 2022			
		<i>F. roseum</i>	<i>R. solani</i>	<i>V. dahliae</i>	Mean	<i>F. roseum</i>	<i>R. solani</i>	<i>V. dahliae</i>	Mean
NPK	*2	13.8 ^d	14.2 ^c	16.3 ^d	14.7	18.6 ^d	12.9 ^f	17.8 ^d	16.4
	*4	13.5 ^d	14.6 ^d	15.5 ^c	14.5	12.9 ^c	14.0 ^d	12.9 ^c	13.2
Rhizobacterin	2	15.5 ^b	16.8 ^b	18.7 ^b	17.0	20.3 ^b	16.3 ^b	19.3 ^b	18.6
	4	14.2 ^c	15.5 ^c	17.3 ^c	15.6	19.5 ^c	15.6 ^c	18.5 ^c	17.8
Seaweed extract	2	6.5 ^g	7.8 ^h	8.5 ^g	7.6	8.0 ^g	9.4 ^h	8.9 ^g	8.7
	4	5.2 ^h	6.4 ⁱ	7.7 ⁱ	6.4	6.9 ^h	7.9 ⁱ	8.1 ^h	7.6
Potassium silicate	2	10.5 ^c	11.6 ^f	9.2 ^f	10.4	12.6 ^c	13.5 ^c	9.6 ^f	11.9
	4	8.9 ^f	10.3 ^g	8.1 ^h	9.1	11.5 ^f	12.3 ^g	8.3 ^h	10.7
Vitavax 200	3	3.4 ⁱ	4.9 ^j	5.5 ^j	4.6	4.5 ⁱ	5.3 ^j	5.0 ⁱ	4.9
Control	-	35.8 ^a	37.4 ^a	39.2 ^a	37.4	32.9 ^a	38.5 ^a	39.2 ^a	36.8

* = g per plant. In the same column, values followed by the same letters do not differ significantly at the $p \leq 0.05$ statistical level, as per Duncan's multiple range test.

Management of root rot and wilt of *R. chinensis* under *in vivo* conditions

Data in Table 7 provide that all treatments significantly decreased the incidence of root rot and wilt of *Rosa chinensis* compared to the control plants in both seasons. In the first season, the lowest disease incidence was recorded by seaweed extract (4 g/L), followed by seaweed extract (2 g/L), potassium silicate (4 g/L), and potassium silicate (2 g/L). The corresponding averages for disease incidence were 5.4, 6.4, 8, and 9.5%, respectively. While the highest averages of disease incidence (15.9, 14.8, and 13.9%) were recorded by Rhizobacterin (2 g/L), Rhizobacterin (4 g/L), and NPK (2 g/plant), respectively. In the second season, the lowest averages of disease incidence were recorded by seaweed extract (4 g/L), seaweed extract (2 g/L), and potassium silicate (4 g/L), recording 6.3, 7.6, and 9.7%, respectively. While the highest averages of disease incidence (17.2, and 16%) were recorded by Rhizobacterin at 2 and 4 g/L, respectively. Vitavax 200 outperformed all treatments, recording the lowest disease incidence (3.6 and 4.8%) in both seasons, respectively.

Table 7. Efficacy of bio and synthetic fertilizers against root rot and wilt of *R. chinensis* Jacq. during the growing seasons 2021 and 2022 under *in vivo* conditions

Treatments	Conc. (g/L)	Average of Disease Incidence %							
		Season 2021				Season 2022			
		<i>F. roseum</i>	<i>R. solani</i>	<i>V. dahliae</i>	Mean	<i>F. roseum</i>	<i>R. solani</i>	<i>V. dahliae</i>	Mean
NPK	*2	12.8 ^d	13.6 ^d	15.5 ^d	13.9	17.5 ^d	11.5 ^f	16.5 ^d	15.1
	*4	12.5 ^d	13.5 ^d	14.5 ^c	13.5	11.0 ^f	15.5 ^b	11.5 ^c	12.6
Rhizobacterin	2	14.5 ^b	15.5 ^b	17.7 ^b	15.9	19.6 ^b	13.6 ^c	18.5 ^b	17.2
	4	13.3 ^c	14.6 ^c	16.5 ^c	14.8	18.4 ^c	12.2 ^c	17.4 ^c	16.0
Seaweed extract	2	5.4 ^g	6.3 ^g	7.6 ^g	6.4	7.0 ^h	8.3 ^g	7.5 ^g	7.6
	4	4.5 ^h	5.2 ^h	6.5 ⁱ	5.4	5.6 ⁱ	6.7 ^h	6.6 ^h	6.3
Potassium silicate	2	9.6 ^c	10.5 ^c	8.6 ^f	9.5	11.9 ^c	12.7 ^d	8.5 ^f	11.0
	4	7.5 ^f	9.7 ^f	6.9 ^h	8.0	10.6 ^g	11.3 ^f	7.2 ^g	9.7
Vitavax 200	3	2.9 ⁱ	3.5 ⁱ	4.6 ^j	3.6	3.8 ^j	4.9 ⁱ	5.7 ⁱ	4.8
Control	-	34.7 ^a	35.9 ^a	38.6 ^a	36.4	33.4 ^a	37.6 ^a	38.4 ^a	36.5

* = g per plant. In the same column, values followed by the same letters do not differ significantly at the $p \leq 0.05$ statistical level, as per Duncan's multiple range test.

*Growth and flower yield features*Growth of *R. gallica* L.

As shown in Figure 1, all fertilization treatments significantly improved the growth of rose compared to control. In this respect, plants treated with vitavax 200 and seaweed extract (4 g/L) recorded the best results for plant height with significant differences, followed by potassium silicate (2 g/L), NPK (4 g/plant), and NPK (2 g/plant). They recorded 80.7, 71.5, 57.8, 56.2, and 55.3 cm, respectively. While the lowest value was recorded 40 cm by Rhizobacterin (2 g/L) (Figure 1A). Also, the highest values of stem diameter were recorded by vitavax 200, seaweed extract (4 g/L), potassium silicate (2 g/L), NPK (4 g/plant), and NPK (2 g/plant), recording 1.5, 1.3, 1.2, 1.1, and 1.0 cm, respectively. While the lowest value was recorded 0.7 cm by Rhizobacterin (2 g/L) (Figure 1B). The highest number of branches/plants was recorded by vitavax 200, seaweed extract (4 g/L), NPK (4 g/plant), and potassium silicate (2 g/L), recording 17.6, 16.3, 15.8, and 15.1, respectively. While the lowest value was recorded 8.9 by Rhizobacterin (2 g/L) (Figure 1C). Similarly, treatment with vitavax 200, seaweed extract (4 g/L), NPK (4 g/plant), and potassium silicate (2 g/L) recorded the highest number of leaves/plants as follows: 40.3, 35.5, 32.5, and 30.5, respectively. While the lowest value was recorded 19.5 by Rhizobacterin (2 g/L) (Figure 1C). Results also show that the highest root length was recorded in plants treated with vitavax 200, followed by seaweed extract (4 g/L), seaweed extract (2 g/L), potassium silicate (4 g/L), and potassium silicate (2 g/L), recording 35.8, 33.1, 32.3, 28.5, and 27.2 cm, respectively. However, the lowest value of 22.5 cm was recorded by Rhizobacterin (2 g/L) (Figure 1D). Concerning the fresh and dry weight of aerial parts/plant, the best results were obtained by vitavax 200, seaweed extract (4 g/L), potassium silicate (2 g/L), and NPK (4 g/plant). They recorded 41.6, 36.5, 33.1 and 31.9 g, respectively, in the fresh weight, and 19.4, 17.4, 16.1, and 15.5 g, respectively, in the dry weight. While the lowest values were recorded by Rhizobacterin (2 g/L) (20.2 and 10.3 g) in the fresh and dry weight of aerial parts/plant, respectively (Figure 1E). In a similar vein, plants treated with vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and potassium silicate (2 g/L) recorded the best results for fresh and dry weight of roots/plant. They recorded 18.9, 17.1, 16.4 and 16.1 g, respectively, in the fresh weight, and 10.4, 9.5, 8.8, and 8.4 g, respectively, in the dry weight. While the lowest values were recorded by Rhizobacterin (2 g/L) (11.2 and 5.7 g) in the fresh and dry weight of roots/plant, respectively (Figure 1F).

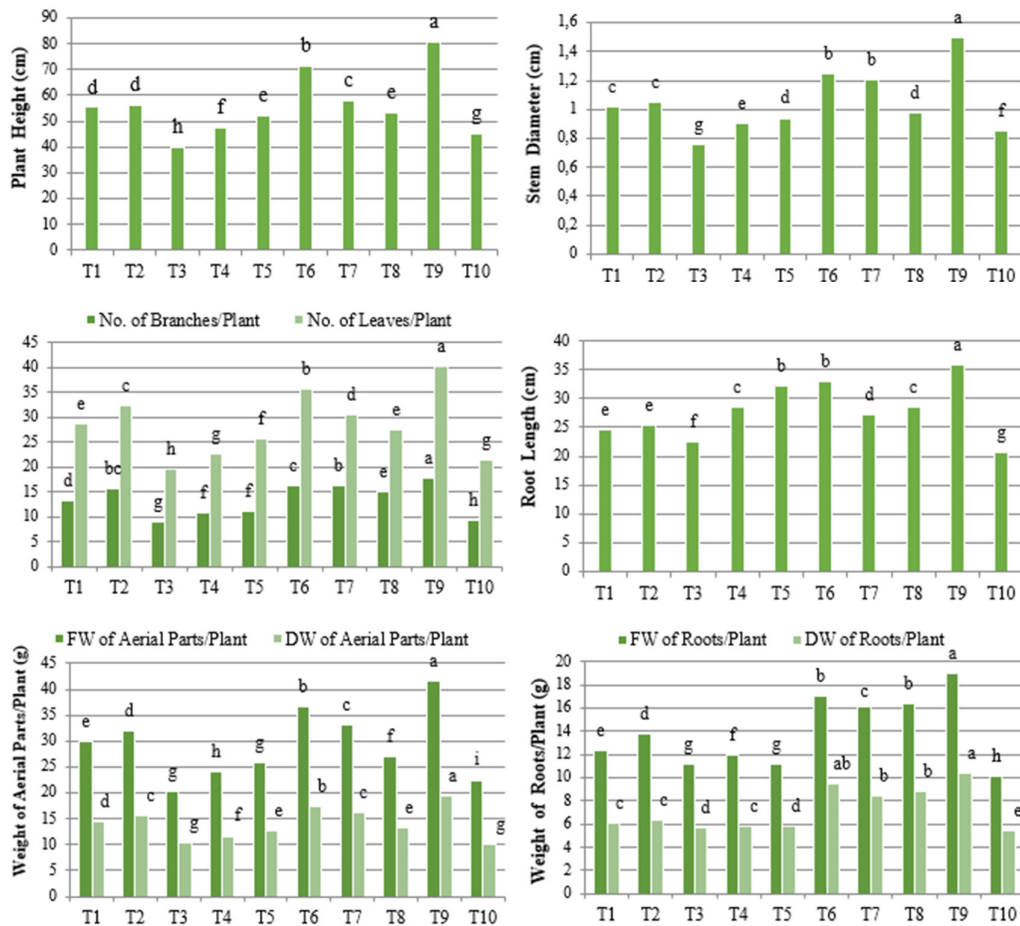


Figure 1. Effect of bio and synthetic fertilizers on (A) plant height; (B) stem diameter; (C) number of branches and leaves/plant; (D) root length; (E) fresh and dry weight of aerial parts/plant; and (F) fresh and dry weight of roots of *R. gallica* L. Data are mean of two repeated trials during the 2021 and 2022 growing seasons

Flower yield of *R. gallica* L.

As shown in Figure 2, it is clear that all fertilization treatments led to an increase in most flowering parameters starting from April to October, as the averages reached maximum values compared to the control treatment. In this regard, plants treated with vitavax 200, seaweed extract (4 g/L), seaweed extract (2 g/L), and potassium silicate (4 g/L) gave the highest values of number of flowers/plants as follows: 21.6, 19.3, 17.9, and 17.2, respectively. While the lowest values were recorded by Rhizobacterin (2 g/L) (11.2) (Figure 2A). In addition, vitavax 200, followed by seaweed extract (4 g/L), seaweed extract (2 g/L), and potassium silicate (4 g/L) recorded the best results for fresh and dry weight of flowers/plant. They recorded 4.6, 3.6, 3.5, and 3.3 g, respectively, in the fresh weight, and 0.95, 0.90, and 0.80 g, respectively, in the dry weight. While the lowest values were recorded by Rhizobacterin (2 g/L) (2.0 and 0.34 g) in the fresh and dry weight, respectively (Figure 2B). Results also show that the highest values of flower diameter were obtained by vitavax 200, seaweed extract (4 g/L), seaweed extract (2 g/L), and potassium silicate (4 g/L), recording 7.5, 6.8, 6.4, and 5.6 cm, respectively. While the lowest value was recorded 4.8 cm by Rhizobacterin (2 g/L) (Figure 2C). Similarly, the highest length of flower stalk was recorded in plants treated with vitavax 200, followed by seaweed extract (4 g/L), seaweed extract (2 g/L), and potassium silicate (4 g/L), recording 25.8, 23.8, 23.2, and 21.2 cm, respectively. While the

lowest value was recorded 17 cm by Rhizobacterin (2 g/L) (Figure 2C). Concerning the fresh and dry weight of flower stalks/plant, the best results were obtained by vitavax 200 and seaweed extract (4 g/L). They recorded 6.2 and 5.7 g, respectively, in the fresh weight, and 4.5 and 3.4 g, respectively, in the dry weight. While the lowest values were recorded by Rhizobacterin (2 g/L) (3.8 and 1.8 g) in the fresh and dry weight, respectively (Figure 2D).

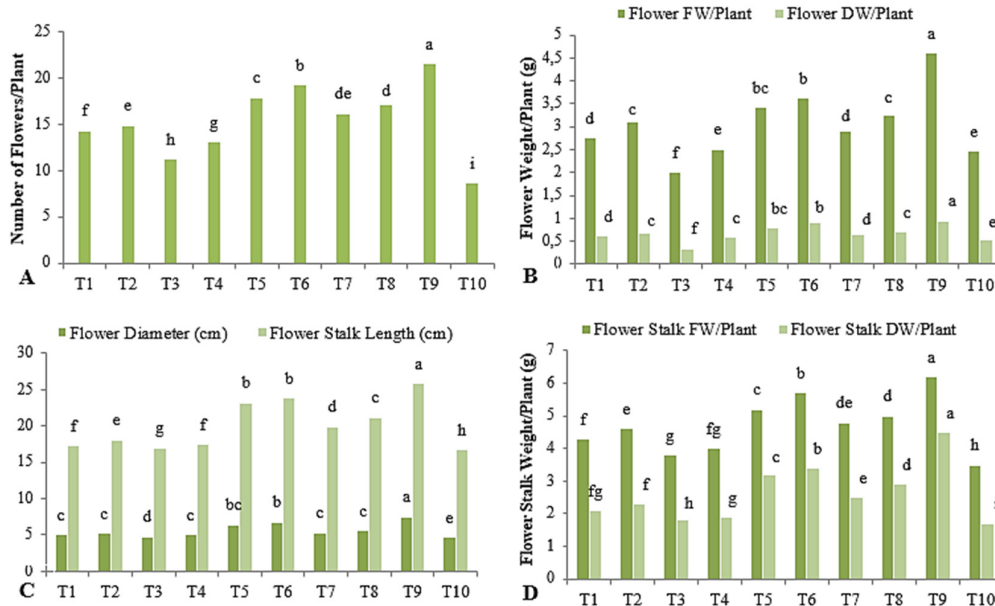


Figure 2. Effect of bio and synthetic fertilizers on the average of (A) number of flowers/plants; (B) fresh and dry weight of flowers/plant; (C) flower diameter and flower stalk length; and (D) fresh and dry weight of flower stalks/plant of *R. gallica* L. Data are mean of two repeated trials during the 2021 and 2022 growing seasons

Growth of *R. chinensis* Jacq.

As shown in Figure 3, all fertilization treatments significantly increased the growth parameters of rose. In this respect, the treatment with vitavax 200 and seaweed extract (4 g/L) recorded the best results for plant height with significant differences, followed by potassium silicate (4 g/L), and NPK (4 g/plant) as follows: 60.6, 58.4, 49.5, and 45.7 cm, respectively. While the lowest value was recorded 40.3 cm by Rhizobacterin (2 g/L) (Figure 3A). Also, the highest values of stem diameter were recorded by vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant), recording 1.5, 1.2, 1.0, and 0.9 cm, respectively. While the lowest value was recorded 0.8 cm by Rhizobacterin (2 g/L) (Figure 3B). Regarding the number of branches/plant, the highest values were recorded by vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant), recording 18.0, 17.3, 16.3, and 16.2, respectively. While the lowest value was recorded 12.1 by Rhizobacterin (2 g/L) (Figure 3C). Similarly, plants treated with vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant) noted the highest number of leaves/plants, 45.8, 44.7, 39.7, and 37.7, respectively. While the lowest value was recorded 30.7 by Rhizobacterin (2 g/L) (Figure 3C). Our results also show that the highest length of roots was recorded in plants treated with vitavax 200, followed by seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (2 g/plant) as follows: 37.7, 35.9, 33.4, and 29.7 cm, respectively. While the lowest value was recorded 25.7 cm by Rhizobacterin (2 g/L) (Figure 3D). Concerning the fresh and dry weight of aerial parts/plant, the best results were obtained by vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant) with significant differences. They recorded 50.6, 48.5, 44.7, and 40.3 g, respectively, in the fresh weight, and 22.7, 20.5, 18.7, and 18.3 g, respectively, in

the dry weight. However, the lowest values were recorded by Rhizobacterin (2 g/L) (30.2 and 12.6 g) in the fresh and dry weight of aerial parts/plant, respectively (Figure 3E). Similarly, plants treated with vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant) recorded the best results for fresh and dry weight of roots/plant, recording 19.7, 18.6, 16.0, and 15.4 g, respectively, in the fresh weight, and 9.6, 8.6, 8.1, and 8.0 g, respectively, in the dry weight. While the lowest values were recorded by Rhizobacterin (2 g/L) (10.5 and 5.4 g) in the fresh and dry weight of roots/plant, respectively (Figure 3F).

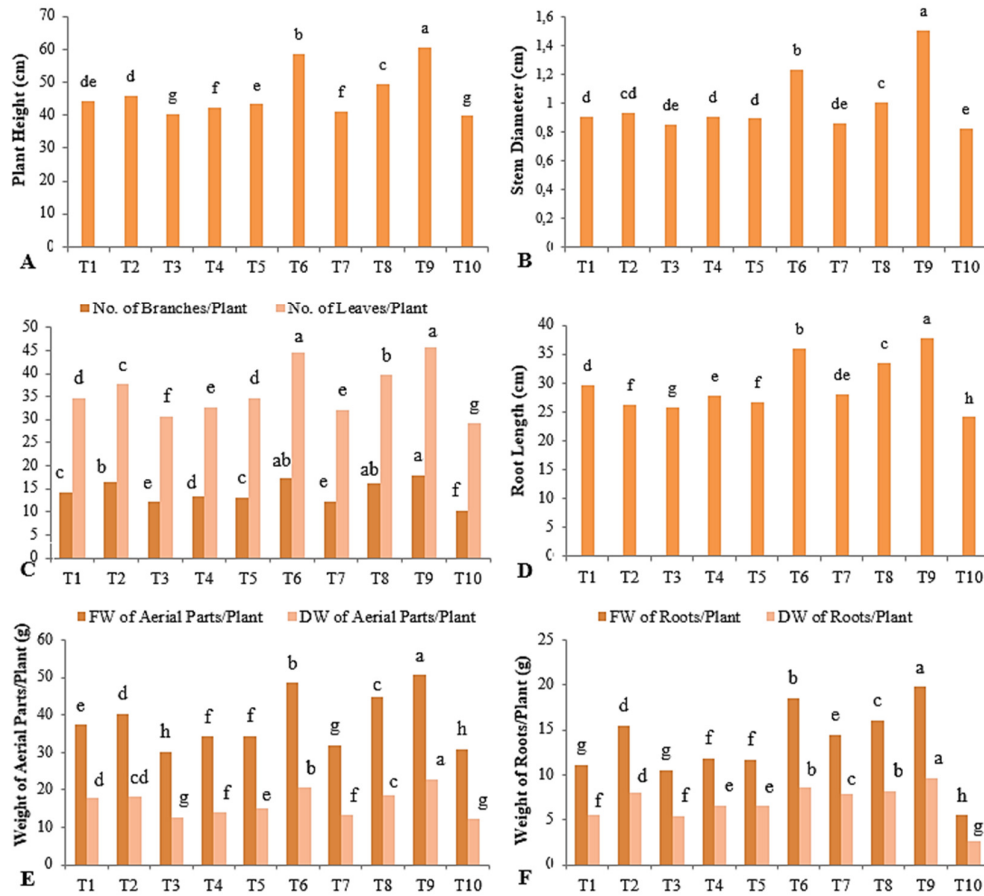


Figure 3. Effect of bio and synthetic fertilizers on (A) plant height; (B) stem diameter; (C) number of branches and leaves/plant; (D) root length (E) fresh and dry weight of aerial parts/plant; and (F) fresh and dry weight of roots of *R. chinensis* Jacq. Data are mean of two repeated trials during the 2021 and 2022 growing seasons

Flower yield of *R. chinensis* Jacq.

As shown in Figure 4, all fertilization treatments significantly enhanced rose flowering characteristics from April to October, as the averages reached maximum values compared to the control treatment. In this concern, plants treated with vitavax 200, followed by seaweed extract (4 g/L), seaweed extract (2 g/L), and potassium silicate (4 g/L) recorded the highest number of flowers/plants as follows: 24.4, 21.7, 18.9, and 17.8, respectively. While the lowest value was recorded by Rhizobacterin (2 g/L) (10.3) (Figure 4A). Similarly, vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant) recorded the best results for fresh and dry weight of flowers/plant as follows: 5.2, 4.8, 4.7, and 4.5 g, respectively, in the fresh weight, and 1.5, 1.2, 1.1, and 1.0 g, respectively, in the dry weight. While the lowest values were recorded by potassium silicate (2 g/L) (3.7 and 0.8 g) in the fresh and dry weight, respectively (Figure 4B). Our results also show that

the highest values of flower diameter were recorded by vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant) with significant differences, recording 9.3, 8.3, 7.8, and 7.2 cm, respectively. While the lowest value of 5.7 cm was recorded by Rhizobacterin (2 g/L) (Figure 4C). Also, the highest length of flower stalks was recorded by vitavax 200, followed by seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant), recording 28.6, 25.6, 24.4, and 23.5 cm, respectively. While the lowest value was recorded 19.9 cm by Rhizobacterin (2 g/L) (Figure 4C). Regarding the fresh and dry weight of stalks/plant, the best results were obtained by vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant) as follows: 7.4, 6.9, 6.5, and 6.2 g, respectively, in the fresh weight, and 4.0, 3.5, 3.2, and 2.8 g, respectively, in the dry weight. While the lowest values of 4.3 and 2.3 g, were recorded by Rhizobacterin (2 g/L) in fresh and dry weight, respectively (Figure 4D).

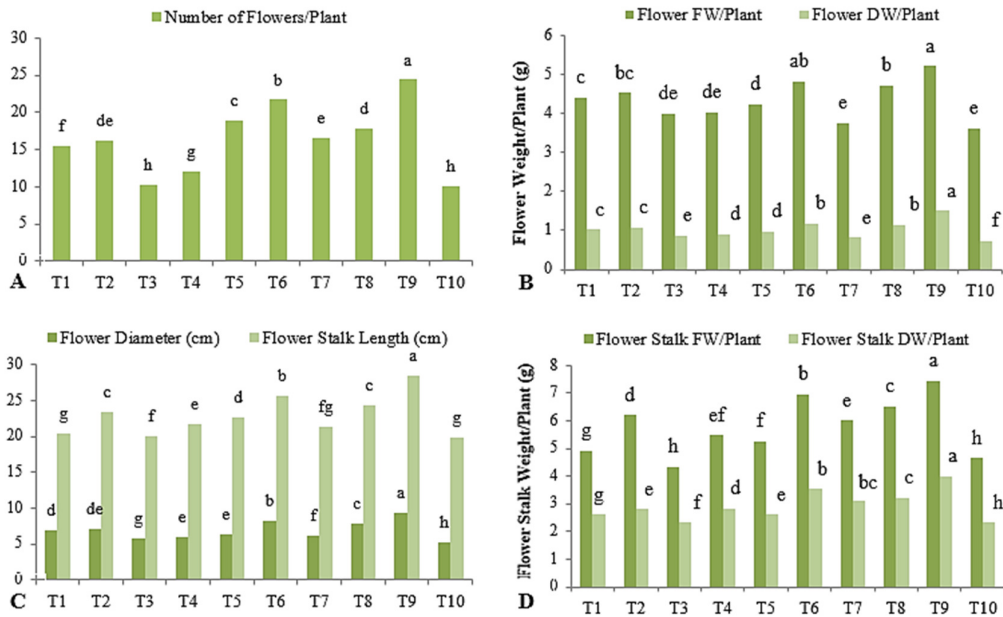


Figure 4. Effect of bio and synthetic fertilizers on the average of (A) number of flowers/plant; (B) fresh and dry weight of flowers/plant; (C) flower diameter and flower stalk length; and (D) fresh and dry weight of flower stalks/plant of *R. chinensis* Jacq. Data are mean of two repeated trials during the 2021 and 2022 growing seasons

Photosynthetic pigments

Data provided in Table 8 show that all treatments significantly increased the content of chlorophyll a, chlorophyll b, and carotenoids in both seasons. In *R. gallica*, the highest content of chlorophyll a was recorded by vitavax 200, followed by seaweed extract (4 g/L) and potassium silicate (4 g/L). They recorded 1.79, 1.69, and 1.54 mg g⁻¹ FW, respectively. While the lowest content was recorded by Rhizobacterin (2 g/L) (1.03 mg g⁻¹ FW). Similarly, the highest content of chlorophyll b was recorded by seaweed extract (4 g/L), followed by vitavax 200 and potassium silicate (4 g/L), recording 0.75, 0.64, and 0.61 mg g⁻¹ FW, respectively. While the lowest content was recorded by Rhizobacterin (2 g/L) (0.38 mg g⁻¹ FW). In addition, the highest contents of carotenoids were recorded by vitavax 200, seaweed extract (4 g/L), and potassium silicate (4 g/L) as follows: 0.98, 0.94, and 0.93 mg g⁻¹ FW, respectively. While the lowest content was recorded by Rhizobacterin (2 g/L) (0.44 mg g⁻¹ FW). In *Rosa chinensis*, the highest contents of chlorophyll a were found in plants treated with vitavax 200 and seaweed extract (4 g/L), while the lowest content was noted by Rhizobacterin (2 g/L). They recorded 1.69, 1.65, and 0.98 mg g⁻¹ FW, respectively. Also, the highest content of chlorophyll b was obtained by seaweed extract (4 g/L) and vitavax 200, recording 0.95 and 0.93 mg g⁻¹ FW, respectively. While the lowest

content was recorded by Rhizobacterin (2 g/L) (0.30 mg g⁻¹ FW). Results also show that the highest contents of carotenoids were recorded by vitavax 200 and seaweed extract (4 g/L), recording 1.20 and 1.19 mg g⁻¹ FW, respectively. While the lowest content was recorded by Rhizobacterin (2 g/L) (0.44 mg g⁻¹ FW).

Table 8. *In vivo*, effect of bio and synthetic fertilizers on chlorophyll a, chlorophyll b, and carotenoids of two species of rose during the growing seasons 2021 and 2022

Treatments	Conc. (g/L)	Chlorophyll a (mg g ⁻¹ FW)	Chlorophyll b (mg g ⁻¹ FW)	Carotenoids (mg g ⁻¹ FW)
<i>Rosa gallica</i> L.				
NPK	*2	1.08 ^h	0.47 ^f	0.58 ^f
	*4	1.23 ^f	0.51 ^c	0.70 ^c
Rhizobacterin	2	1.03 ⁱ	0.38 ^s	0.44 ^h
	4	1.17 ^s	0.47 ^f	0.47 ^s
Seaweed extract	2	1.40 ^d	0.54 ^d	0.78 ^c
	4	1.69 ^b	0.75 ^a	0.94 ^b
Potassium silicate	2	1.33 ^c	0.52 ^{dc}	0.75 ^d
	4	1.54 ^c	0.61 ^c	0.93 ^b
Vitavax 200	3	1.79 ^a	0.64 ^b	0.98 ^a
Control	-	0.93 ^j	0.36 ^h	0.42 ⁱ
<i>Rosa chinensis</i> Jacq.				
NPK	*2	1.06 ^f	0.34 ^h	0.48 ^c
	*4	1.20 ^d	0.43 ^f	0.67 ^d
Rhizobacterin	2	0.98 ^h	0.30 ⁱ	0.44 ^f
	4	1.04 ^s	0.39 ^s	0.59 ^c
Seaweed extract	2	1.22 ^d	0.59 ^d	0.71 ^c
	4	1.65 ^b	0.95 ^a	1.19 ^a
Potassium silicate	2	1.12 ^c	0.48 ^c	0.68 ^d
	4	1.34 ^c	0.61 ^c	0.83 ^b
Vitavax 200	3	1.69 ^a	0.93 ^b	1.20 ^a
Control	-	0.75 ⁱ	0.29 ^j	0.44 ^f

* = g per plant. In the same column, values followed by the same letters do not differ significantly at the $p \leq 0.05$ statistical level, as per Duncan's multiple range test. Data are mean of two repeated trials during the growing seasons 2021 and 2022 under *in vivo* conditions.

Chemical analysis

Data presented in Table 9 show that all treatments significantly increased the percentage of total carbohydrates, nitrogen, phosphorus, and potassium in both seasons. In *R. gallica*, the highest percentage of total carbohydrates was recorded in plants treated with vitavax 200, followed by seaweed extract (4 g/L) and potassium silicate (4 g/L), recording 71.45, 69.56, and 67%, respectively. While the lowest value was recorded by Rhizobacterin (2 g/L) (41.37%). Our results also show that the highest percentage of nitrogen was recorded by vitavax 200, followed by seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant) as follows: 3.44, 3.39, 2.57 and 2.47%, respectively. However, the lowest value was recorded by Rhizobacterin (2 g/L) (1.95%). Regarding phosphorus, the highest values were found in plants treated with vitavax 200, seaweed extract (4 g/L), potassium silicate (4 g/L), and NPK (4 g/plant), recording 0.18, 0.18, 0.17, and 0.16%, respectively. While the lowest value was recorded by Rhizobacterin (2 g/L) (0.11%). Also, the highest percentages of potassium were recorded by seaweed extract (4 g/L), vitavax 200, and potassium silicate (4 g/L), recording 2.21, 2.05, and 1.92%, respectively. While the lowest value was recorded by Rhizobacterin (2 g/L) (1.19%). In *Rosa chinensis*, the highest values of total carbohydrates were recorded by seaweed extract (4 g/L), vitavax 200, and potassium silicate (4 g/L) as follows: 73.91, 71.23, and 70.71%, respectively. While the lowest

value was noted by Rhizobacterin (2 g/L) (43.25%). In addition, the highest percentage of nitrogen was recorded by each vitavax 200 and seaweed extract (4 g/L) (3.0%), followed by potassium silicate (4 g/L) (2.63%) and NPK (4 g/plant) (2.39%). However, the lowest value was recorded by Rhizobacterin (2 g/L) (1.92%). Similarly, the highest percentages of phosphorus were found in plants treated with seaweed extract (4 g/L), vitavax 200, potassium silicate (4 g/L), and NPK (4 g/plant), recording 0.29, 0.27, 0.23, and 0.21%, respectively. While the lowest value was recorded by Rhizobacterin (2 g/L) (0.14%). Also, the highest percentage of potassium was recorded by seaweed extract (4 g/L), followed by vitavax 200 and potassium silicate (4 g/L), recording 2.11, 1.94, and 1.90%, respectively. While the lowest value was recorded by Rhizobacterin (2 g/L) (1.04%).

Table 9. *In vivo*, effect of bio and synthetic fertilizers on total carbohydrates, nitrogen, phosphorus, and potassium of two species of rose during the growing seasons 2021 and 2022

Treatments	Conc. (g/L)	Total Carbohydrates %	Nitrogen %	Phosphorus %	Potassium %
<i>Rosa gallica</i> L.					
NPK	*2	42.05 ^h	2.14 ^f	0.14 ^c	1.44 ^c
	*4	57.45 ^f	2.47 ^d	0.16 ^c	1.79 ^d
Rhizobacterin	2	41.37 ^h	1.95 ^h	0.11 ^g	1.19 ^h
	4	48.10 ^g	2.10 ^g	0.13 ^f	1.22 ^g
Seaweed extract	2	62.42 ^d	2.28 ^c	0.15 ^d	1.80 ^d
	4	69.56 ^b	3.39 ^b	0.18 ^a	2.21 ^a
Potassium silicate	2	58.05 ^c	2.10 ^g	0.14 ^c	1.31 ^f
	4	67.00 ^c	2.57 ^c	0.17 ^b	1.92 ^c
Vitavax 200	3	71.45 ^a	3.44 ^a	0.18 ^a	2.05 ^b
Control	-	40.12 ⁱ	1.70 ⁱ	0.11 ^g	1.03 ⁱ
<i>Rosa chinensis</i> Jacq.					
NPK	*2	45.78 ^g	2.16 ^c	0.16 ^g	1.35 ^g
	*4	58.34 ^c	2.39 ^c	0.21 ^d	1.67 ^c
Rhizobacterin	2	43.25 ^g	1.92 ^h	0.14 ^h	1.04 ⁱ
	4	52.86 ^f	2.03 ^g	0.17 ^f	1.18 ^h
Seaweed extract	2	65.40 ^d	2.24 ^d	0.19 ^c	1.73 ^d
	4	73.91 ^a	3.00 ^a	0.29 ^a	2.11 ^a
Potassium silicate	2	59.00 ^c	2.08 ^f	0.17 ^f	1.39 ^f
	4	70.71 ^c	2.63 ^b	0.23 ^c	1.90 ^c
Vitavax 200	3	71.23 ^b	3.00 ^a	0.27 ^b	1.94 ^b
Control	-	42.77 ^h	1.80 ⁱ	0.13 ⁱ	0.98 ^j

* = g per plant. In the same column, values followed by the same letters do not differ significantly at the $p \leq 0.05$ statistical level, as per Duncan's multiple range test. Data are mean of two repeated trials during the growing seasons 2021 and 2022 under *in vivo* conditions.

Discussion

Rose plants suffer from many fungal diseases during their different growth stages, which causes severe losses in flower production (Salamone *et al.*, 2011). However, root rot and wilt which belong to soil-borne diseases are the most damaging diseases of rose worldwide (Hammett, 1971; Kageyama *et al.*, 2002; Li *et al.*, 2007; Armanious, 2016). Rose diseases are generally controlled with several fungicides. However, with the increasing international demand to reduce the use of toxic fungicides, this approach has become undesirable (Apte and Kamble, 2008; Christopher *et al.*, 2010). Therefore, the present investigation was conducted to

manage the root rot and wilt of rose in an eco-friendly manner through the use of seaweed extract, Rhizobacterin, potassium silicate, and NPK. Our results showed that seven soil-borne fungi, including *F. moniliforme*, *F. roseum*, *F. semitectum*, *F. solani*, *M. phaseolina*, *R. solani*, and *V. dahlia* were isolated from rotted and wilted rose samples, collected from Beni-Suef and Giza governorates, Egypt. *R. solani* and *F. moniliforme* had the highest frequency followed by *V. dahliae*, *F. semitectum*, and *M. phaseolina*, while *F. solani* and *F. roseum* were the least frequent. In addition, *F. roseum*, *V. dahlia*, and *R. solani* were the most damaging fungi to the two rose species, recording 60.5, 66, and 70.6% of the surviving plants, respectively. These results are consistent with those investigated by (Hammett, 1971; Kageyama *et al.*, 2002; Li *et al.*, 2007; Armanious, 2016; Barguil *et al.*, 2019).

Our *in vitro* studies revealed that all treatments significantly reduced the linear growth of tested fungi at all used concentrations. However, potassium silicate followed by seaweed extract, each at 400 ppm recorded the highest inhibition of linear growth. The corresponding inhibition values were 96.6 and 94.4% for *V. dahlia*, 94.4 and 93.3% for *F. roseum*, 90 and 90% for *R. solani*, respectively. While seaweed extract at 50 ppm recorded the lowest inhibition by 12.2, 16.6, and 26.6% for *R. solani*, *F. roseum*, and *V. dahlia*, respectively. Several reports showed the efficiency of potassium silicate in inhibiting the growth of fungi causing root rot and wilt diseases *in vitro*. Among these reports, Ahmed *et al.*, 2023, who found that potassium silicate at 2000 ppm was the most effective in reducing the linear growth of *F. solani*, *M. phaseolina*, and *F. oxysporum*, causing root rot and wilt of roselle by a reduction of 62.3, 60.7, and 60.3%, respectively. Likewise, Abdel-Monaim *et al.* (2015) reported that potassium silicate significantly inhibited the mycelium growth of *R. solani*, *F. solani*, *F. oxysporum*, *F. equiseti*, and *F. semitectum*, the causal agents of root rot and wilt diseases of fodder beet. On the other hand, the antifungal activity of seaweed extract against the mycelial growth of several pathogenic fungi was investigated. For example, Ambika and Sujatha (2014) found that seaweed extract of *S. myricocystum* (brown alga) exhibited significant antifungal activity against *F. oxysporum* f. sp. *udum* followed by *Gracilaria edulis* (red alga) and *Caulerpa racemosa* (green alga). Similarly, Abdellatif and Armanious (2015) observed that seaweed extract significantly reduced the fungal growth of *F. oxysporum*, *F. solani*, and *M. phaseolina* *in vitro* conditions. In addition, Ben Salah *et al.* (2018) found that polysaccharides extracted from seaweeds, namely ulvan and alginate produced significant inhibitory rates on mycelial growth of *V. dahliae* *in vitro*. In a similar vein, Mabrouki *et al.* (2020) evaluated 54 organic and 18 aqueous extracts of 18 seaweeds against the mycelium growth of *Sclerotium rolfsii* *in vitro*. The results indicated that among the organic extracts, the maximum inhibition was obtained by *Plocamium cartilagineum* in dichloromethane (89%), followed by *Ellisolandia elongata* in methanol (62%). For aqueous seaweed extracts, the highest inhibitory effect was obtained by *E. elongata* (81%) followed by *P. cartilagineum* (62%). Moreover, the aqueous extract of *E. elongata* gives complete inhibition of sclerotia germination. Our finding also showed that treatment with vitavax 200 at 400 ppm inhibited the growth of tested fungi *in vitro*, making it significantly more effective. These results are similar to those of Adhikari *et al.* (2018) who found that vitavax 200 was most effective in inhibiting mycelial radial growth of *R. solani* at the lowest concentration (10 ppm). Also, Saad *et al.* (2014) reported that vitavax 200 had a significantly greater inhibition effect on *F. solani* linear growth than other treatments. Similarly, Dubey *et al.* (2020) observed that vitavax is highly effective against *Pythium* spp. isolated from diseased chili pepper, inhibiting mycelium growth by 93.3%.

Our results demonstrated that all treatments applied under *in vivo* conditions significantly reduced the disease incidence of root rot and wilt in both *R. gallica* and *R. chinensis*. In this regard, the lowest disease incidence was recorded by seaweed extract (4 g/L), followed by seaweed extract (2 g/L), potassium silicate (4 g/L), and potassium silicate (2 g/L). While the highest disease incidence was recorded by Rhizobacterin (2 g/L) in both seasons. Extensive reports showed the potential of seaweeds in controlling fungal diseases. Among these reports Abdellatif and Armanious, 2015, who reported that seaweed extract achieved positive results in

reducing the incidence of snap bean wilt. Similarly, Ben Salah *et al.* (2018) reported that a polysaccharide extracted from seaweed, namely ulvan was most effective in controlling olive wilt caused by *V. dahlia*, and significantly reduced the area under the disease progress curve for severity to 39.9% and final incidence to 28.9%. In addition, Esserti *et al.* (2017) reported that foliar spraying with a brown seaweed extract was more effective against *V. dahliae* in tomato plants. In a similar vein, Ara *et al.* (1996) found that soil amendment with dry powder of seaweeds (*Sargassum tenerrimum*, *S. wightii*, and *S. swartzii*) significantly reduced the development of *M. phaseolina* and *F. solani*, the causative agents of sunflower root rot. Several reports showed the efficiency of potassium silicate to suppress root rot and wilt diseases. For example, it was found that potassium silicate solution (4 g/L) used as seed soaking and foliar spray significantly decreased the disease incidence of root rot and wilt of roselle caused by *M. phaseolina*, *F. solani*, and *F. oxysporum* (Ahmed *et al.*, 2023). Similarly, it has been observed that spraying cotton plants with potassium silicate was effective against wilt disease caused by *F. oxysporum* f. sp. *vasinfectum* (Whan *et al.*, 2016). In addition, Chérif *et al.* (1994) reported that cucumber treated with potassium silicate significantly decreased the incidence of root rot caused by *Pythium* spp. The antifungal activity of potassium silicate probably results from the combined effect of both potassium and silicon. Silicon has been found to increase the activity of defense-related enzymes and antimicrobial compounds, such as phytoalexins, pathogenicity-related proteins, and phenols. Si also regulates resistance in host plants through signaling hormones, such as jasmine acid, salicylic acid, and ethylene (Wang *et al.*, 2017). As for potassium, it improves the health and vigor of the plant, which reduces the possibility of infection and also helps in rapid recovery (Perrenoud, 1993). Also, potassium may exert its effect on plant diseases through its effect on some metabolic functions, changing the relationship between the pathogen and the environment, and producing pathogen-inhibiting compounds, such as phenolic compounds, phytoalexins, and auxins (Abd-El-Kareem *et al.*, 2004). Our finding also showed that vitavax 200 (3 g/L) exhibited significant superiority in reducing diseases compared to other treatments. This result is similar to that obtained by Dubey *et al.* (2020) and Arora *et al.* (2021).

Our results indicated that all fertilization treatments led to a significant improvement in the parameters of growth of both *R. gallica* and *R. chinensis*, including plant height, stem diameter, number of branches and leaves per plant, root length, as well as fresh and dry weight of aerial parts and roots. These results are in agreement with those reported by (Wang *et al.*, 2017; Esserti *et al.*, 2018; De Borba *et al.*, 2019). In this regard, the improvement of growth by seaweed extract may be attributed to their higher content of organic matter which provides plants with minerals needed for good growth (Devdhara *et al.*, 2019). In addition, organic seaweed compost may improve the structure and texture of the growing medium, electrical conductivity (EC), pH, organic matter and organic carbon contents, fertility, and CEC, while improving the total porosity and WHC of the mixture, and thus the availability of water and nutrients to plants (Velasco-Ramírez *et al.*, 2020). The efficiency of seaweed extract in improving growth has been investigated. For example, it was found that the use of seaweed extract at 2.5 or 3.0 mL/L significantly improved the growth of *Amaranthus tricolor* plants irrigated with saline water 1000 ppm (Abdel-Aziz *et al.*, 2011). Several studies have shown the role of potassium silicate (K_2SiO_3) in enhancing the growth qualities of many plants. Among these studies, Hasanv and Nejad (2016) found that weekly application of K_2SiO_3 at 1 mM significantly improved growth, physiological, and biochemical characteristics of geranium under salinity stress. Similarly, Abdelsadek *et al.* (2021) reported that plant height, number of branches and leaves, root length and total fresh and dry weight of *Dendranthema grandiflorum* cv. White Rivor is greatly increased as a result of the application of K_2SiO_3 at 900 ppm. Also, Khalifa *et al.* (2017) reported that soil drenching of K_2SiO_3 was the most effective for decomposing onion white rot disease and increasing plant fresh weight and bulb yield under *in vivo* conditions. This activity of potassium silicate in enhancing growth may be due to the combined effect of both potassium (K) and silicon (Si). Silicon enhances some of the plant's desirable physiological processes by enhancing certain enzymatic systems (Hasanvand and Nejad, 2016). It provides plants resistance to diverse stresses and is effective in controlling

various diseases caused by fungi and bacteria (Khalifa *et al.*, 2017). Moreover, Si plays a vital role in stimulating antioxidant enzymes in the plant and improving plant water status, besides its role in improving nitrogen utilization efficiency and ion distribution (Malav and Ramani, 2017). According to Wang *et al.* (2017), Si has been shown to improve plant root structure, photosynthesis, leaf erection, and water relations. Also, potassium performs several functions in plants, such as protein and starch synthesis, cell divisions, and improving seed size and quality. It also promotes root length and growth, regulates osmosis, and increases chlorophyll pigments, movement of stomata, and status of water (Perrenoud, 1993; Hasanuzzaman *et al.*, 2019). To date, both chemical and organic fertilizers are used alone or mixed with any of the bio- or stimulant fertilizers for the commercial production of ornamental plants, as these fertilizers cooperate to provide the plants with the nutrients and growth-promoting substances needed for good healthy growth (Bi *et al.*, 2010). In addition, compost is highly valued in the fertilizer industry and may improve soil structure and texture, increase CEC and fertility, and raise the WHC of the medium, and thus water uptake by plants (UL-Nisa *et al.*, 2016). In this context, El-Naggar and El-Sayed, 2008 reported that spraying the leaves of *Dianthus charyphyllus* with a solution of 0.6% macro- and microelements gave the best vegetative and root growth. Similarly, Abbasniyazare *et al.* (2012) found that triple superphosphate + Barvar -2 (P-biofertilizer) significantly increased leaves number and fresh and dry weight of *Spathiphyllum illusion*, while Barvar-2 + Nitrokara (N-biofertilizer) gave better effect on leaf size. Also, El-Mokadem and Sorour (2014) recommended the use of 19 N:19 P₂O₅:19 K₂O chemical fertilizer at 25 g/plant with N-fixing bacteria + P₂O₅-dissolving bacteria at a rate of 2 mL/L, twice to promote the growth of *Petunia hybrida* cv. 'Bravo White' in high quality. Similarly, Bordoloi and Talukdar (2019) found that the highest plant length, leaves number, leaf area and plant propagation in *Anthurium andreanum* were achieved by RDF + Azospirillum + 100 ppm GA₃. Also, Dachung and Kalu (2019) found that the application of cow manure with NPK fertilizer (15:15:15) provided more nutrients for maximum growth.

Our results revealed that all treatments significantly increased flower yield characteristics of both *R. gallica* and *R. chinensis*, including number of flowers/plant, flower fresh and dry weight, flower diameter, flower stalk length, and flower stalk fresh and dry weight. In this regard, the ability of seaweed extract in improving flower yield properties may be attributed to its role in improving soil fertility and providing plants with adequate nutrients needed for good flowering. Additionally, Ali *et al.* (2021) stated that seaweed biological products have plant stimulation effects on rose and other flowering crops, which leads to increased plant growth and flower production traits. Besides, its components induces defensive plant responses against many plant pathogens abiotic stresses, such as drought, salinity, and cold. These findings agreed with those of Sumangala *et al.* (2019), who found that treating *Rosa hybrida* cultivars with a seaweed extract (20%) as often as once a week resulted in a significant increase in plant height, leaf area, plant biomass, number of flowers, flower diameter, and flower dry weight. Similarly, Kularathne *et al.* (2021) reported that the application of a seaweed extract (20%) at a rate of once per week resulted in significant improvement in leaf area, fresh and dry biomass and flower yield in roses. Moreover, Parinitha *et al.* (2022) observed that spraying *Floribunda rose* cv. Charishma with seaweed extract (2000 ppm) gave the best results for flower diameters and stalk lengths. Regarding the role of potassium silicate in improving the characteristics of the flower yield, it has been proven that silicon improves the activity of antioxidant enzymes, the state of plant water and the distribution of ions in the plant, and this reflects positively on growth and flowering. In this context, Farahani *et al.* (2020) found that the foliar spraying of *Rosa damascena* plants under the conditions of water stress with potassium silicate (0.2%) improved the flower yield and the composition of the essential oil. Likewise, Abdelsadek *et al.* (2021) reported that spraying *Dendranthema grandiflorum* cv. White Rivor with potassium silicate (900 ppm) provided the number of inflorescences, flower heads/plant and the length of the flower stalk. On the other hand, chemical, organic, and biofertilizers have been successively used for many years to enhance flowering ornamental plants due to their high potential to supply plants with minerals and flowering stimulating

substances for the purpose of producing better and higher flower yield. Extensive reports contributed to clarifying this fact. Among these reports, Patel *et al.* (2017), who found that stalk length, flower diameter, and number of flowers of *Rosa hybrida* cv. 'Gladiator' were significantly higher when plants treated with castor cake (0.8 kg) + azotobacter (1 mL) + PSM (1 mL) + KSB (1 mL) per plant. Likewise, Ali *et al.* (2021) noted that treating *Rosa damascena* with 30 kg of phosphorous fertilizer/ha with pruning at the level of 80 cm gave the highest number of flowers and the best components of the crop. In addition, Massoud *et al.*, 2016 indicated that the fertilization of *Achillea millefolium* with NPK (3 g/plant) has achieved the highest production of inflorescences. Moreover, Pandey *et al.* (2020) found that foliar spraying of *Tagetes erecta* with urea solution (0.2%) significantly increased number of days to the first opening of the flower, number of flowers per plant, flower stalk length, fresh and dry weight of flowers. Similarly, Sahu *et al.* (2021) mentioned that treating *Dahlia variabilis* cv. 'Kenora Sunburst' plants with 80% RDF through NPK + 20% farmyard manure (FYM) gave the best flower productivity and quality.

Our results also showed all fertilization treatments significantly increased the content of photosynthetic pigments, total carbohydrates, nitrogen, phosphorus, and potassium in both *R. gallica* and *R. chinensis*. The improvement of leaf chemical composition by seaweed extract may be attributed to the high value of such organic and bio-stimulant product, which improves soil fertility and provides plants with nutrients needed for good and healthy growth (Devdhara *et al.*, 2019). In this regard, Al-Sayed *et al.*, 2020 found that the use of biofertilizers increased total chlorophyll, carotenoids, and NPK uptake by roselle plant. This activity may be due to improving the texture and structure of the medium, EC, pH, organic matter and organic carbon ratios, CEC, porosity, and WHC of the growing medium (Velasco-Ramírez *et al.*, 2020). Similarly, Mahmood, 2022 reported that foliar spraying of seaweed (algae 600) at 1.5 mg/L significantly increased chlorophyll, nitrogen, phosphorus, and potassium concentrations in *Acacia farnesiana* leaves. In terms of potassium silicate applications, Si also enhance plant uptake of nutrients and partition of mineral ions within plant cells. In this context, Malav and Ramani, 2017 stated that Si plays an important role in improving N utilization efficiency and ion distribution within the plant. In addition, Farahani *et al.*, 2020 showed that foliar spraying of Si (0.2%) improved the essential oil composition of *Damask rose* under water-deficient conditions. Similarly, Abdelsadek *et al.* (2021) found that spraying *Dendranthema grandiflorum* cv. White Rivor with potassium silicate (900 ppm) significantly increased total carbohydrates and total chlorophyll in leaves. It was noted that the combination of NPK chemical fertilizers with organic fertilizers or bio-stimulants usually leads to a synergistic effect, as the benefits of these components are combined and the plants are provided with many nutrients and stimuli necessary for good and healthy growth. These facts are consistent with those of Nofal *et al.* (2021), who found that the concentration of the pigment B-carotene in the dry flower of *Tagetes erecta* was maximized by treating the plant with NPK (2 g/plant) along with seaweed extract (2 g/L). Also, Ali *et al.* (2021) found that treating *Rosa damascena* with 30 kg of phosphorous/ha with pruning at the level of 80 cm gave the best results for chlorophyll, sugars, nitrogen, phosphorus, and potassium in the leaves.

Conclusions

Our results concluded that the possibility of increasing the tolerance of *R. gallica* and *R. chinensis* against root rot and, while improving growth and flowering features by using some bio- and synthetic fertilizers. Seaweed extract and potassium silicate at a concentration of 400 ppm achieved the highest efficiency in inhibiting the linear growth of pathogenic fungi. All treatments applied *in vivo* led to a significant decrease in the incidence of diseases on both species of rose in both seasons, leading to an improvement in all growth and flowering parameters and an increase in the content of photosynthetic pigments, total carbohydrates, nitrogen, phosphorus, and potassium. In this regard, seaweed extract (4 and 2 g/L) and potassium silicate (4 g/L) were

the most efficient, while Rhizobacterin (2 g/L) and NPK (2 g/plant) were the least effective. However, vitavax 200 was the most effective of all the treatments used.

Authors' Contributions

Conceptualization: GAA, RMS, HFAA, DAI, MAMB and MFS; methodology: GAA, RMS, HFAA, DAI and MAMB; software: MFS and NK; validation: GAA, RMS, HFAA and MFS; formal analysis: GAA, RMS, HFAA, DAI, MAMB; investigation: GAA, RMS, HFAA, DAI, MAMB and MFS; resources: GAA and RMS; data curation: MFS and NK; writing—original draft preparation: GAA, RMS, HFAA, DAI and MAMB; writing—review and editing: MFS and NK; visualization: MFS and NK;

All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

Acknowledgements

Researchers Supporting Project number (RSPD2024R751), King Saud University, Riyadh, Saudi Arabia.

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

- Abbasniayzare SK, Sedaghatthoor SH, Dahkaei MNP (2012). Effect of biofertilizer application on growth parameters of *Spathiphyllum illusion*. American-Eurasian Journal of Agricultural & Environmental Sciences 12:669-673.
- Abdel-Aziz NG, Mahgoub MH, Siam HS (2011). Growth, flowering, and chemical constituents performance of *Amaranthus tricolor* plants as influenced by seaweed (*Ascophyllum nodosum*) extract application under salt stress conditions. Journal of Applied Sciences Research 7:1472-1484.
- Abd-El-Kareem F, El-Mougy NS, El-Gamal NG, Fotouh YO (2004). Induction of resistance in squash plants against powdery mildew and Alternaria leaf spot diseases using chemical inducers as protective or therapeutic treatments. Egyptian Journal of Phytopathology 32:65-76.
- Abdellatif YMR, Armanious HAH (2015). Management of Fusarium wilt and improving the productivity of snap bean using brassinosteroid, glycinebetaine and seaweed extract. Egyptian Journal of Phytopathology 43:159-178. <http://doi.org/10.21608/EJP.2015.94682>
- Abdel-Monaim MF, Atwa MAM, Morsy KM (2015). Induce systemic resistance against root rot and wilt diseases in fodder beet (*Beta vulgaris* var. *rapacea* Koch.) by using potassium salts. Journal of Plant Pathology & Microbiology 6:315. <http://dx.doi.org/10.4172/2157-7471.1000315>
- Abdel-Raouf N, Al-Homaidan AA, Ibrabeem IBM (2012). Agricultural importance of algae. African Journal of Biotechnology 11:11648-11658. <https://doi.org/10.5897/AJB11.3983>

- Abdelsadek OA, Elbohy NFS, Diab RI (2021). Impact of potassium silicate and salicylic acid on growth, flowering and quality characters of *Dendranthema grandiflorum* plant under greenhouse conditions. Scientific Journal of Flowers & Ornamental Plants 8:483-496. <https://doi.org/10.21608/sjfp.2021.249390>
- Adhikari M, Kharel N, Gaire L, Poudel R, Shrestha SM, Gaire SP, Acharya B (2018). *In vitro* evaluation of different chemicals against *Rhizoctonia solani* by poisoned food technique. Field Crop 1:5-8. <http://dx.doi.org/10.5376/fe.2018.01.0002>
- Adjou ES, Kouton S, Dahouenon-Ahoussi, E, Sohounhloue, CK, Soumanou MM (2012). Antifungal activity of *Ocimum canum* essential oil against toxinogenic fungi isolated from peanut seeds in post-harvest in Benin. International Research Journal of Biological Sciences 1:20-26.
- Ahmed HFA, Elnaggar S, Abdel-Wahed GA, Taha RS, Ahmad A, Al-Selwey WA, Ahmed HMH, Khan N, Seleiman MF (2023). Induction of systemic resistance in *Hibiscus sabdariffa* Linn. to control root rot and wilt diseases using biotic and abiotic inducers. Biology 12:789. <http://doi.org/10.3390/biology12060789>
- Ahmed HFA, Seleiman MF, Al-Saif AM, Alshiekheid MA, Battaglia ML, Taha RS (2021). Biological control of celery powdery mildew disease caused by *Erysiphe heraclei* DC *in vitro* and *in vivo* conditions. Plants 10:2342. <http://doi.org/10.3390/plants10112342>
- Alhammad BA, Zaheer MS, Ali HH, Hameed A, Ghanem KZ, Seleiman MF (2023). Effect of co-application of *Azospirillum brasilense* and *Rhizobium pisi* on wheat performance and soil nutrient status under deficit and partial root drying stress. Plants 12(17):3141. <https://doi.org/10.3390/plants12173141>
- Ali HH, Shehzadi N, Zaheer MS, Seleiman MF, Aldhuwaib KJ, Din Khan Wu, Raza A (2023). Exploring the impact of salicylic acid and farmyard manure on soil rhizospheric properties and cadmium stress alleviation in maize (*Zea mays* L.). Plants 12(17):3115. <https://doi.org/10.3390/plants12173115>
- Ali O, Ramsabhag A, Jayaraman J (2021). Biostimulant properties of seaweed extracts in plants: implications towards sustainable crop production. Plants 10:531. <http://doi.org/10.3390/plants10030531>
- Al-Sayed HM, Hegab SA, Youssef MA, Khalafalla MY, Almaroai YA, Ding Z, Eissa MA (2019). Evaluation of quality and growth of roselle (*Hibiscus sabdariffa* L.) as affected by bio-fertilizers. Journal of Plant Nutrition 43(7):1025-1035. <http://doi.org/10.1080/01904167.2020.1711938>
- Al-Selwey WA, Alsadon AA, Alenazi MM, Tarroum M, Ibrahim AA, Ahmad A, Osman M, Seleiman MF (2023). Morphological and biochemical response of potatoes to exogenous application of ZnO and SiO₂ nanoparticles in a water deficit environment. Horticulturae 9(8):883. <https://doi.org/10.3390/horticulturae9080883>
- Ambika S, Sujatha K (2014). Comparative studies on brown, red and green alga seaweed extracts for their antifungal activity against *Fusarium oxysporum* f. sp. *udum* in Pigeon pea var. CO (Rg)7 (*Cajanus cajan* (L.) Mills.). Journal of Biopesticides 7:167-176.
- Amita VB, Urfi F, Devi S (2021). Varietal evaluation of different floribunda rose (*Hybrid teas x polyanthas*) under Prayagraj agro-climatic conditions. International Journal of Current Microbiology & Applied Sciences 10:3028-3035. <https://doi.org/10.20546/ijcmas.2021.1001.352>
- Apte AR, Kamble SS (2008). Efficacy of carbendazim in combating castor blight in western Maharashtra. Bioinfolet 5:73-74.
- Ara J, Ehteshamul-Haque S, Sultana V, Qasim R, Ghaffar A (1996). Effect of *Sargassum* seaweed and microbial antagonists in the control of root rot disease of sunflower. Pakistan Journal of Botany 28:219-224.
- Armanious HAH (2016). Verticillium wilt on rose plants in Minia governorate and its control. Egyptian Journal of Phytopathology 44:133-153. <https://doi.org/10.21608/ejp.2016.91551>
- Arora H, Sharma A, Sharma S, Haron FF, Gafur A, Sayyed RZ, Datta R (2021). Pythium damping-off and root rot of *Capsicum annuum* L.: Impacts, diagnosis, and management. Microorganisms 9:823. <http://doi.org/10.3390/microorganisms9040823>
- Barguil BM, Viana FMP, Anjos RM, Cardoso JE (2019). First report of dry rot caused by *Fusarium oxysporum* on rose (*Rosa* spp.) in Brazil. Plant Disease 93(7):766. <http://doi.org/10.1094/PDIS-93-7-0766A>
- Barnett HL, Hunter BB (1986). Illustrated genera of imperfect fungi. 4th ed., Macmillan Publishing Co., New York.
- Baysal-Gurel F, Kabir N (2018). Comparative performance of fungicides and biocontrol products in suppression of *Rhizoctonia* root rot in viburnum. Journal of Plant Pathology & Microbiology 9:451. <http://doi.org/10.4172/2157-7471.1000451>

- Ben Salah I, Aghrouss S, Douira A, Aissam S, El Alaoui-Talibi Z, Filali-Maltouf A, El Modafar C (2018). Seaweed polysaccharides as bio-elicitors of natural defenses in olive trees against *Verticillium* wilt of olive. *Journal of Plant Interactions* 13:248-255. <http://doi.org/10.1080/17429145.2018.1471528>
- Bi G, Evans WB, Spiers JM, Witcher AL (2010). Effects of organic and inorganic fertilizers on marigold growth and flowering. *HortScience* 45(9):1373-1377. <http://doi.org/10.21273/HORTSCI.45.9.1373>
- Blake CA (1956). *Methods of soil analysis. Part I and II.* American Society of Agronomy. Publ. Madison. Wise U.S.A.
- Booth C (1977). *Fusarium laboratory guide to the identification of the major species.* Commonwealth Agricultural Bureaux Commonwealth Mycological Institute, Kew, Surrey, England, pp 1-58.
- Bordoloi S, Talukdar MC (2019). Effect of GA₃ and biofertilizer on growth and yield parameters of Anthurium (*Anthurium andreanum* Lindex Ex Andre) cv. Tropical in soilless culture. *International Journal of Current Microbiology & Applied Sciences* 8:1157-1165. <https://doi.org/10.20546/ijcmas.2019.807.137>
- Chérif M, Benhamou N, Bélanger RR (1994). Defense responses induced by soluble silicon in cucumber roots infected by *Pythium* spp. *Phytopathology* 84:236-242.
- Christopher DJ, Suthinraj T, Usharani S, Udhayakumar R (2010). Role of defense enzymes activity in tomato as induced by *Trichoderma virens* against Fusarium wilt caused by *Fusarium oxysporum* f.sp. *lycopersici*. *Journal Bio Pesticides* 3:158-162.
- Dachung G, Kalu M (2019). Effect of organic and inorganic fertilizers on the early growth of *Tamarindus indica* L. in Makurdi, Nigeria. *Journal of Research in Forestry, Wildlife and Environment* 11:1-7.
- Datnoff LE, Elmer WH, Huber DM (2007). *Mineral Nutrition and Plant Disease.* St. Paul Davis: APS Press.
- De Borba MC, de Freitas MB, Stadnik MJ (2019). Ulvan enhances seedling emergence and reduces Fusarium wilt severity in common bean (*Phaseolus vulgaris* L.). *Crop Protection* 118:66-71. <https://doi.org/10.1016/j.cropro.2018.12.014>
- Devdhara UR, Polara ND, Gawade NV (2019). Effect of foliar application of biostimulants and micronutrients on growth and flowering of African marigold cv. Pusa Narangi Gaiinda. *International Journal of Chemical Studies* 7(6):764-768.
- Dubey MK, Zehra A, Aamir M, Yadav M, Samal S, Upadhyay RS (2020). Isolation, identification, carbon utilization profile and control of *Pythium graminicola*, the causal agent of chilli damping-off. *Journal of Phytopathology* 168:88-102. <https://doi.org/10.1111/jpb.12872>
- El Boukhari MEM, Barakate M, Bouhia Y, Lyamlouli K (2020). Trends in seaweed extract based biostimulants: manufacturing process and beneficial effect on soil-plant systems. *Plants* 9:359. <https://doi.org/10.3390/plants9030359>
- El-Mokadem HE, Sorour M (2014). Effect of bio and chemical fertilizers on growth and flowering of *Petunia hybrida* plants. *American Journal of Plant Physiology* 9:68-77. <http://doi.org/10.3923/ajpp.2014>
- El-Naggar AH, El-Sayed SG (2008). Response of *Dianthus caryophyllus* L. plants to foliar nutrition. *Journal of Agricultural and Environmental Sciences* 7:53-67.
- Esserti S, Smaili A, Rifai LA, Koussa T, Makroum K, Belfaiza M, Kabil EM, Faize L, Burgos L, Alburquerque N (2017). Protective effect of three brown seaweed extracts against fungal and bacterial diseases of tomato. *Journal of Applied Phycology* 29:1081-1093. <http://doi.org/10.1007/s10811-016-0996-z>
- Farahani H, Sajedi NA, Madani HM, Changizi M, Naeini MR (2021). Effect of foliar-applied silicon on flower yield and essential oil composition of Damask rose (*Rosa damascena* Miller) under water deficit stress. *Silicon* 13:4463-4472. <http://doi.org/10.1007/s12633-020-00762-1>
- Farr DF, Rossman AY (2016). *Fungal databases, Systematic Mycology and Microbiology Laboratory, ARS, USDA.* Retrieved 2016 March 14th from: <http://nt.ars-grin.gov/fungaldatabases/>
- Gahukar RT (2003). Factors influencing thrips abundance and distribution on rose flowers in central India. *Journal of Entomological Research* 27:271-279.
- Gamliel A, Katan T, Yunis H, Katan J (1996). Fusarium wilt and crown rot of sweet basil: Involvement of soil-borne and airborne inoculum. *Phytopathology* 86:56-62.
- Gastelum FR, Rodriguez GH, Valenzuela CM (2014). First report of powdery mildew (*Podosphaera pannosa*) of roses in Sinaloa, Mexico. *Plant Disease* 98:1442. <https://doi.org/10.1094/pdis-06-14-0605-pdn>

- Gomaa MA, Kandil EE, El-Dein AAMZ, Abou-Donia MEM, Ali HM, Abdelsalam NR (2021). Increase maize productivity and water use efficiency through application of potassium silicate under water stress. *Scientific Reports* 11(1):224. <http://doi.org/10.1038/s41598-020-80656-9>
- Gudin S (2000). Rose genetics and breeding. In: Janick J (Ed). John Wiley and Sons 17:159-189. <http://doi.org/10.1002/9780470650134.ch3>
- Gupta N, Debnath S, Sharma S, Sharma P, Purohit J (2017). Role of nutrients in controlling the plant diseases in sustainable agriculture. *Agriculturally Important Microbes for Sustainable Agriculture: Volume 2: Applications in Crop Production and Protection*, pp 217-262. <http://doi.org/10.1007/978-981-10-5343-6-8>
- Hafez EH, Seleiman MF (2017). Response of barley quality traits, yield and antioxidant enzymes to water-stress and chemical inducers. *International Journal of Plant Production* 11:477-490. <https://doi.org/10.22069/ijpp.2017.3712>
- Hammett KRW (1971). Symptom differences between rose wilt virus and Verticillium wilt of roses. *Plant Disease Report* 55:916-920
- Hasanuzzaman M, Bhuyan M, Anee TI, Parvin K, Nahar K, Mahmud JA, Fujita M (2019). Regulation of ascorbate-glutathione pathway in mitigating oxidative damage in plants under abiotic stress. *Antioxidants* 8:384. <https://doi.org/10.3390/antiox8090384>
- Hasanvand F, Nejad AR (2016). Effect of potassium silicate on growth, physiological and biochemical characteristics of *Pelargonium graveolens* under salinity stress. *Iranian Journal of Horticultural Science* 48(4):743-752. <http://doi.org/10.22059/ijhs.2018.210950.1040>
- Herbert D, Philip PJ, Strange RE (1971). Determination of total carbohydrates. *Methods in Microbiology* 5:290-344.
- Hermosa R, Viterbo A, Chet I, Monte E (2012). Plant-beneficial effects of *Trichoderma* and of its genes. *Microbiology* 158:17-25. <https://doi.org/10.1099/mic.0.052274-0>
- Horn WA (1992). Micropropagation of rose (*Rosa* spp. L.). In: Bajaj YP (Ed). *Biotechnology in Agriculture and Forestry*. Berlin: 20-High-Tech and Micropropagation, Springer-Verlag, pp 320-340.
- Jackson ML (1973). *Soil chemical analysis*. Prentice Hall of India Private Ltd M-97, Delhi, India, pp 498.
- John MK (1970). Colorimetric determination of phosphorus in soil and plant materials with ascorbic acid. *Soil Science* 109:214-220.
- Kageyama K, Aoyagi T, Sunouchi R, Fukui H (2002). Root rot of miniature roses caused by *Pythium helicoides*. *Journal of General Plant Pathology* 68:15-20. <http://dx.doi.org/10.1007/PL00013047>
- Kawalekar SJ (2013). Role of biofertilizers and biopesticides for sustainable agriculture. *Journal of Bio Innovation* 2:73-78.
- Khalifa MMA, Fetyan NAH, Abdel-Magid MS, El-Sheery NI (2017). Effectiveness of potassium silicate in suppression white rot disease and enhancement physiological resistance of onion plants, and its role on the soil microbial community. *Middle East Journal of Agriculture Research* 6:376-394.
- Khan W, Rayirath UP, Subramanian S, Jithesh MN, Rayorath P, Hodges DM, Critchley AT, Craigie JS, Norrie J, Prithiviraj B (2009). Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation* 28:386-399. <http://doi.org/10.1007/s00344-009-9103-x>
- Kim CK, Oh JY, Chung JD, Burrell AM, Byrne DH (2004). Somatic embryogenesis from *in vitro* grown leaf explants of *Rosa hybrid* L. *HortScience* 39(6):1378-1380. <http://dx.doi.org/10.21273/HORTSCI.39.6.1378>
- Kularathne MAM, Srikrishnah S, Sutharsan S (2021). Influence of seaweed (*Padina antrillarum*) extract foliar application on growth and flowering of roses variety "Local". *International Journal of Applied Sciences and Biotechnology* 9(4):235-241. <http://doi.org/10.3126/ijasbt.v9i4.36010>
- Leandro A, Pereira L, Gonçalves AMM (2020). Diverse applications of marine macroalgae. *Marine Drugs* 18(1):17. <http://doi.org/10.3390/md18010017>
- Leslie JF, Summerell BA (2006). *The Fusarium Laboratory Manual*. Blackwell Publishing, Hoboken 1-2. <http://doi.org/10.1002/9780470278376>
- Li L, Kageyama K, Kinoshita N, Yu W, Fukui H (2007). Development of bioassay for screening of resistant rose against root rot disease caused by *Pythium helicoides* Drechsler. *Journal of the Japanese Society for Horticultural Science* 76(1):79-84.

- Mabrouki S, Lakhdar F, Bouhraoua J, Belarbi E, Khelifi S, Benba J, Etahiri S (2020). *In vitro* antifungal activity of seaweed extracts against *Sclerotium rolfsii*: a causal agent of root rot disease on sugar beet (*Beta vulgaris* L.). International Journal of Pharmaceutical Sciences Review and Research 63:90-97.
- Mahanty T, Bhattacharjee S, Goswami M, Bhattacharyya P, Das B, Ghosh A, Tribedi P (2017). Biofertilizers: a potential approach for sustainable agriculture development. Environmental Science and Pollution Research International 24(4):3315-3335. <http://doi.org/10.1007/s11356-016-8104-0>
- Mahmood KA (2022). Influence of seeds inoculation with PGPR, gibberellic acid and seaweed extract on seeds germination and seedling growth of *Acacia farnesiana* L. Euphrates Journal of Agriculture Science 14(1):59-77.
- Malav JK, Ramani VP (2017). Effect of silicon on nitrogen use efficiency yield and nitrogen and silicon contents in rice under loamy sand soil. Research Journal of Chemistry and Environment 21(4):58-63.
- Massoud HY, Abdel-Kader H.H, Ibrahim FR, Ibrahim AM (2016). Effect of mineral fertilizer and compost on vegetative growth and essential oil content of yarrow (*Achillea millefolium* L.) plant. Journal Plant Production 7:559-565. <https://doi.org/10.21608/jpp.2016.45523>
- Mead R, Curnow RN, Harted AM (1993). Statistical methods in agricultural and experimental biology. 2nd Ed., Chapman and Hall Ltd., London, pp 335.
- Mihajlovic M, Rekanovic E, Hrustic J, Tanovic B (2017). Methods for management of soil-borne plant pathogens. Pesticidi i Fitomedicina 32(1):9-24. <https://doi.org/10.2298/PIF1701009M>
- Mukhtar S, Shahid I, Mehnaz S, Malik KA (2017). Assessment of two carrier materials for phosphate solubilizing biofertilizers and their effect on growth of wheat (*Triticum aestivum* L.). Microbiology Research 20:107-117. <https://doi.org/10.1016/j.micres.2017.08.011>
- Nofal EMS, El-Mahrouk ME, El-Sayed BA, Radwan AMM (2021). Effect of NPK fertilizer and some natural extract treatments on the chemical composition of African marigold (*Tagetes erecta* L. var. Dwarf Chrysanthemum). Applied Ecology and Environmental Research 19(4):3167-3179. https://doi.org/10.15666/aeer/1904_31673179
- Olsen SR, Sommers LE (1982). Phosphorus. In: Page AI, Miller RH, Keeny TR (Eds). Methods of Soil Analysis. American Society of Agronomy: Madison, WI, USA, Part 2, pp 403-430.
- Pandey DK, Pandey A, Pandey AK, Singh KK (2020). Effect of nutrients on growth, flowering and yield of African marigold (*Tagetes erecta* L.) cv. Pusa Basanthi at Hadauti region. Indian Journal of Pure & Applied Biosciences 8(6):663-666. <http://dx.doi.org/10.18782/2582-2845.8575>
- Panth M, Hassler SC, Baysal-Gurel F (2020). Methods for management of soil-borne diseases in crop production. Agriculture 10:16. <https://doi.org/10.3390/agriculture10010016>
- Parinitha D, Seetharamu GK, Ramanna M, Taj A (2022). Effect of bio-stimulants and biofertilizers on quality and yield of *Floribunda roses*. Pharma Innovation 11(9):2372-2376.
- Patel VS, Malam VR, Nurbhanej KH, Vihol AN, Chavada JR (2017). Effect of organic manures and biofertilizers on growth, flowering and flower yield of rose (*Rosa hybrida* L.) cv. Gladiator. International Journal of Chemical Studies 5:1924-1927.
- Perrenoud S (1993). Fertilizing for High Yield Potato. In: IPI Bulletin 8, 2nd ed., International Potash Institute: Basel, Switzerland.
- Pinto E, Vale-Silva L, Cavaleiro C, Salgueiro L (2009). Antifungal activity of the clove essential oil from *Syzygium aromaticum* on *Candida*, *Aspergillus* and *Dermatophyte* species. Journal of Medical Microbiology 58(11):1454-1462. <https://doi.org/10.1099/jmm.0.010538-0>
- Pires TCSP, Dias MI, Barros L, Calhelha RC, Alves MJ, Oliveira MBPP, Santos-Buelga C, Ferreira ICFR (2018). Edible flowers as sources of phenolic compounds with bioactive potential. Food Research International 105:580-588. <https://doi.org/10.1016/j.foodres.2017.11.014>
- Qureshi AK, Farooq U, Shakeel Q, Ali S, Ashiq S, Shahzad S, ... Manachini B (2023). The green synthesis of silver nanoparticles from *Avena fatua* extract: Antifungal activity against *Fusarium oxysporum* f. sp. *lycopersici*. Pathogens 12(10):1247. <https://doi.org/10.3390/pathogens12101247>
- Reid DA, Hayward AC, Waterston JM (1965). CMI descriptions of pathogenic Fungi and Bacteria. Kew Bulletin 19:414.
- Rekanovic E, Potocnik I, Milijasevic-Marcic S, Stepanovic M, Todorovic B, Mihajlovic M (2010). Efficacy of seaweed concentrate from *Ecklonia maxima* (Osbeck) and conventional fungicides in the control of Verticillium wilt of pepper. Pesticidi i Fitomedicina 25(4):319-324. <https://doi.org/10.2298/PIF1004319R>

- Rodrigues FA, Duarte HSS, Domiciano GP, Souza CA, Korndörfer GH, Zambolim L (2009). Foliar application of potassium silicate reduces the intensity of soybean rust. *Australasian Plant Pathology* 38:366-372. <https://doi.org/10.1071/AP09010>
- Romero PIA, Velasco RG, Herrera MEM, Siclan MLS, Serrano DD (2018). Identification and alternative management of downy mildew in rose. *Revista Mexicana De Ciencias Agrícolas* 9(8):1577-1589. <http://doi.org/10.29312/remexca.v9i8.1715>
- Saad ASA, Kadous EA, Tayeb EH, Massoud MA, Ahmed SM, Abou El-Ela ASA (2014). The inhibitory effect of some antioxidants and fungicides on the growth of *Alternaria solani* and *Fusarium solani* *in vitro*. *Middle East Journal of Agriculture Research* 3:123-134.
- Sahi IY, Khalid AN (2007). *In vitro* biological control of *Fusarium oxysporum* causing wilt in *Capsicum annuum*. *Mycopathology* 5:85-88.
- Sahu D, Prasad VM, Fatmi U (2021). Effect of NPK on organic manures of flowering and flower yield of dahlia (*Dahlia variabilis* L.) cv. Kenora Sunburst. *International Journal of Current Microbiology & Applied Sciences* 10:643-650. <https://doi.org/10.20546/ijcmas.2021.1003.082>
- Salamone A, Scarito G, Pane A, Cacciola SO (2011). Root and basal stem rot of rose caused by *Phytophthora citrophthora* in Italy. *Plant Disease* 95:358-360. <http://doi.org/10.1094/PDIS-09-10-0659>
- Saleem K, Asghar MA, Raza A, et al. (2023). Alleviating drought stress in strawberry plants: unraveling the role of paclobutrazol as a growth regulator and reducer of oxidative stress induced by reactive oxygen and carbonyl species. *Journal of Plant Growth Regulation*. <https://doi.org/10.1007/s00344-023-11120-x>
- Seleiman MF, Ahmad A, Alhammad BA, Tola E (2023). Exogenous application of zinc oxide nanoparticles improved antioxidants, photosynthetic, and yield traits in salt-stressed maize. *Agronomy* 13(10):2645. <https://doi.org/10.3390/agronomy13102645>
- Sevilla-Perea A, Mingorance MD (2015). Field approach to mining-dump revegetation by application of sewage sludge co-compost and a commercial biofertilizer. *Journal of Environmental Management* 58:95-102. <http://doi.org/10.1016/j.jenvman.2015.04.017>
- Shukla PS, Mantin EG, Adil M, Bajpai S, Critchley AT, Prithiviraj B (2019). *Ascophyllum nodosum*-based biostimulants: sustainable applications in agriculture for the stimulation of plant growth, stress tolerance, and disease management. *Frontiers in Plant Science* 10:655. <https://doi.org/10.3389/fpls.2019.00655>
- Sinha R (2017). Study on rose diseases: identification, detection and cure. *IJEDR* 5:287-295.
- Sumangala K, Srikrishnah S, Sutharsan S (2019). Roses growth and flowering responding to concentration and frequency of seaweed (*Sargassum crassifolium* L.) liquid extract application. *Current Agriculture Research Journal* 7(2):236-244. <http://dx.doi.org/10.12944/CARJ.7.2.11>
- Sumanta N, Haque CI, Nishika J, Suprakash R (2014). Spectrophotometric analysis of chlorophylls and carotenoids from commonly grown Fern species by using various extracting solvents. *Research Journal of Chemical Sciences* 4(9):63-69. <http://doi.org/10.1055/s-0033-1340072>
- Synge PM (1971). *The dictionary of rose in color*. 1st Edn., Madison Square Press, New York, ISBN- 10:0448025043, pp 191.
- Taha RS, Seleiman MF, Alhammad BA, Alkahtani J, Alwahibi MS, Mahdi AH (2021). Activated Yeast extract enhances growth, anatomical structure, and productivity of *Lupinus termis* L. plants under actual salinity conditions. *Agronomy* 11(1):74. <https://doi.org/10.3390/agronomy11010074>
- UL-Nisa M, Slathia D, Nazki IT, Mushtaq N, Malik KM (2016). Impact of integrated use of biofertilizers with reduced doses of chemical fertilizers in flower crops. *Advances in Life Sciences* 5(21):9555-9559.
- Velasco-Ramírez SF, Velasco P, Hernández-Herrera RM, Garcia-Contreras FM (2020). Effect of liquid seaweed extract on potted growth of (*Eustoma grandiflorum* (Raf.) Shinners. *Tropical and Subtropical Agroecosystems* 23:44.
- Wang M, Gao L, Dong S, Sun Y, Shen Q, Guo S (2017). Role of silicon on plant–pathogen interactions. *Frontiers in Plant Sciences* 5:701. <http://doi.org/10.3389/fpls.2017.00701>
- Whan JA, Dann EK, Aitken EA (2016). Effects of silicon treatment and inoculation with *Fusarium oxysporum* f. sp. *vasinfectum* on cellular defenses in root tissues of two cotton cultivars. *Annals of Botany* 118(2):219-226. <http://doi.org/10.1093/aob/mcv095>

- Whitaker VM, Zuzek K, Hokanson SC (2007). Resistance of 12 rose genotypes to 14 isolates of *Diplocarpon rosae* Wolf (rose black spot) collected from eastern North America. Plant Breeding 126:83-88. <https://doi.org/10.1111/j.1439-0523.2007.01339.x>
- Whitehead MD (1957). Sorghum, a medium suitable for the increase of inoculum for studies of soil-borne and certain other fungi. Phytopathology 47:450.
- Williamson B, Tudzynski B, Tudzynski P, Van Kan JA (2007). *Botrytis cinerea*: the cause of grey mold disease. Molecular Plant Pathology 8(5):561-580. <http://doi.org/10.1111/j.1364-3703.2007.00417.x>
- Yan H, Zhang H, Wang Q, Jian H, Qiu X, Baudino S, Just J, Raymond O, Gu L, Wang J, Bendahmane M, Tang K (2016). The *Rosa chinensis* cv. *viridiflora* phyllody phenotype is associated with miss expression of flower organ identity genes. Plant Science 7:996. <http://doi.org/10.3389/fpls.2016.00996>
- Zheng Y, Xue QY, Xu LL, Xu Q, Lu S, Gu CA (2011). A screening strategy of fungal biocontrol agents towards Verticillium wilt of cotton. Biological Control 56:209-216. <https://doi.org/10.1016/j.biocontrol.2010.11.010>



The journal offers free, immediate, and unrestricted access to peer-reviewed research and scholarly work. Users are allowed to read, download, copy, distribute, print, search, or link to the full texts of the articles, or use them for any other lawful purpose, without asking prior permission from the publisher or the author.



License - Articles published in *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* are Open-Access, distributed under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) License. © Articles by the authors; Licensee UASVM and SHST, Cluj-Napoca, Romania. The journal allows the author(s) to hold the copyright/to retain publishing rights without restriction.

Notes:

- **Material disclaimer:** The authors are fully responsible for their work and they hold sole responsibility for the articles published in the journal.
- **Maps and affiliations:** The publisher stay neutral with regard to jurisdictional claims in published maps and institutional affiliations.
- **Responsibilities:** The editors, editorial board and publisher do not assume any responsibility for the article's contents and for the authors' views expressed in their contributions. The statements and opinions published represent the views of the authors or persons to whom they are credited. Publication of research information does not constitute a recommendation or endorsement of products involved.