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Research Article

Impacts of Compost Application on Controlling Powdery Mildew of Dill (*Anethum graveolens* L.) Caused by *Erysiphe heraclei* and its Effect on Soil Fertility and Productivity

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ABSTRACT

Field experiments were carried out under natural infection in the Experimental Farm of Sids Agricultural Research Station, Agricultural Research Center, Beni-Sweif governorate in 2017 and 2018 to evaluate the efficiency of compost amended with rock phosphate, gypsum and inoculated by some bioagents (*Bacillus subtilis, Trichoderma harzianum* and *Arbuscular mycorrhizal* fungi) in controlling of powdery mildew on dill caused by *Erysiphe heraclei* and improving its productivity as well as soil fertility using two application methods: soil amendment and/or foliar spray. Overall, all the tested compost treatments were effective in reducing the disease incidence, severity and improve plant growth leading to a significant increase in fresh, dry weights and fruits yield, NPK uptake. Furthermore, all the tested treatments showed significant increases in the defence-related enzymes, peroxidase, polyphenol oxidase and phenols in treated plants as compared with the untreated control. However, compost treatments improve some physical and chemical properties of the soil at the end of growing seasons and increase dehydrogenase activity as a result of enhancing soil fertility.

Keywords: Powdery mildew; Rock phosphate; Gypsum; *Erysiphe heraclei*; Bioagents; Defence-related enzymes; Phenol; Dehydrogenase activity; Soil fertility; Productivity; Dill

INTRODUCTION

Dill (*Anethum graveolens* L.) is an annual aromatic and medicinal plants belonging to the family Apiaceae, which is commonly used for flavoring as fresh leaves. The dill fruits are a rich source of various metabolite groups, including volatile oil, coumarins, flavonoids, phenolic acids, fatty oil and minerals. Carvone is the most important constituent of dill, used as a diuretic, stimulant and a carminative in pharmaceutical industry [1].

Powdery mildew caused by *E. heraclei* is one of the most important restricting factors for the production of dill in Egypt [2]. The disease appeared at all stages of growth, a white fungal progressively spread from the basal leaves and petioles to the entire plant with disease incidence and severity that often reached 100% [3].

Severely diseased leaves have become twisted and the disease may have contributed to premature senescence and plant drying [4]. Recently, chemical free-production and food safety has been one of the main objectives related to fresh products as a valuable medicinal plant to ensure the product's high quality and safety [5]. Hence, using alternatives to synthetic fungicides and chemical fertilizers, or at least minimizing the levels of these chemical fertilizers, would be beneficial [6]. Additionally, the soil health is degrading with extensive tillage operations without adding of organic matter.

Compost as organic material influences agricultural sustainability by improving soil chemical, physical, biological properties as well as fertility by improving soil organic matter quality and soil structure and the moisture holding capacity [7], supplies a wide range of beneficial microorganisms [8] and

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essential plant nutrients to stimulate plant growth and yields [1]. However, the use of compost as soil amendments and their water extracts can provide natural biological control against foliar diseases [9-11] and improve plant health [12].

Nutrients are essential for plant growth and development and they are important factors in disease control [13] that may influence disease resistance or tolerance by increasing the capacity of the host plant to restrict invasive pathogens' penetration, development and reproduction [14]. Calcium is a major structural component of both cell walls and other plant membranes such as those surrounding organelles.

A calcium deficiency results in tissues of plants that are less capable of actively fighting disease organism invasion, including downy and powdery mildew [15]. Phosphorus, the second most commonly off- putting macronutrient for plant augmentation after nitrogen, which plays an important role in virtually all major metabolic processes in plants and pathogen [16].

Phosphorus (P) is one of the major growth-limiting nutrients in plants, although it is abundant in soils as it is in an unavailable form for root uptake. In sustainable agriculture, the use of natural rock phosphate as a source of phosphorus and gypsum ($CaSO_4.2H_2O$) as a calcium and sulphur fertilizer or as a soil conditioner at higher rates is more benefits than synthetic fertilizer. However, these elements have been used to induce systemic resistance and affect overall control of powdery mildew in crops [17-19].

Bio-control agents such as *B. subtilis, T. harzianum* and Arbuscular mycorrhizal fungi (AM) have the ability to control powdery mildew [20,21], provide plants with growth promoting substances and play an important role in phosphate solubilizing and supplying P to plants [22-24]. Therefore, this study was aimed to evaluate the potential of compost amended with rock phosphate, gypsum and inoculated by some bioagents (*B. subtilis, T. harzianum* and Arbuscular mycorrhizal Fungi) to control powdery mildew on dill and its productivity as well as soil fertility under field conditions in two application methods: soil amend ment and/or foliar spray.

MATERIALS AND METHODS

Preparation of compost and compost extracts

The organic waste material used in compost preparation was medicinal and aromatic plants straw after distillation for oil extraction. Medicinal and aromatic plants straw was cut into small pieces and taken to make the heaps (about 12 heaps each containing 50 kg straw). Farm yard manure (FYM) was applied to each heap at the rate of 100 kg/ton. The materials of conditioners used and their application rates were gypsum (5%) at the rate of 50 kg/ton and rock phosphate (2%) at the rate of 20 kg/ton.

The heaps were moistened with water and left up to the summer of each 2017 and 2018 growing season (four months). *B. subtilis* and Arbuscular mycorrhizal (mixed genera of *Glomus, Gigaspora* and *Acaulospora*) inoculums were used in this study were kindly obtained from Department of Microbiology, Soil, Water and Environment Res. Inst., ARC, Giza, Egypt while *T. harzianum* was isolated from rhizosphere of dill plants and identified in Assiut University, Mycological Center, Faculty of Science, Assiut, Egypt (AUMC).

Bacterial suspension was multiplied by cultivating *B. subtilis* in nutrient broth medium where 500 ml conical flasks containing 200 ml of the respective media were inoculated by one ml bacterial inoculums of 24 h old culture and incubated in rotary shaking incubator (120 rpm) at 28 ± 2°C for 48 h., while *T. harzianum* was grown in *Trichoderma*-selective medium broth (TSM) [25], amended with 300 mg/l streptomycin and 50 $\mu g\ ml^{-1}$ rose Bengal in conical flask, incubated at 25°C for 15 days.

Trichoderma (1 × 10^6 conidia/ml), Bacillus (1 × 10^8 cfu) suspensions at the rate of 2L/ton compost and AM fungi at the rate of 1 kg AM/ton compost were added individually to the composting materials as a biodegradable agent a month after composting in order to accelerate the composting process [26]. During composting process, water was monitored every week throughout the composting period to maintain it at 60% [27].

Total 12 treatments were prepared by thoroughly mixing the medicinal and aromatic plants straw with different additives. Treatments were arranged in piles according to the components of each pile and laid out in randomized block design, replicated three times and periodically was monitored during the process of composting until maturation.

For preparation of compost extract, 1 kg of mature compost from each treatment was mixed individually with 20 L of water in a container (ratio 1:20). The compost mixtures were homogenized and incubated in the laboratory for 7-8 days. Compost extracts were filtered through several layers of cheesecloth. The resultant compost extracts were applied as spray onto dill leaves. Some characteristics of compost and compost extracts were performed.

In vitro assay

Effect of compost extracts on conidial germination: Drops of the tested compost extracts were placed on glass slides and conidia of *E. heraclei* were directly lifted with help of small paint brush from heavily infected dill leaves. The slides were then placed in moist chambers prepared by placing two moist filter papers in the inner surfaces of a Petri plate. Conidia immersed in distilled water only as well as the fungicide Topas 100 EC suspension served as the control. Three replications were made for each treatment. The slides were incubated at 25 ± 2°C for 24 h and the percent of germination was calculated under a light microscope.

Field experiments: A two-year field experiment was performed under natural infection in the Experimental Farm of Sids Agricultural Research Station, Agricultural Research Center, Beni-Sweif governorate during the two growing seasons of 2017 and 2018 to assess the potential of compost amended with rock phosphate, gypsum and inoculated by some bioagents (*B. subtilis, T. harzianum* and AM fungi) to control powdery mildew on dill and its productivity as well as soil fertility in two application methods: soil amendment and/or foliar spray.

Some physical and chemical characteristics of the studied soil before planting, FYM and organic residue (medicinal and aromatic plants straw) used in this study were presented in Table 1. The experiment was set in a randomized complete blocks design with two factors, three replications for each treatment. The first factor (main plot) assigned to the treatments tested and the second one (subplot, 3 × 3.5 m) to application methods.

During both experimental seasons, the following treatments were applied as soil amendment and/or foliar spray:

T_1: Compost; T_2: Compost + Gypsum; T_3: Compost + Phosphate rock; T_4: Compost + AM fungi; T_5: Compost + *B. subtilis*; T_6: Compost + *T. harzianum*; T_7: Compost + Gypsum + AM fungi; T_8: Compost + Gypsum + *B. subtilis*; T_9: Compost + Gypsum + *T. harzianum*; T_{10}: Compost + Phosphate rock + AM fungi; T_{11}: Compost + Phosphate rock + *B. subtilis*; T_{12}: Compost + Phosphate rock + *T. harzianum*; T_{13}: The fungicide Topas 100 EC at the rate of 25 cm ^{3}/100L water and T_{14}: Untreated control.

Table 1: Physico-chemical characteristics analysis of soil before sowing, FYM and medicinal and aromatic plants straw.

Characteristics	Soil	FYM	Organic residue
Particle size distributions (%)			
Coarse sand	4.55		
Fine sand	9.22		
Silt	32.48		
Clay	53.75		
Textural class	Clay		
ESP	17.20		
Field capacity	39.55		
Wilting point	18.20		
Available water	21.35		
pH*	8.58	7.889	
Total carbonate (%)	1.55		
Organ carbon (%)	0.727	23.019	54.0
Organic matter (%)	1.211	39.688	93.0
EC ds/m* (1:5)	1.58	8.26	
Cation exchange capacity (mg/ 100 g)	33.75		
Total nitrogen (%)	0.132		
Available N mg/kg soil	47.37	1.408**	0.579**
Available P mg/kg soil	7.52	0.403**	0.469**
Available K mg/kg soil	211	1.135**	0.845**
C/N ratio	6.30	16.35	93.3

pH (soil paste) in soil and (1:10) in FYM EC ds/m (soil paste) in soil and (1:10) in FYM** Total contents (%)

Application treatments were thoroughly mixed with the surface soil (0-15 cm) during the soil preparation at the rate of 6 ton/ fed. Recommended field practices were undertaken (N, P and K as recommended fertilizers). Dill fruits were sown in the field at the rate of 10 kg/fed on October, 15th in the two experimental seasons.

Weeds were removed by manual operations as needed and plants were irrigated regularly as necessary, throughout the growing seasons to maintain constant growth. The plants were sprayed every 10 days, always performed early in the morning with the tested compost extracts, 1% Tween 20 before the appearance of first symptoms until run off. Monitoring and scouting the plants weekly for the appearance of powdery mildew and disease incidence and severity were estimated as follow:

Disease incidence: Percentage of disease incidence was recorded for each treatment and then the average of disease incidence was calculated.

Disease severity: Disease severity was measured according to [28]. Percentage of disease severity was recorded according to the following equation:

$$\text{Disease severity (\%)} = [\sum (n \times c)]/(N \times C) \times 100$$

Whereas: n = Number of infected leaves, c = Category number, N = Total number of examined leaves and C = The highest category number of infection.

The plants were harvested two times in each growing season. The first cut was done on 1st January; the second one was done on 15th February by cutting the vegetative parts of the plants 10 cm above the soil surface with three replications in each cut. Fresh and dry weights of herb yield (ton/fed.) were determined.

At fruiting stage, plant height (cm), branch number/plant and umbel number/plant were determined as average from replicates. At the end of experiments dill fruits in each plot were harvested and weighed. Nutrients content of dill herbs and fruits were analyzed according to Chapman and Pratt [29]. Some physical and chemical characteristics of the studied soil were determined according to Piper [30] and Jackson [31].

Peroxidase activity was determined using the method described in the Worthington enzyme manual [32]. Polyphenol oxidase activity was measured following the method described by Esterbaner et al. [33]. Analysis of enzymes were carried at the Central Laboratory of Biotechnology, Plant Pathology Research Institute, ARC. Dehydrogenase activity was determined according to the method described by Thalmann [34] at the Soil, Water & Environment Research Institute. Total phenol was was estimated using Folin ciocalteau reagent method described by Lafka et al. [35].

Data were statistically analyzed for computing L.S.D. test at 5% probability according to the procedure outlined by Snedecor and Cochran [36].

RESULTS

Physical and chemical properties of compost and compost extract as affected by addition of different supplements

Data presented in Table 2, showed the effect of composting treatments (gypsum, phosphate rock and bioagents) on the resultant compost and compost extracts. Overall, addition of tested materials of conditioners and bioagents to compost increased electrical conductivity (EC), organic carbon (OC), organic material (OM) contents and decrease pH and C/N ration in compost as well as increased NPK content in compost and compost extracts than unamended compost.

Table 2: Some characteristics of the resultant compost and compost extracts as affected by the tested materials of conditioners and bioagents.

	Mean of the two growing seasons										
	Compost analysis								Compost extracts analysis		
Treatments	EC ds/m (1:10)	pH (1:10)	OC (%)	OM (%)	C/N ratio	N (%)	P (%)	K (%)	N* ppm	P* ppm	K* Ppm
T_1	3.92	8.34	17.47	30.12	15.32	1.14	0.32	0.93	700	114.88	1308.25
T_2	5.60	8.12	19.16	33.03	14.07	1.36	0.36	1.05	810	124.48	1528.50
T_3	5.07	8.29	18.28	31.51	13.73	1.33	0.37	1.14	770	140.64	1568.00
T_4	5.30	8.29	18.04	31.10	13.55	1.33	0.35	1.08	750	117.28	1507.00
T_5	5.76	8.31	18.71	32.26	14.47	1.29	0.35	1.08	780	122.72	1463.00
T_6	5.02	8.33	18.62	32.10	14.07	1.32	0.34	1.07	770	120.00	1533.50
T_7	4.96	8.01	18.04	31.10	13.56	1.39	0.38	1.07	825	130.72	1585.75
T_8	5.29	8.05	19.84	34.20	14.98	1.39	0.39	1.10	865	135.36	1590.25
T_9	4.88	8.01	19.60	33.79	15.26	1.40	0.38	1.08	850	132.00	1628.75
T_{10}	5.18	8.19	18.87	32.53	14.67	1.39	0.42	1.15	825	141.76	1660.25
T_{11}	4.90	8.15	20.23	34.88	15.36	1.38	0.43	1.17	820	145.28	1645.50
T_{12}	5.16	8.17	20.23	34.88	15.82	1.38	0.42	1.13	810	143.84	1685.25

*Soluble NPK in compost extract.

Effect of compost extract on spore germination of *E. heraclei in vitro*

Result presented in Table 3, showed that all the treatments significantly reduced the spore germination of the fungus.

The highest reduction was observed with the treatments of fungicide Topas 100 EC (T_{13}), compost + phosphate rock + *B. subtilis* treatment (T_{11}) and compost + phosphate rock + *T. harzianum* treatment (T_{12}) with no significant differences among them which caused 93.0%, 92.4% and 88.8% reduction in spore germination, respectively followed by treatments of compost + gypsum + *B. subtilis* (T_8) and compost + gypsum + *T. harzianum* (T_9) with averages of 83.6 and 72.4%, respectively. Moreover, moderate reduction was observed with the treatments of compost + *B. subtilis* (T_5) and compost + *T. harzianum* (T_6) with significant differences between them. The use of compost only (T_1) showed lowest inhibition in spore germination followed by treatments of compost + AM fungi (T_4) and compost + gypsum + AM fungi (T_7) with no significant differences among them. The corresponding mean values of reduction percent were 17.0%, 19.1% and 21.5%, respectively.

Table 3: Effect of different treatments of compost extract amended with soil conditioners and bioagents on spore germination of *E. heraclei*.

Treatments	Germination (%)	Reduction* (%)
T_1	27.4	17.0
T_2	25.3	23.3
T_3	22.0	33.3
T_4	26.7	19.1
T_5	13.5	59.1
T_6	15.4	53.3
T_7	25.9	21.5
T_8	5.4	83.6
T_9	9.1	72.4
T_{10}	23.4	29.1
T_{11}	2.5	92.4
T_{12}	3.7	88.8
T_{13}	2.3	93.0
T_{14}	33.0	--
L.S.D $_{0.05}$	1.9	--

*Reduction % related to the control.

Effect of compost and compost extract on powdery mildew disease incidence and severity

Data presented in Tables 4 and 5 and Figure 1 illustrated that there were significant differences between treatments in their effect on powdery mildew incidence and severity. In general, addition of phosphate rock and gypsum with bioagents to compost was more efficient than each one alone. Among all treatments, the fungicide Topas 100 EC (T_{13}) was the most efficient in this regard which recorded the lowest disease incidence, being 8.9% and 13.1%, respectively for the two plant cuts and significantly delayed the progress of dill powdery mildew to 5.8% and 8.5%, respectively followed by compost + phosphate rock + *B. subtilis* treatment (T_{11}) and compost + phosphate rock + *T. harzianum* treatment (T_{12}). The corresponding mean values in disease incidence were 12.7% & 24.4% and 14.6% & 27.8% and disease severity, being 8.9% & 9.5% and 10.8% & 12.4%, respectively for the two plant cuts in the first growing season (2017).

Application of compost + gypsum + *B. subtilis* (T_8) showed moderate efficiency in reducing disease incidence and severity followed by compost + gypsum + *T. harzianum* (T_9). On the other hand, addition of bioagents to compost increased its efficiency in reducing the disease incidence and severity than addition of phosphate rock or gypsum to compost. In this regard, treatment of compost + *B. subtilis* (T_5) showed more efficient followed by compost + *T. harzianum* (T_6). Application of compost only without any addition gave the lowest efficiency. The same trend was observed in the second growing season (2018).

Generally, the effectiveness of the tested treatments significantly varied according to application method. Soil amendment with the tested treatments and sprayed the leaves with compost extracts was the most effective in reducing the disease incidence and severity than sprayed the leaves by compost extracts only.

Table 4: Effect of different compost treatments on the incidence of powdery mildew through the two dill plant cuts during the two successive growing seasons 2017 and 2018 under field conditions.

Treatments (T)	Disease incidence (%)					
	Application methods (M)					
	Season of 2017					
	1 st cut			2 nd cut		
	Soil amendment + foliar spray	Foliar spray	Mean (T)	Soil amendment + foliar spray	Foliar spray	Mean (T)
T_1	54.1	58.4	56.3	77.2	85.8	81.5
T_2	45.8	50.5	48.2	67.9	77.2	72.6

T_3	40.7	44.0	42.4	61.4	71.7	66.6
T_4	39.6	57.9	48.8	61.3	83.2	72.3
T_5	24.9	28.8	26.9	43.4	50.6	47.0
T_6	31.0	35.0	33.0	53.9	61.9	57.9
T_7	28.8	52.2	40.5	43.8	78.1	61.0
T_8	15.8	20.9	18.4	29.4	37.7	33.6
T_9	17.4	21.9	19.7	32.1	39.4	35.8
T_{10}	25.1	46.8	36.0	42.9	68.3	55.6
T_{11}	10.4	15.0	12.7	20.6	28.2	24.4
T_{12}	11.8	17.3	14.6	23.0	32.6	27.8
T_{13}	7.9	9.8	8.9	10.6	15.5	13.1
T_{14}	66.5	65.8	66.2	90.0	95.6	92.8
Mean (M)	30.0	37.5	--	47.0	59.0	--
L.S.D $_{0.05}$	T = 1.6 M = 0.6 TM = 2.3			T = 2.7 M = 1.0 TM = 3.8		
			Season of 2018			
T_1	55.3	62.3	58.8	80.1	83.4	81.8
T_2	45.8	51.0	48.4	68.6	74.7	71.7
T_3	40.3	48.4	44.4	60.8	68.2	64.5
T_4	39.5	60.7	50.1	60.4	80.1	70.3
T_5	23.8	32.6	28.2	43.5	49.3	46.4
T_6	30.8	41.9	36.4	53.6	57.9	55.8
T_7	29.0	48.4	38.7	42.4	72.3	57.4
T_8	13.5	20.9	17.2	27.9	36.0	32.0
T_9	15.8	25.4	20.6	30.6	39.4	35.0
T_{10}	24.2	47.4	35.8	41.5	64.9	53.2
T_{11}	9.4	16.2	12.8	20.1	29.1	24.6
T_{12}	11.6	19.6	15.6	21.3	35.5	28.4
T_{13}	8.9	10.5	9.7	10.7	13.8	12.3
T_{14}	69.7	73.2	71.5	93.5	94.0	93.8
Mean (M)	29.8	39.9	--	46.8	57.0	--
L.S.D $_{0.05}$	T = 1.8 M = 0.7 TM = 2.6			T = 2.6 M = 1.0 TM = 3.7		

Table 5: Effect of different compost treatments on severity of powdery mildew through the two dill plant cuts during the two successive growing seasons 2017 and 2018 under field conditions.

Treatments (T)	Disease severity					
	Application methods (M)					
	Season of 2017					
	1 st cut			2 nd cut		
	Soil amendment + foliar spray	Foliar spray	Mean (T)	Soil amendment + foliar spray	Foliar spray	Mean (T)
T_1	38.8	43.3	41.1	53.1	62.6	57.9
T_2	34.8	40.2	37.5	47.3	53.5	50.4
T_3	31.9	37.6	34.8	42.6	58.2	50.4
T_4	35.6	42.0	38.8	50.4	60.0	55.2
T_5	14.0	23.6	18.8	30.1	35.9	33.0
T_6	19.2	27.3	23.3	36.8	40.8	38.8
T_7	22.3	36.7	29.5	38.9	51.4	45.2
T_8	8.4	15.3	11.9	10.9	17.0	14.0
T_9	10.7	18.9	14.8	15.1	26.2	20.7
T_{10}	18.2	34.1	26.2	33.0	55.2	44.1
T_{11}	6.0	11.7	8.9	6.2	12.8	9.5
T_{12}	6.9	14.7	10.8	8.2	16.6	12.4
T_{13}	4.4	7.1	5.8	5.5	11.4	8.5
T_{14}	45.3	47.9	46.6	67.0	68.6	67.8
Mean (M)	21.2	28.6	--	31.8	40.7	--
L.S.D $_{0.05}$	T = 2.2 M = 0.8 TM = 4.1			T = 2.2 M = 0.8 TM = 3.2		
	Season of 2018					
T_1	40.2	45.8	43.0	51.3	60.4	55.9
T_2	34.2	39.4	36.8	43.9	50.9	47.4
T_3	29.0	35.3	32.2	40.6	45.6	43.1

T_4	34.6	45.6	40.1	49.6	57.0	53.3
T_5	12.6	19.9	16.3	27.4	31.1	29.3
T_6	16.3	20.4	18.4	35.0	38.2	36.6
T_7	20.9	41.3	31.1	34.0	46.6	40.3
T_8	7.5	14.6	11.1	9.9	15.8	12.9
T_9	9.5	18.2	13.9	12.6	23.2	17.9
T_{10}	15.9	32.4	24.2	27.5	45.4	36.5
T_{11}	4.6	9.9	7.3	5.7	11.1	8.4
T_{12}	5.1	10.9	8.0	6.3	13.9	10.1
T_{13}	3.6	5.5	4.6	5.0	8.0	6.5
T_{14}	44.6	49.3	47.0	70.0	68.0	69.0
Mean (M)	19.9	27.8	--	29.9	36.8	--
L.S.D $_{0.05}$	T = 1.7 M = 0.6 TM = 2.4			T = 1.9 M = 0.7 TM = 2.7		

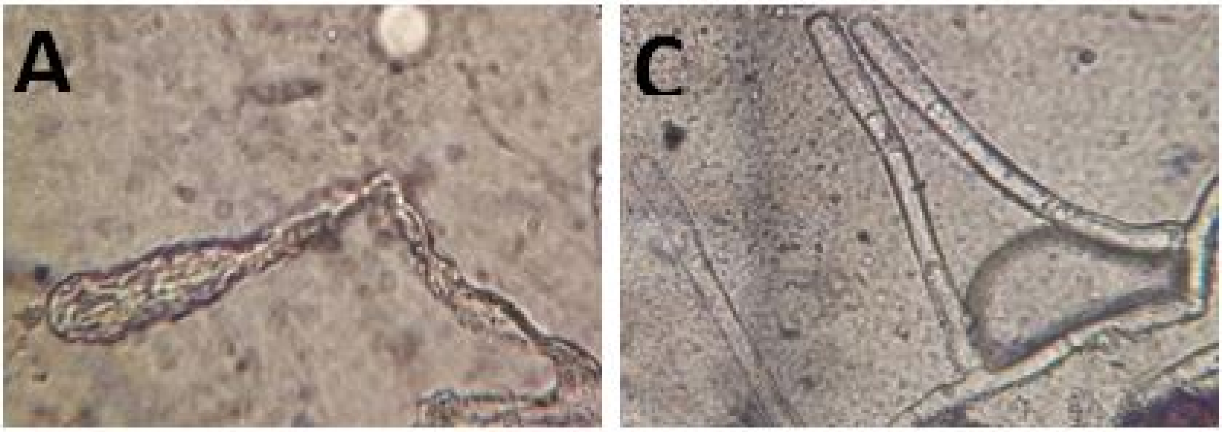

Figure 1: The malformation of *E. heraclei* conidia and conidiophore due to sprayed the dill leaves with compost + phosphate rock + *B. subtilis* treatment (A) (400x) compated to untreated control (C) (200x).

The interaction effect of the different compost treatments and their application methods was significant for the two plant cuts during the two successive growing seasons. Disease incidence and severity percent were the highest when dill plants sprayed by compost extract only (T_1) followed by treatment of sprayed the plants by compost + AM fungi extract with no significant differences between them while the lowest obtained with T_{13} (treatment of treated dill fruits and sprayed the leaves with the fungicide Topas 100 EC), being 7.9% & 10.6% for disease incidence and disease severity was 4.4% & 5.5%, respectively for the two plant cuts followed by T_{11} (treatment of soil amendment by compost + phosphate rock + *B. subtilis* and sprayed the leaves by their compost extract), T_{12} (treatment of soil amendment by compost + phosphate rock + *T. harzianum* and sprayed the leaves by compost extract), T_{13} (treatment of fungicide as foliar spray only), with no significant differences among them.

Effect on the growth and yield components

In general, addition of compost, alone or combined with rock phosphate, gypsum and different bioagents tested promoted the growth of dill plants and significantly increased the plant height, number of branches and number of umbels/plant in both seasons compared to the untreated plants (Table 6). The highest values recorded with T_{11} (treatment of compost combined with phosphate rock and inoculated with *B. subtilis*) followed by T_{12} (compost + phosphate rock + *T. harzianum* treatment) with significant differences between them. The corresponding mean values were 157.2 & 154.9 cm, respectively for plant height; 9.1 & 8.5, respectively for branches number/plant and 111.0 &

106.4, respectively for umbels number/plant. Compost + phosphate rock + AM fungi treatment (T_{10}) gave moderate values in this respect followed by compost + gypsum + *B. subtilis* (T_8) and compost + gypsum + *T. harzianum* (T_9). Meanwhile, addition of compost only without any amendments (T_1) gave the lowest plant height (132.2 cm), branches no./plant (5.6) and umbels no./plant (61.1) among all compost treatments tested. Generally, soil amendment with the tested compost treatments and sprayed the dill leaves with compost extract caused a significant promotion to plant growth than sprayed the leaves with compost extracts only.

The interaction between tested compost treatments and their application method had significant effect on the aforementioned plant growth parameters. the maximum plant height, no. of branches and no. of umbels were obtained from plots amended with compost + phosphate rock + *B. subtilis* and sprayed the leaves with its compost extract (T_{11}) (159.8 cm, 9.5 and 121.4, respectively), while the lowest plant height (129.9 cm), no. of branches/plant (5.3) and no. of umbels/plant (58.1) were obtained from plots received compost extract as foliar spray only (T_1) compared to the other tested compost treatments.

The present results have indicated that dill fresh and dry weights (ton/fed.) as well as fruits yield (kg/fed.) were significantly affected by the application of various compost treatments during the two growing seasons (Tables 7, 8 and 9). The heaviest significant plant fresh (8.29 and 10.36 ton/fed.), dry weights (1.57 and 1.71 ton/fed.), respectively for the two plant cuts and fruits yield (508.9 kg/fed.) were obtained from T_{11} (treatment of compost + phosphate rock + *B. subtilis*) followed by T_{12} (compost + phosphate rock + *T. harzianum*). However the treatments of compost + gypsum + *B. subtilis* (T_8), compost + gypsum + *T. harzianum* (T_9) and compost + phosphate rock + AM fungi (T_{10}) showed moderate fresh, dry herb weight and fruits yield with significant differences among them. While application of compost only without any addition gave the lightest fresh, dry weights and fruits yield compared to the other treatments. The corresponding mean values of fresh weight were 6.63, 8.17 and dry weight, being 1.19, 1.33, respectively for the two plant cuts meanwhile recorded 463.6 kg/fed., for fruits yield. On the other hand application of various compost treatments as soil amendments and sprayed the dill leaves by compost extracts significantly increased the fresh, dry weights and fruits yield than sprayed the dill leaves by compost extracts only.

Table 6: Effect of interaction between compost, bioagents, phosphate rock and gypsum on some plant growth parameters during the two successive growing seasons.

Treatments (T)	Mean of the two growing seasons								
	Application methods (M)								
	Plant height (cm)			No. of branches/plant			No. of umbels /plant		
	Soil Amendment + foliar spray	Foliar spray	Mean (T)	Soil Amendment + foliar spray	Foliar spray	Mean (T)	Soil Amendment + foliar spray	Foliar spray	Mean (T)
T_1	134.4	129.9	132.2	5.9	5.3	5.6	64.1	58.1	61.1
T_2	135.9	131.5	133.7	5.9	5.7	5.8	72.3	65.1	68.7
T_3	138.6	134.7	136.7	6.5	6.0	6.3	78.5	70.1	74.3
T_4	139.9	131.8	135.9	6.2	5.5	5.9	88.0	59.5	73.8
T_5	140.0	135.2	137.6	7.1	6.6	6.9	93.2	78.5	85.9
T_6	138.6	133.2	135.9	6.9	6.9	6.9	88.1	72.6	80.4
T_7	140.9	132.4	136.7	7.2	6.0	6.6	98.6	69.7	84.2
T_8	142.3	140.3	141.3	7.6	7.6	7.6	104.4	87.4	95.9
T_9	141.6	138.0	139.8	7.4	7.3	7.4	100.3	83.0	91.7
T_{10}	153.6	133.4	143.5	8.5	6.5	7.5	108.3	73.9	91.1
T_{11}	159.8	154.5	157.2	9.5	8.7	9.1	121.4	100.6	111.0

T_{12}	157.9	151.8	154.9	9.3	7.7	8.5	114.8	97.9	106.4
T_{13}	131.1	129.7	130.4	5.5	5.0	5.3	58.0	55.5	56.8
T_{14}	127.7	126.3	127.0	4.4	4.9	4.7	55.9	54.3	55.1
Mean (M)	141.6	135.9	--	7.0	6.4	--	89.0	73.3	--
L.S.D $_{0.05}$	T = 1.9 M = 1.6 TM = 5.9			T = 0.3 M = 0.1 TM = 0.4			T = 3.3 M = 1.3 TM = 4.7		

The interaction between various compost treatments and their application methods had significant effect on fresh, dry weights of herb and fruits yield during the two growing seasons. the highest fresh (8.96, 10.94 ton/fed.), dry weights (1.72, 1.95 ton/fed.), respectively for the two plant cuts and fruits yield (551.8 kg/fed.) obtained from T_{11} (treatment of compost + phosphate rock + *B. subtilis*) applied as soil amendment and sprayed the plant leaves by its extract followed by T_{12} (treatment of compost + phosphate rock + *T. harzianum*) as soil amendment and sprayed the plant leaves by its extract (8.56, 10.60 ton/fed. and 1.67, 1.90 ton/fed.), respectively for the two plant cuts and 540.5 kg/fed., with no significant differences between them except the values of fresh weight in the first plant cut. While treatment of sprayed the leaves by compost extract only without any addition (T_1) and compost + AM fungi treatment (T_4) gave the lowest fresh, dry weights and fruits yield with no significant differences between them compared to the other compost treatments.

Table 7: Effect of interaction between compost, bioagents, phosphate rock and gypsum on herb fresh weight (ton/fed.) during the two successive growing seasons.

Treatments (T)	Fresh weight (ton/fed.)					
	Application methods (M)					
	Mean of the two growing seasons					
	1 st cut			2 nd cut		
	Soil amendment + foliar spray	Foliar spray	Mean (T)	Soil amendment + foliar spray	Foliar spray	Mean (T)
T_1	7.03	6.23	6.63	8.75	7.59	8.17
T_2	7.27	6.33	6.80	8.97	7.73	8.35
T_3	7.39	6.45	6.92	9.17	7.92	8.55
T_4	7.80	6.25	7.02	9.25	7.66	8.46
T_5	7.63	6.92	7.28	9.53	8.38	8.96
T_6	7.44	6.70	7.07	9.36	8.23	8.80
T_7	7.97	6.39	7.18	9.64	7.79	8.72
T_8	8.32	7.28	7.80	10.04	8.50	9.27
T_9	8.22	7.06	7.64	9.77	8.32	9.05
T_{10}	8.36	6.52	7.44	10.42	8.00	9.21
T_{11}	8.96	7.61	8.29	10.94	9.77	10.36

T_{12}	8.56	7.40	7.98	10.60	9.43	10.02
T_{13}	6.20	6.16	6.18	7.21	7.17	7.19
T_{14}	5.25	5.25	5.25	6.26	6.31	6.29
Mean (M)	7.60	6.61	--	9.28	8.06	--
L.S.D $_{0.05}$	T = 0.22 M = 0.08 TM = 0.31			T = 0.31 M = 0.12 TM = 0.43		

Table 8: Effect of interaction between compost, bioagents, phosphate rock and gypsum on herb dry weight (ton/fed.) during the two successive growing seasons.

Treatments (T)	Dry weight (ton/fed.)					
	Application methods (M)					
	Mean of the two growing seasons					
	1 st cut			2 nd cut		
	Soil amendment + foliar spray	Foliar spray	Mean (T)	Soil amendment + foliar spray	Foliar spray	Mean (T)
T_1	1.28	1.10	1.19	1.40	1.26	1.33
T_2	1.33	1.14	1.24	1.48	1.28	1.38
T_3	1.36	1.18	1.27	1.54	1.33	1.44
T_4	1.42	1.12	1.27	1.56	1.26	1.41
T_5	1.48	1.26	1.37	1.66	1.36	1.51
T_6	1.45	1.24	1.35	1.63	1.34	1.49
T_7	1.49	1.16	1.33	1.69	1.30	1.50
T_8	1.64	1.32	1.48	1.80	1.42	1.61
T_9	1.57	1.29	1.43	1.76	1.40	1.58
T_{10}	1.63	1.19	1.41	1.86	1.30	1.58
T_{11}	1.72	1.42	1.57	1.95	1.47	1.71
T_{12}	1.67	1.37	1.52	1.90	1.45	1.68
T_{13}	1.14	1.10	1.12	1.30	1.25	1.28
T_{14}	0.95	0.95	0.95	1.05	1.06	1.06
Mean (M)	1.44	1.20	--	1.61	1.32	--
L.S.D $_{0.05}$	T = 0.06 M = 0.02 TM = 0.09			T = 0.09 M = 0.03 TM = 0.12		

Table 9: Effect of interaction between compost, bioagents, phosphate rock and gypsum on dill fruits yield (kg/fed.) during the two successive growing seasons.

Treatments (T)	Fruits yield (kg/fed.)		
	Application methods (M)		
	Mean of the two growing seasons		
	Soil Amendment + foliar spray	Foliar spray	Mean (T)
T_1	483.5	443.6	463.6
T_2	492.6	452.5	472.6
T_3	502.2	455.7	479.0
T_4	510.9	441.4	476.2
T_5	518.5	458.3	488.4
T_6	506.4	457.7	482.1
T_7	527.5	453.7	490.6
T_8	538.5	460.5	499.5
T_9	530.5	458.9	494.7
T_{10}	536.7	459.7	498.2
T_{11}	551.8	465.9	508.9
T_{12}	540.5	464.5	502.5
T_{13}	445.8	440.5	443.2
T_{14}	385.2	381.3	383.3
Mean (M)	505.0	449.5	--
L.S.D $_{0.05}$	T = 11.4 M = 4.3 TM = 16.1		

Effect on NPK uptake

Data recorded in Tables 10 and 11 revealed that nitrogen, phosphorus and potassium content of dill herbs and fruits were significantly affected by compost treatments in the two experimental seasons. It is worthy to note that inoculation of different bioagents tested to compost combined with phosphate rock or gypsum treatments significantly augmented the uptake of the three elements (N, P and K). In this regard the maximum value of nitrogen, phosphorus and potassium content was obtained when the plants received compost + phosphate rock + *B. subtilis* treatment (T_{11}) followed by compost + phosphate rock + *T. harzianum* (T_{12}) with no significant differences between them. The corresponding mean values were 33.2, 7.7 & 17.8 kg/fed. and 31.5, 7.5 & 17.2 kg/fed., respectively for the three elements in the first plant cut and being, 33.6, 8.0 & 17.4 kg/fed and 32.5, 7.6 & 17.0 kg/fed., respectively in the second plant cut. While recorded 10.7, 3.0 & 5.8 kg/fed and 10.4, 2.9 & 5.7 kg/fed., respectively in dill fruits. The treatment of compost + gypsum + *B. subtilis* (T_8) gave 31.5 & 31.8 kg/fed for nitrogen, 7.1 & 7.4 kg/fed for phosphorus and 17.1 & 16.6 Kg/fed. for potassium content, respectively for the two plant cuts and 10.6, 2.9 & 5.8 kg/fed respectively for the three elements in dill fruits followed by treatment of compost + gypsum + *T. harzianum* (T_9) with no significant differences between them. Application of the tested bioagents only to compost gave moderate rate of N, P and K uptake followed by the treatments of phosphate rock or gypsum. The minimum N, P and K were obtained from plants received compost only without any addition (T_1). Overall, the method of compost application significantly affects the rate of N, P and K uptake by dill plants and fruits. In this respect, application of various compost treatments as soil amendment + foliar spray with compost extract significantly gave the higher uptake rate than application of compost extract as foliar spray only during the two growing seasons. The combined effect between the two factors on the three elements (N, P and K) content of dill plants and fruits had significant in the two seasons. Among different treatments tested, the most effective treatments was T_{11} (compost + phosphate rock + *B. subtilis* treatment when applied as soil amendment and sprayed the leaves with its extract) which gave 38.8, 9.2 and 20.8 kg/fed., respectively for the three elements in the first plant cut, 40.2, 9.8 and 20.9 Kg/fed. in the second plant cut beside 12.0, 3.4 and 6.3 kg/fed., in dill fruits. While the least effective treatment was application of compost extract only as foliar spray (T_1).

Table 10: Effect of interaction between compost, bioagents, phosphate rock and gypsum on N, P and K content of dill plants (kg/fed.) in the two growing seasons.

Treatments (T)	Mean of the two growing seasons								
	Application methods (M)								
	1 st cut								
	N (kg/fed.)			P (kg/fed.)			K (kg/fed.)		
	Soil Amendment + foliar spray	Foliar spray	Mean (T)	Soil Amendment + foliar spray	Foliar spray	Mean (T)	Soil Amendment + foliar spray	Foliar spray	Mean (T)
T_1	27.8	19.8	23.8	5.8	4.5	5.2	14.7	11.1	12.9
T_2	30.0	21.0	25.5	6.3	4.8	5.6	16.0	11.7	13.9
T_3	29.9	21.5	25.7	6.7	5.0	5.9	15.8	12.0	13.9
T_4	31.5	20.5	26.0	7.0	4.7	5.9	16.6	11.4	14.0
T_5	32.8	23.4	28.1	7.5	5.4	6.5	17.4	12.8	15.1
T_6	32.2	22.6	27.4	7.2	5.3	6.3	16.8	12.5	14.7
T_7	33.9	22.1	28.0	7.4	5.0	6.2	18.1	11.9	15.0
T_8	37.4	25.6	31.5	8.5	5.7	7.1	20.1	14.0	17.1
T_9	35.5	24.6	30.1	7.9	5.5	6.7	19.2	13.5	16.4

T_{10}	36.3	22.6	29.5	8.5	5.1	6.8	19.6	12.5	16.1
T_{11}	38.8	27.6	33.2	9.2	6.2	7.7	20.8	14.8	17.8
T_{12}	37.3	25.7	31.5	8.9	6.0	7.5	20.1	14.2	17.2
T_{13}	20.0	19.3	19.7	4.4	4.3	4.4	10.9	10.5	10.7
T_{14}	16.6	16.6	16.6	3.7	3.7	3.7	9.0	9.0	9.0
Mean (M)	31.4	22.4	--	7.1	5.1	--	16.8	12.3	--
L.S.D $_{0.05}$	T = 1.8 M = 0.7 TM = 2.5			T = 0.3 M = 0.1 TM = 0.4			T = 1.0 M = 0.4 TM = 1.4		
				2 nd cut					
T_1	27.4	20.4	23.9	5.9	4.8	5.4	14.7	10.9	12.8
T_2	30.3	22.3	26.3	6.5	5.2	5.9	16.1	11.8	14.0
T_3	30.9	22.9	26.9	7.1	5.5	6.3	16.3	12.2	14.3
T_4	31.5	21.7	26.6	7.4	5.2	6.3	16.6	11.5	14.1
T_5	33.5	23.9	28.7	7.9	5.7	6.8	17.8	12.4	15.1
T_6	33.0	23.1	28.1	7.6	5.5	6.6	17.2	12.2	14.7
T_7	35.2	23.4	29.3	8.1	5.3	6.7	18.2	12.1	15.2
T_8	37.8	25.8	31.8	8.8	6.0	7.4	19.5	13.6	16.6
T_9	36.5	25.3	30.9	8.2	5.6	6.9	18.9	13.3	16.1
T_{10}	37.9	23.4	30.7	9.1	5.4	7.3	20.1	12.4	16.3
T_{11}	40.2	27.0	33.6	9.8	6.2	8.0	20.9	13.8	17.4
T_{12}	38.8	26.2	32.5	9.1	6.1	7.6	20.3	13.6	17.0
T_{13}	21.5	20.6	21.1	4.9	4.8	4.9	11.5	11.1	11.3
T_{14}	17.3	17.4	17.4	4.0	4.0	4.0	7.3	9.3	8.3
Mean (M)	32.3	23.1	--	7.5	5.4	--	16.8	12.2	--
L.S.D $_{0.05}$	T = 1.4 M = 0.5 TM = 2.0			T = 0.5 M = 0.2 TM = 0.7			T = 0.6 M = 0.2 M = 0.9		

Table 11: Effect of interaction between compost, bioagents, phosphate rock and gypsum on N, P and K content of dill fruits (kg/fed.) in the two growing seasons.

Treatments (T)	Mean of the two growing seasons								
	Application methods (M)								
	N (kg/fed.)			P (kg/fed.)			K (kg/fed.)		
	Soil Amendment + foliar spray	Foliar spray	Mean (T)	Soil Amendment + foliar spray	Foliar spray	Mean (T)	Soil Amendment + foliar spray	Foliar spray	Mean (T)
T_1	9.9	8.1	9.0	2.8	2.4	2.6	5.1	4.6	4.9

T_2	10.7	8.8	9.8	3.0	2.5	2.8	5.8	5.1	5.5
T_3	10.8	8.4	9.6	2.9	2.5	2.7	5.6	5.1	5.4
T_4	10.6	8.6	9.6	3.0	2.4	2.7	5.8	5.0	5.4
T_5	11.2	8.8	10.0	3.0	2.5	2.8	5.9	5.2	5.6
T_6	10.6	8.9	9.8	3.1	2.5	2.8	5.8	5.1	5.5
T_7	11.5	9.1	10.3	3.2	2.5	2.9	6.0	5.1	5.6
T_8	11.8	9.3	10.6	3.3	2.5	2.9	6.3	5.3	5.8
T_9	11.6	9.1	10.4	3.2	2.5	2.9	6.1	5.2	5.7
T_{10}	11.5	9.1	10.3	3.4	2.6	3.0	6.3	5.2	5.8
T_{11}	12.0	9.3	10.7	3.4	2.6	3.0	6.3	5.3	5.8
T_{12}	11.4	9.3	10.4	3.3	2.5	2.9	6.2	5.2	5.7
T_{13}	8.7	8.6	8.7	2.5	2.5	2.5	5.0	5.0	5.0
T_{14}	6.9	6.8	6.9	2.0	2.0	2.0	3.9	3.9	3.9
Mean (M)	10.7	8.7	--	3.0	2.5	--	5.7	5.0	--
L.S.D $_{0.05}$	T = 0.4 M = 0.2 TM = 0.5			T = 0.11 M = 0.04 TM = 0.15			T = 0.2 M = 0.1 TM = 0.3		

Effect of compost on soil properties

Data presented in Table 12 demonstrated the effect of different compost treatments tested on some physical and chemical characteristics of soil at the end of growing season. Generally, all different compost treatments either alone or in combination with bioagents, phosphate rock and gypsum caused decrease in soil pH values as compared with control value.

Table 12: Effect of interaction between compost, bioagents, phosphate rock and gypsum on some physical and chemical properties of soil in the two growing seasons.

Treatments	Mean of the two growing seasons						
	pH	EC	OC	OM	N (ppm)	P (ppm)	K (ppm)
T_1	8.41	1.30	0.774	1.334	40.0	13.9	243.0
T_2	8.34	1.37	0.795	1.371	46.6	14.7	267.7
T_3	8.36	1.35	0.800	1.379	45.0	15.4	278.3
T_4	8.37	1.32	0.805	1.388	46.8	15.3	257.2
T_5	8.38	1.33	0.800	1.379	46.8	14.7	260.7
T_6	8.38	1.33	0.810	1.396	46.8	15.3	256.6
T_7	8.27	1.38	0.833	1.436	50.3	14.7	264.2
T_8	8.27	1.38	0.839	1.446	52.6	14.3	273.0
T_9	8.28	1.38	0.833	1.436	52.1	14.3	265.4
T_{10}	8.31	1.36	0.825	1.422	48.0	16.1	278.3
T_{11}	8.30	1.37	0.839	1.446	48.6	16.6	281.8
T_{12}	8.30	1.36	0.830	1.431	50.9	16.4	281.8
T_{13}	8.44	1.22	0.747	1.288	37.9	8.2	186.7
T_{14}	8.45	1.23	0.735	1.267	37.9	8.1	193.8
L.S.D $_{0.05}$	0.08	0.05	0.03	0.05	2.0	0.7	8.9

Soil pH value of 8.45 was recorded in control whilst; minimum pH value (8.27) was recorded in T_7 (compost + gypsum + AM fungi treatment) and T_8 (treatment of compost + gypsum + *B. subtilis*) followed by T_9 (treatment of compost + gypsum + *T. harzianum*), T_{11} (compost + phosphate rock + *B. subtilis*), T_{12} (compost + phosphate rock + *T. harzianum*), T_{10} (compost +

phosphate rock + AM fungi) and T_2 (compost + gypsum treatment) with no significant differences among them.

The data revealed a relative increase in soil salinity (EC) as compared with control value (1.23 dS m^{-1}) in all compost applications. The highest value (1.38 dS m^{-1}) was obtained with T_7 (compost + gypsum + AM fungi treatment), T_8 (treatment of compost + gypsum + *B. subtilis*) and T_9 (treatment of compost + gypsum + *T. harzianum*) followed by T_{11} (compost + phosphate rock + *B. subtilis*), T_2 (compost + gypsum treatment), T_{10} (compost + phosphate rock + AM fungi), T_{12} (compost + phosphate rock + *T. harzianum*) and T_3 (compost + Phosphate rock) with no significant differences among them while the lowest one was obtained with T_1 (treatment of compost without any addition) being, 1.30 dS m^{-1}.

Organic carbon (OC) and organic matter (OM) contents of the soil significantly increased with various compost treatments application compared to the control treatment. The highest OC and OM contents were determined in compost + gypsum + *B. subtilis* treatment (T_8) followed by compost + phosphate rock + *B. subtilis* (T_{11}), compost + gypsum + AM fungi (T_7), compost + gypsum + *T. harzianum* (T_9), compost + phosphate rock + *T. harzianum* (T_{12}), treatment of compost + phosphate rock + AM fungi (T_{10}) and treatment of compost + *B. subtilis* (T_6) with no significant differences among them. The corresponding mean values for OC were 0.839, 0.839, 0.833, 0.833, 0.830, 0.825 and 0.810, respectively and for OM were 1.447, 1.447, 1.436, 1.436, 1.431, 1.422 and 1.396, respectively. While the lowest OC and OM content was obtained in the treatment of application of compost only without any addition (T_1) followed by compost + gypsum treatment (T_2), treatment of compost + Phosphate rock (T_3) and treatment of compost + *B. subtilis* (T_5) with no significant differences among them but still higher than control values.

On the other hand, all the tested compost treatments significantly increased NPK content compared with control treatment. The highest value of available N was recorded in compost + gypsum + *B. subtilis* treatment (T_8) followed by compost + gypsum + *T. harzianum* (T_9), compost + phosphate rock + *T. harzianum* (T_{12}) and compost + gypsum + AM fungi (T_7) with no significant differences among them. The corresponding mean values were 52.6, 52.1, 50.9 and 50.3 ppm, respectively. While the lowest one was recorded in the treatment of application of compost only without any addition (T_1). Regarding phosphorus, the highest values were recorded in treatments of addition of phosphate rock to compost especially inoculated with the tested bioagents being, 16.6 ppm in compost + phosphate rock + *B. subtilis* treatment (T_{11}), 16.4 ppm in treatment of compost + phosphate rock + *T. harzianum* (T_{12}) and 16.1 ppm in treatment of compost + phosphate rock + AM fungi (T_{10}) with no significant differences among them. The lowest values were recorded with T_1 (treatment of compost only), T_8 (compost + gypsum + *B. subtilis* treatment) and T_9 (compost + gypsum + *T. harzianum* treatment) which lies in the same statistical group. In case of available K, the highest values were recorded with T_{11} (compost + phosphate rock + *B. subtilis* treatment), T_{12} (compost + phosphate rock + *T. harzianum*), T_{10} (compost + phosphate rock + AM fungi treatment) and T_3 (compost + Phosphate rock treatment) which lies in the same statistical group. Meanwhile the lowest values were recorded with T_1 (treatment of compost only).

Effect on the total phenol content and defense-related enzymes

Data presented in Table 13 show the effect of the tested compost treatments on the defense related enzyme activities as well as total phenols in the treated dill plants compared to the untreated control. Overall, all tested treatments significantly increased the activity of defense related enzymes and phenols in dill plants. Combined treatments of compost with phosphate rock or gypsum and inoculated with the tested bioagents resulted excess in the activity for peroxidase, Polyphenol oxidase enzymes and phenols compared to the treatment separately. Maximum increase in peroxidase, Polyphenol oxidase activities and phenols was detected with compost + phosphate rock + *B. subtilis* treatment (T_{11}), being 1.179, 0.491 and 0.201%, respectively. The lowest activity of these enzymes and phenols was detected in dill plants received compost only without any addition (T_1). The method of compost application significantly affects the enzymatic activities and phenols in dill plants. Application of various compost treatments as soil amendment + foliar spray with compost extract significantly increased the activities of peroxidase, Polyphenol oxidase and phenols than application of compost extract as foliar spray only.

Table 13: Enzyme activities and Total phenols in dill plants as affected by different compost treatments.

Treatments (T)	Application methods (M)								
	Enzymatic activities						Total phenol (%)		
	Peroxidase			Polyphenol oxidase					
	Soil Amendment + foliar spray	Foliar spray	Mean (T)	Soil Amendment + foliar spray	Foliar spray	Mean (T)	Soil Amendment + foliar spray	Foliar spray	Mean (T)
T_1	0.676	0.355	0.516	0.209	0.193	0.201	0.134	0.103	0.119

T_2	0.687	0.541	0.614	0.213	0.199	0.206	0.137	0.117	0.127
T_3	0.702	0.655	0.679	0.215	0.206	0.211	0.144	0.124	0.134
T_4	0.898	0.362	0.630	0.244	0.197	0.221	0.151	0.109	0.130
T_5	0.923	0.773	0.848	0.250	0.237	0.244	0.155	0.143	0.149
T_6	0.923	0.745	0.834	0.248	0.241	0.245	0.159	0.144	0.152
T_7	1.072	0.566	0.819	0.274	0.201	0.238	0.166	0.119	0.143
T_8	1.074	0.795	0.935	0.331	0.243	0.287	0.179	0.155	0.167
T_9	1.069	0.789	0.929	0.440	0.241	0.341	0.189	0.153	0.171
T_{10}	1.082	0.666	0.874	0.592	0.204	0.398	0.183	0.131	0.157
T_{11}	1.493	0.865	1.179	0.712	0.270	0.491	0.239	0.162	0.201
T_{12}	1.135	0.855	0.995	0.706	0.259	0.483	0.196	0.159	0.178
T_{13}	0.723	0.715	0.719	0.235	0.230	0.233	0.143	0.141	0.142
T_{14}	0.133	0.128	0.131	0.060	0.063	0.062	0.077	0.083	0.080
Mean (M)	0.899	0.629	--	0.338	0.213	--	0.161	0.132	--
L.S.D $_{0.05}$	T = 0.024 M = 0.009 TM = 0.033			T = 0.017 M = 0.007 TM = 0.025			T = 0.008 M = 0.003 TM = 0.012		

Compost treatments tested × their application method interaction were found to be significant. Treatment of soil amendment by compost + phosphate rock + *B. subtilis* and sprayed the leaves by their compost extract (T_{11}) showed the highest peroxidase, Polyphenol oxidase activities and phenols (1.493%, 0.712% and 0.239%, respectively) while plants sprayed with compost extract only (T_1) showed the lowest values being, 0.355, 0.193 and 0.103%, respectively.

Effect on dehydrogenase enzyme

It is worthy to note that all tested compost treatments significantly improved the microbial status in the rhizosphere of dill plants as expressed as dehydrogenase activity (Table 14). Generally, combined treatments of compost with phosphate rock and inoculated with the tested bioagents resulted excess in the activity for dehydrogenase activity. Combined treatment of compost with phosphate rock and inoculated with *B. subtilis* (T_{11}) exhibited the superiority in rhizosphere microbial activity among all compost treatments followed by treatment of compost + phosphate rock + *T. harzianum* (T_{12}) and treatment of compost + phosphate rock +AM fungi (T_{10}). The corresponding values of dehydrogenase activity were 5.39, 5.02 and 3.87, respectively. Addition of gypsum to compost and inoculated with *B. subtilis* (T_8), *T. harzianum* (T_9) or AM fungi (T_7) moderately increased the dehydrogenase activity with no significant differences among them. However, addition of rock phosphate to the compost (T_3) significantly increased dehydrogenase activity than gypsum treatment (T_2). Dehydrogenase activity drastically decreased for the soil samples obtained from the chemical fungicide Topas 100 EC, being 1.36. On the other hand application of various compost treatments as soil amendment and sprayed the dill leaves with compost extract significantly improved the microbial status in the rhizosphere of dill plants as indicated by increasing the dehydrogenase activity than sprayed the plants by compost extract only. The interaction between compost treatments tested and application methods had significant effect on dehydrogenase activity. Soil amendment by compost + phosphate rock + *B. subtilis* treatment and sprayed the leaves by their compost extract (T_{11}) showed the highest activity of dehydrogenase enzyme which recorded 7.30 μg T.P.F./g dry soil/day while the lowest value was noticed when dill plants sprayed with compost extract only without any addition (T_1) among the other compost treatments followed by treatment of sprayed the leaves with compost + gypsum (T_2) and treatment of sprayed the leaves with compost + AM fungi (T_4) with no significant differences among them. The corresponding mean values of dehydrogenase activity were 2.35, 2.50 and 2.50 μg T.P.F./g dry soil/day, respectively.

Table 14: Effect of interaction between compost, bioagents, phosphate rock and gypsum on microbial status as expressed as dehydrogenase activity in rhizosphere of dill plants grown under field conditions.

Treatments (T)	Dehydrogenase activity (µg T.P.F./g dry soil/ day)		
	Application methods (M)		
	Soil Amendment + foliar spray	Foliar spray	Mean (T)
T_1	3.50	2.35	2.93
T_2	3.64	2.50	3.07
T_3	4.00	2.82	3.41
T_4	3.50	2.50	3.00
T_5	3.83	3.23	3.53
T_6	3.56	3.20	3.38
T_7	4.30	2.70	3.50
T_8	4.50	3.30	3.90
T_9	4.52	3.30	3.91
T_{10}	4.70	3.03	3.87
T_{11}	7.30	3.48	5.39
T_{12}	6.74	3.29	5.02
T_{13}	1.39	1.33	1.36
T_{14}	2.11	1.97	2.04
Mean (M)	4.11	2.79	--
L.S.D $_{0.05}$	T = 0.22 M = 0.08 TM = 0.31		

DISCUSSION

Compost use is one of the most important factors, which contribute to increased productivity, soil fertility and sustainable agriculture. However, it has been known that compost and compost extracts alter the balance of soil microflora and can suppress foliar disease in some crops [11,37]. The present study demonstrated that compost extracts alone or combined with phosphate rock or gypsum and inoculated with tested bioagents suppressed conidial germination of *E. heraclei in vitro* assay. The suppressive activity of microbial enriched compost extracts observed in this study is likely biological in nature. Previous reports have described the direct inhibition of both conidial germination and mycelia growth of various plant pathogens by beneficial microorganisms present in the water extract of compost [38,39] which responsible for preventing the formation of a germ tube and led to the lysis of conidia [40]. Accumulation of soluble nutrients from compost to compost extract during brewing time enhanced beneficial microorganisms in extract [41], which produce antimicrobial compounds. Also the present study demonstrated that addition of phosphate rock and gypsum to compost and inoculated with bioagents (*B. subtilis*, *T. harzianum* and AM fungi) significantly caused different degrees of reduction of dill powdery mildew incidence and severity compared to the control under field conditions. Addition of phosphate rock to compost and inoculated with *B. subtilis* showed highest efficacy in this concern. This result was in line with the report of Segarra et al. [42,43]. Brinton et al. [44] reported that the principal active agents in compost teas appear to be bacteria in the genera *Bacillus* and *Trichoderma* which caused inhibition of spore germination, antagonism and competition with pathogens and induced resistance against pathogens when sprayed on plant leaves act in the phyllosphere (i.e. the leaf surface). Mechanisms of action underlying the efficacy of compost and compost extracts to control plant pathogens have been reported as single or multiple mechanisms involving microbial antagonism (through antibiosis, parasitism, competition for nutrients/space or induced plant resistance) [10,12,45] or suppressive physicochemical properties (improved nutrient status of the plant, toxic compounds or induced resistance) [46]. Calcium plays an important role in the defense of plants against pathogens, since it is essential in the structure of the middle lamellae of plant cells and in maintaining selectivity of cell plasma lemmas [47]. However, disease reduction was accompanied with a gradual increase in peroxidase and polyphenol oxidase activity as well phenol contents during experiment period. In the present study, soil amendment with the tested compost treatments and sprayed the leaves with their compost extracts significantly strongly induced synthesis and accumulation of peroxidase, polyphenol oxidase and increase total phenols than sprayed the leaves by compost extracts only. This result is in agreement with reports of Stone et al. [11] and Nwogbaga & Iwuagwu [48]. Siddiqui et al. [40] and Haggag & Saber [49] reported that compost teas increase peroxidase, polyphenol oxidase, phenylalanine ammonia lyase, β-1,3-glucanase and chitinase in okra, tomato and onion plants when applied to foliage. The induction of plant resistance by compost extract could be attributed to the presence of beneficial microorganisms which responsible for induction of systemic resistance [43]. Also, the compost was rich in inorganic salts, organic carbon and phenols, which can affect pathogen growth and phyllosphere microorganisms [42].

Results in this study showed a general improvement in both vegetative growth characters (plant height, branches number/ plant, umbels number/plant, fresh and dry weights of herb) and fruits yield of dill plants due to application of the tested compost treatments as soil amendments and compost extracts as foliar spray either alone or amended with phosphate rock or gypsum and inoculated with the tested bioagents than control plants. The enhancement effect of compost may be resulted from a greater concentration of plant nutrients like N, P, K, and Mg and a root reinforcement induced by compost [50,51]. The highest significant values recorded with compost amended with phosphate rock and inoculated with bioagents. This could be attributed to the highest values of available phosphorus compared to other treatments. Addition of phosphate solubilizing microorganisms as *B. subtilis*, *T. harzianum* and AM fungi influenced phosphate rock solubility and stimulated dill roots to absorb more P from the soil and its accumulation towards shoots, resulting in enhanced the overall plant growth as compared to each treatment alone. Phosphorus is a basic structural element of the membrane system of the cell, the mitochondria and chloroplast [52]. The methods of enhancing the quality of phosphate rock and its agronomic efficiency include composting with organic manures [53,54]. Incorporation of poultry manure or cow dung with phosphate rock significantly improved release of P and performance of crops [55,56]. The microbial activities stimulated nutrients uptake and plant growth may be due to hormones such as auxin or gibberellic acid production as stated by Richardson et al. [57] and Contreras-Cornejo et al. [58]. The arbuscular mycorrhizal fungi (AMF) form a symbiotic relationship with the roots of most plants by increasing plant phosphate (P) uptake and growth, whilst the plants supply the AM fungi with exudates for metabolism [59]. Gypsum is a moderately soluble source of the essential plant nutrients, calcium and sulfur, and can improve overall plant growth. Our study demonstrated that application of different treatments of compost tested to soil cultivated with dill plant increased soil salinity (EC), organic carbon (OC), organic matter (OM), available nitrogen, phosphorous and potassium (NPK) contents and decreased pH. The reduction in pH agreed with Chang et al. [60] and Sağlam [61] who reported that CO_2 released into soil atmosphere due to decomposition of organic wastes can be converted into carbonic acid (H_2CO_3) by reacting with water (H_2O) and decreases soil pH. Dahdoh and Hassan [62] showed the same results where application of compost increased the EC results and attributed that to the releasing substances from compost treatment which may directly or indirectly raised soil EC due to the microbial decomposition. The increased NPK contents in the soil are in agreement with Abou El-Naga et al. [63], who stated that increasing organic manure addition increased nutrient availability in the soil due to further amounts of available nutrients released from the decomposed organic manure. Rodriguez-Vila et al. [64] found that organic amendments sustain soil properties by increasing organic matter, nutrient content, and microbial activity and thus increase crop growth and yield. Gypsum amendments can also improve the physical and chemical properties of soils, thus reducing erosion losses of soils and nutrient concentrations (especially phosphorus) in surface water runoff [65]. Dehydrogenase activity is involved in the initial breakdown of organic matter that reflects the total range of oxidative activity of soil microflora and is consequently used as an indicator of microbial activity [66,67] and it has been suggested as a good indicator of soil fertility [68,69]. Soil microbial communities help in maintaining vital functions in the soil like recovery of nutrients and degradation of organic pollutants (i.e. industrial waste and pesticides) [70-72]. The present study demonstrated that the dehydrogenase activity of compost-treated soils either alone or combined with rock phosphate, gypsum and/or bioagents tested was significantly higher than that of the untreated soil and reached its maximum in the treatment of combined compost with phosphate rock and inoculated with the tested bioagents. The results are in line with Marinari et al. [73] who reported that a higher level of dehydrogenase activity was observed in soil treated with vermicompost and manure compost compared with soil treated with mineral fertilizer. Also Martens et al. [74] reported that the enzyme activities in organic matter amended soil increased an average of twofold to fourfold compare with unamended soil. Stronger dehydrogenase activity in compost applied plots may be due to higherorganic matter content [75]. The inoculation with beneficial microorganisms and organic matter represented in compost and its extracts helped in increasing the respiration and consequently increase in dehydrogenase enzyme [76]. Increasing the dehydrogenase activity reflect the increase of microbial activity in the rhizosphere of dill plant resulting in enhancement in plant growth and yield productivity due to improving the soil fertility and indirectly contribute in control of dill powdery mildew through induction of systemic resistance. Therefore, this study can support the usefulness of inoculation of compost with any of the tested bioagents and used as soil amendment with sprayed the dill plants with compost extract for the control of powdery mildew and production of dill plants as well as improved soil fertility.

CONCLUSION

Although all of the tested composted treatments reduced the disease incidence and severity, improved the plant growth and yield of dill plants as well as soil fertility, but compost amended with rock phosphate, gypsum and inoculated by *B. subtilis*, *T. harzianum* and AM fungi was superior in this regard. Based on their efficiency and eco-safety, we can recommend the use of these combination in controlling powdery mildew of dill, increased its productivity and soil fertility, with a reduced application of synthetic fungicides and fertilizers.

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