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Application of Compost for Controlling Powdery Mildew of Pepper and its Effect on Productivity

Farag M.F.[1]; Taha, M.B.[2]; Kamel, S.M.[1] and Mohamed, A.G.[3]

1- *Plant Pathology Research Institute, ARC, Giza, Egypt.*
2- *Soils, Water and Environment Research Institute, ARC, Giza, Egypt.*
3- *Horticulture Research Institute, ARC, Giza, Egypt.*

Efficiency of compost (corn stover amended with sheep manure) supplemented with sulphur, phosphate rock, gypsum and some bioagents (*Bacillus subtilis*, *Trichoderma harzianum* and arbuscular mycorrhizal fungi) was evaluated for suppressing powdery mildew of pepper under field conditions. Experiments were carried out under natural infection in the Experimental Farm of Sids Horticultural Research Station, Agric. Res. Center, Beni-Sweif governorate. Two different methods of application were used; soil amendment and or foliar spraying to reduce pepper powdery mildew and improving its productivity, as well as enhance soil fertility. All tested compost treatments reduced the number of infected leaves and powdery mildew severity as well as increased the yield compared to control treatment. On the other hand, spraying and amendment pepper plants during the growing season with compost combined with *Trichoderma harzianum* resulted in a significant decrease in disease severity of the disease with significant increment in pepper yield compared with the control treatment. In addition, combination the compost with *Bacillus subtilis* gave the best results in controlling powdery mildew of pepper.

Keywords: Biocides; compost; pepper; powdery mildew; Sulphur; gypsum.

Sweet pepper (*Capsicum annuum* L.) belongs to Solanaceae, and is considered one of the most essential, common and favorite vegetable crops cultivated in Egypt for local consumption and exportation. High cash crops such as sweet pepper have occupied an important rank in Egyptian and world agriculture due to its high profit and nutritional values for human health (Rajput and Poruleker, 1998). Like many other vegetable crops, pepper requires nutrition. For instance, each 100 g of green pepper contains 564mg potassium (K), 25-49mg phosphorus (P, 10 mg magnesium (Mg, 10-16 mg), Calcium (Ca and 0.7-1.4 mg, Ferrous (Fe) which are absorbed from soil (Csillery, 2006). Powdery mildew is a widespread leaf disease that affects several vegetable crops, in field and in greenhouse (Bourbos *et al*., 1999 and Matsuda *et al*., 2001). Pepper powdery mildew grows unseen, within the leaf tissue for a latency period of up to 21 days and the causative agent is *Leveillula taurica.*

Recently, highly attention has been focused on the possibility of using natural and safe bio-fertilizers for increasing growth and productivity of vegetable crops. Applying bio-fertilization to crops during plant growth stages promoting certain microorganisms and is currently considered as a healthy alternative to chemical fertilization. (Zhang *et al.*, 2013).

Compost extract is a highly concentrated solution produced by extracting beneficial microbes through a liquid-phase of compost and its extraction period ranging from few hours to two weeks, with or without active aeration with the addition of some active nutrients, *i.e*., molasses, casein, etc. (Zaccardelli *et al.*, 2012). Application of compost extracts is increasing due to their positive effects on the crops.

It can be used as foliar or soil organic nutrients, containing micronutrients for easy plant absorption. Such nutrients are biologically available for plant uptake. Compost extract is gaining importance as an alternative to chemical fertilizers and pesticides. The microbial population in the compost extract enhances its beneficial effectiveness on plant growth and considered as a valuable soil amendment (Gharib *et al*., 2008). These bio-fertilizers have the ability to mobilize plant nutrients in the soil from unusable to usable form. It is considered environmentally friendly, plays a significant role in crop production, helps to build up the micro flora and improve the soil fertility. Applications of alternative materials in suppressing foliar diseases in fields by using compost are limited. However, the available researches showed that composts suppress foliar diseases under field conditions, mainly by inducing plant defense systemic resistance (Zhang *et al*. 1996; Stone *et al*. 2003; Vallad *et al*. 2003).

Compost as an organic material influences agricultural sustainability by improving soil chemical, physical and biological properties as well as fertility by improving soil organic matter quality and soil structure and the moisture holding capacity (Rivero *et al.,* 2004), supplies a wide range of beneficial microorganisms (Ryckeboer *et al.*, 2003). However, the use of compost as soil amendments and their water extracts can provide natural biological control against foliar diseases (Zhang *et al.*, 1996, 1998 and Stone *et al.*, 2003) and improve plant health (Litterick *et al.*, 2004).

Nutrients are essential for plant growth and development and they are important factors in disease control (Agrios, 2005) that may influence disease resistance or tolerance by increasing the capacity of the host plant to restrict invasive pathogens' penetration, development and reproduction (Dutta *et al.*, 2017). 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 is including downy and powdery mildew (Reuveni and Reuveni, 1998). 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 (Khan *et al.*, 2010). 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.

Bio-control agents such as *B. subtilis*, *T. harzianum* and arbuscular mycorrhizal fungi (AM) have the ability to control powdery mildew (Kim *et al.*, 2013), provide plants with growth promoting substances and play an important role in phosphate solubilizing and supplying P to plants (Tallapragada and Gudimi, 2011; Tanwar *et al.*, 2013 and García-López and Delgado, 2016).

Therefore, the aim of this study was to assess the potential of compost modified with rock phosphate, gypsum and inoculated by certain bioagents (*B. subtilis, T. harzianum* and arbuscular mycorrhizal fungi) to control powdery mildew on pepper and to improve its productivity as well as soil fertility under field conditions using two methods of application: soil alteration and/or foliar spray

Materials and Methods

Preparation of compost and compost extract:

The organic waste material used in compost preparation from corn stover was cut into small pieces and taken to make the heaps (about 16 heaps each containing 50 Kg stover). Farm yard manure (FYM) was added 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, rock phosphate (1 %) at the rate of 10 kg/ton and sulphur (1%) at the rate of 10kg / 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 fungi (mixed fungi belonging to genera *Glomus*, *Gigaspora* and *Acaulospora*) inocula 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 the rhizosphere of pepper plants and identified in Assiut Univ., Mycological Center, Fac. of Sci., 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 inocula of 24 h old culture and incubated in rotary shaking incubator (120 rpm) at 28±2ºC for 48 h., Meanwhile, *T. harzianum* was grown in *Trichoderma*-selective medium broth (TSM) (Elad *et al*., 1981), amended with streptomycin and 50 µg ml^{-1} rose Bengal in conical flask, incubated at 25^{o}C for 15 days. *Trichoderma*, *Bacillus* 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. During composting process, water was monitored every week throughout the composting period to maintain it at 60 %.The 16 treatments were prepared by thoroughly mixing the corn stover 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 were 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 pepper leaves. Some characteristics of compost and compost extracts were performed

In vitro assay:

Effect of compost extract on conidial germination:

Drops of the tested compost extract were placed on glass slides and conidia of *L. taurica* were directly lifted with help of small paint brush from heavily infected pepper 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 control. Three replications were made for each treatment. The slides were incubated at 25 ± 2^0C for 24 h and the percent of germination was calculated under a light microscope.

Field studies:

The trials were carried out under field conditions at Sids Horticultural Research Station, Agric. Res. Center, Beni-Sweif governorate in pepper fields through autumn seasons 2017 and 2018 to assess the potential of compost amended with sulphur, rock phosphate, gypsum and inoculated by some bioagents (*B. subtilis*, *T. harzianum* and AM fungi) to control powdery mildew on pepper and to improve its productivity as well as soil fertility using two application methods: soil amendment and/or foliar spray. Some physical and chemical characteristics of the used soil were determined before planting (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:

C1: Compost.
C2: Compost + Sulphur.
C3: Compost + Gypsum.
C4: Compost + Phosphate rock.
C5: Compost + AM fungi.
C6: Compost + *B. subtilis*.
C7: Compost + *T. harzianum*.
C8: Compost + Sulphur + AM fungi.
C9: Compost + Sulphur + *B. subtilis.*
C10: Compost + Sulphur + *T. harzianum*.
C11: Compost + Gypsum + AM fungi.
C12: Compost + Gypsum + *B. subtilis*.

C13: Compost. + Gypsum + *T. harzianum*.

C14: Compost. + Phosphate rock + AM fungi.

C15: Compost. + Phosphate rock + *B. subtilis*.

C16: Compost. + Phosphate rock + *T. harzianum*.

C17: The fungicide Topas 100 EC at the rate of 25 cm3/100L water.

C18: Untreated control.

Table 1: The chemical and physical properties of the soil in experimental fields before planting.

No.	Value	Soil characteristics
1		Particle size distribution
2	4.25	Coarse sand
3	9.31	Fine sand
4	33.74	Silt
5	52.70	Clay
6	Clayey	Textural class
7	16.32	Exchangeable sodium percentage
8	41.59	Field capacity
9	19.51	Wilting point%
10	22.08	Available water%
11	8.60	pH (1-2.5 soil- water suspension
12	1.45	Calcium carbonate %
13	1.08	Organic carbon %
14	1.868	Organic matter %
15	0.90	Electric conductivity (ds/m)
16	16.35	Cation exchange capacity mg/100g
17	0.089	Total nitrogen
18	9.49	Available P (mg/kg soil)
19	239.81	Available K (mg/kg soil)

Recommended field practices were undertaken (N, P and K as recommended fertilizers). Pepper transplants (Balady cv.) were transplanted in autumn seasons 2017-2018 growing seasons. Application treatments were thoroughly mixed with the soil surface (0 - 15 cm) in the half of plants per plot otherwise, the second half of plants in each plot was not treated with compost but both halves of plants were carefully sprayed three times with compost extract onto pepper plants always performed early in the morning with the tested compost extracts. 1% Tween 20 was used 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 assessment:

Disease incidence:

Percentage of the disease incidence was recorded as the number of diseased plants relative to the number of growing plants for each row, then the average of disease incidence was calculated.

Disease severity:

Percentage of the disease severity was recorded as follow:

$$D.S.\% = \frac{\Sigma(n \times c)}{N \times C} \times 100$$

Whereas: D.S. = Disease severity %, n = Number of infected leaves per category, c = Category number, N= Total examined leaves, C = The highest category number of infection

Disease severity scale from 0 to 4 according to Cohen *et al*., (1991) was followed, whereas: 0 = No visible infection lesions; 1 = 25% or less; 2 = 26-50 %; 3 = 51-75 % and 4 = 76-100% infected area of plant leaf.

Evaluation of pepper yield and its components:

At maturity, for each treatment, fruit yield and its components (fresh weight (ton/fed.), dry weight (kg/fed.), final weight and fruit yield per plant (kg) also, plant height (cm), primary branches and plant numbers) were recorded. At the end of the growing season, the accumulated yield was calculated for each particular treatment.

Evaluation of vitamin C:

Ascorbic acid (vitamin c mg/100 g fresh weight) was determined as 2,6 dichlorophenol indophenols dye according to (A.O.A.C, 1975)

Measurement of enzymatic activities:

Peroxidase activity was determined using the method described in the Worthington enzyme manual Worthington (1971) Polyphenoloxidase activity was measured following the method described by Esterbaner *et al.* (1977).

Statistical Analysis

Data were statistically analyzed for computing L.S.D. test at 5 % probability according to the procedure outlined by Snedecor and Cochran (1989).

Results

Compost and compost extract analysis:

Data provided in Table 2, show the impact of composting treatments (sulpher, gypsum, phosphate rock and bioagents) on the compost and compost extract resultants. Overall, the addition of the tested conditioner and bioagents materials to compost increased electrical conductivity (EC), organic carbon (OC), content of organic material (OM) and reduction of pH and C / N ratio in compost, as well as increased NPK content in compost and compost extracts compared to the unamended plots with compost.

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

Treatments	Mean of the two growing seasons										
	Compost analysis								Compost extracts analysis		
	OC%	OM %	N%	C/N ratio	P%	K%	PH	EC	N* ppm	P* ppm	K*%
C1	30.62	52.79	1.46	20.97	0.341	1.707	8.26	12.65	1300	206.0	0.180
C2	33.41	57.61	1.55	21.55	0.368	1.815	7.12	13.85	1375	239.5	0.186
C3	32.11	55.36	1.60	20.07	0.448	2.026	8.12	11.45	1525	292.2	0.202
C4	33.05	56.98	1.63	20.28	0.394	1.920	7.93	11.03	1500	298.6	0.207
C5	31.80	54.83	1.49	21.34	0.349	1.786	8.22	12.37	1350	227.5	0.184
C6	32.37	55.81	1.51	21.44	0.365	1.755	8.19	11.92	1467	275.2	0.202
C7	31.99	55.16	1.50	21.33	0.350	1.739	8.18	11.97	1458	271.5	0.193
C8	34.19	58.94	1.55	22.06	0.374	1.842	7.11	13.74	1392	252.5	0.188
C9	35.30	60.86	1.55	22.77	0.383	1.868	7.14	13.40	1433	263.3	0.190
C10	34.65	59.74	1.54	22.22	0.365	1.840	7.18	13.44	1425	263.3	0.189
C11	33.27	57.36	1.61	20.71	0.445	2.040	8.03	11.18	1525	304.2	0.208
C12	33.62	57.97	1.63	20.63	0.459	2.060	8.01	11.19	1567	315.3	0.211
C13	33.64	58.35	1.61	21.44	0.460	2.000	8.07	11.31	1550	306.5	0.211
C14	34.73	59.88	1.65	21.10	0.403	1.935	7.86	10.64	1550	337.5	0.209
C15	36.23	62.46	1.64	22.10	0.409	1.966	7.78	10.65	1300	206.0	0.180
C16	35.08	60.48	1.61	21.74	0.400	1.959	7.83	10.83	1375	239.5	0.186

*Soluble NPK in compost extract.

Effect of compost extract on conidial germination:

Results presented in Table, 3 show that all treatments significantly reduced spore germination of *L. taurica*. The highest reduction was observed with treatment of fungicide Topas 100 EC (C_{17}) followed by compost + phosphate rock + *B. subtilis* treatment (C_{15}) with significant differences between them, being 89.3 and 82.1%, respectively followed by compost + phosphate rock + *T. harzianum* treatment (C_{16}) and compost + gypsum + *B. subtilis* (C_{12}), without significant differences between them being 78.6%. Moreover, moderate reduction was observed with the treatments of Compost. + Gypsum + *T. harzianum* (C_{13}), Compost + *B. subtilis*. (C_6), Compost. + Phosphate rock + AM fungi (C_{14}) and Compost + *T. harzianum* (C_7), being 75.0, 75.0, 71.4 and 71.4%, respectively. The use of compost only (C_1) and compost + sulphur (C_2) showed the lowest inhibition in spore germination, being 50% without significant differences between them followed by treatments of compost + AM fungi (C_5) and compost + sulphur + AM fungi (C_8) without significant differences between them being 57.1% .

Table (3): Effect of components of compost extract on spore germination of *Leveillula taurica*.

Treatments	Spore germination %	Reduction* %
C1	14	50.0
C2	14	50.0
C3	11	60.7
C4	9	67.9
C5	12	57.1
C6	7	75.0
C7	8	71.4
C8	12	57.1
C9	11	60.7
C10	10	64.3
C11	10	64.3
C12	6	78.6
C13	7	75.0
C14	8	71.4
C15	5	82.1
C16	6	78.6
C17	3	89.3
C18	28	---
LSD at 0.05	1.0	---

Effect of compost and compost extract on disease incidence and severity:

Data presented in Table, 4, and Figs. 1 and 2 illustrate that there were significant differences among treatments in their effect on powdery mildew incidence and severity. In general, addition of phosphate rock and gypsum with bioagents to compost improved its efficiency than each one alone. Among all treatments, the fungicide Topas 100 EC (C_{17}) was the most efficient in this regard which recorded the lowest disease incidence, being 6.9%, followed by compost + phosphate rock + *B. subtilis* treatment (C_{15}) and compost + phosphate rock + *T. harzianum* treatment (C_{16}). The corresponding mean values in disease incidence were 6.9 and 7.1 % and disease severity, being 5.7 and 5.8 %, respectively on the average of two seasons 2017 and 2018 .Application of compost + gypsum + *B. subtilis* (C_{12}) showed moderate efficiency in reducing disease incidence and severity followed by compost + gypsum + *T. harzianum* (C_{13}). On the other hand, addition of bioagents to compost increased their 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* (C_6) was more efficient followed by compost + *T. harzianum* (C_7). Application of compost alone or supplemented with sulphur or with mycorrhizae gave the lowest efficiency. Generally, the effectiveness of the tested treatments significantly varied according to the application method. Soil amendment with the tested treatments and spraying the leaves with compost extract was the most effective in reducing the disease incidence and severity than spraying the foliar by compost extract only.

Table (4): Effect of different compost treatments and two different methods of application on the incidence and severity of powdery mildew on pepper plants.

Treatments	Mean of the two growing seasons								
	Application methods (M)								
	Disease incidence %			Disease severity %			AUDPC		
	Foliar spray	Soil amend. + Foliar spray	Mean (T)	Foliar spray	Soil amend. + Foliar spray	Mean (T)	Foliar spray	Soil amend. + Foliar spray	Mean (T)
C1	14.5	12.2	13.4	11.3	7.6	9.5	424.0	289.0	356.5
C2	14.3	11.1	12.7	10.1	7.6	8.9	255.15	226.5	240.9
C3	13.4	10.9	12.2	9.4	7.1	8.3	267.1	298.0	282.6
C4	11.8	9.9	10.9	8.9	6.6	7.8	272.3	260.0	266.2
C5	13.7	11.1	12.4	10.1	7.5	8.8	289.8	345.5	317.7
C6	10.2	8.6	9.4	8.1	6.3	7.2	256.9	282.0	269.5
C7	11.7	8.8	10.3	8.2	6.3	7.3	175.7	337.0	256.4
C8	13.4	11.0	12.2	9.8	7.5	8.7	407.5	301.5	254.5
C9	13.4	10.9	12.2	9.6	7.3	8.5	271.6	309.0	290.3
C10	12.5	10.3	11.4	9.4	7.1	8.3	558.8	268.0	413.4
C11	12.4	10.3	11.4	9.2	7.0	8.1	337.5	251.5	294.5
C12	10.1	7.6	8.9	7.2	4.7	6.0	252.0	281.5	266.8
C13	10.2	7.9	9.1	8.1	5.9	7.0	256.6	313.0	284.8
C14	11.8	9.5	10.7	8.4	6.4	7.4	257.3	285.0	271.2
C15	9.5	6.9	8.2	6.8	4.5	5.7	292.9	298.5	295.7
C16	9.7	7.1	8.4	7.1	4.5	5.8	273.7	318.0	295.9
C17	7.8	5.9	6.9	5.6	3.9	4.8	225.4	250.0	237.7
C18	66.4	57.2	61.8	66.4	57.2	61.8	861.5	882.5	872.0
Mean (M)	14.8	12.1	---	11.9	9.2	---	329.8	322.0	---
LSD at 0.05	T = 0.7 M = 0.2 TM = 1.0			T = 0.9 M = 0.3 TM = 1.2			T = 15.7 M = 5.2 TM = 22.2		

Fig. (1): Effect of compost supplemented with bioagents on pepper powdery mildew C, D compared with control A, B foliage

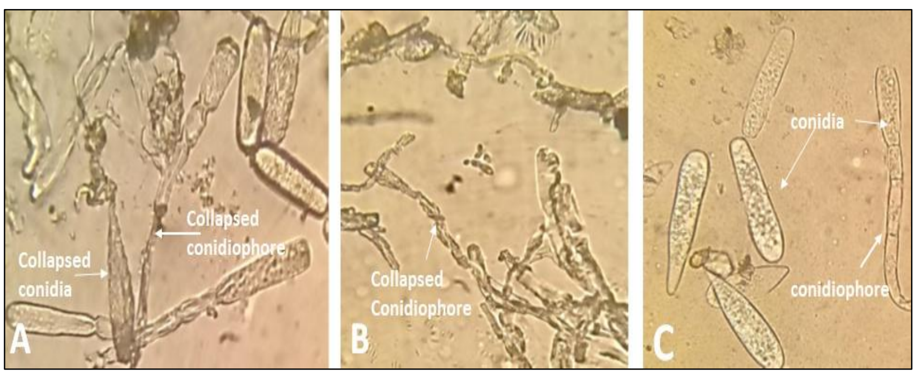

Fig. (2): A- Effect of compost mixed with Trichoderma spray; B- Effect of compost mixed with *Bacillus subtilis* spray; C- control, (400X)

Evaluation of pepper yield and its components and NPK uptake:

In fact, addition of compost, alone or combined with sulphur, rock phosphate, gypsum and different tested bioagents promoted the growth of pepper plants and significantly increased the plant height, number of branches, fruit weight, fruit yield per plant and vitamins in both seasons compared to the untreated plants (Tables, 5 and 6).

Table (5): Effect of interaction between compost extract, supplemented with bioagents, sulphur, phosphate rock and gypsum on plant height and Number / branches plant Number during the two successive growing seasons.

Treatments	Mean of the two growing seasons					
	Application methods (M)					
	Plant height (cm)			Primary branches / plant (No)		
	spray	A.*+ spray	Mean (T)	spray	A.+ spray	Mean (T)
C1	54.50	55.65	55.08	3.00	3.30	3.15
C2	55.70	57.19	56.45	3.10	3.50	3.30
C3	57.70	60.88	59.29	3.20	4.00	3.60
C4	58.33	61.35	59.84	3.50	4.10	3.80
C5	55.00	56.55	55.78	3.10	3.50	3.30
C6	56.33	59.56	57.95	3.20	3.80	3.50
C7	56.65	59.49	58.07	3.20	3.70	3.45
C8	56.60	57.57	57.09	3.15	3.70	3.43
C9	57.60	60.31	58.96	3.25	3.90	3.58
C10	57.50	57.59	57.55	4.25	3.80	4.03
C11	58.60	62.33	60.47	3.30	4.00	3.65
C12	60.60	65.77	63.19	3.50	4.50	4.00
C13	60.00	63.42	61.71	3.35	4.20	3.78
C14	60.40	62.95	61.68	3.35	4.25	3.80
C15	61.10	66.13	63.89	3.60	4.60	4.10
C16	60.75	64.95	62.85	3.50	4.40	3.95
C17	54.50	56.50	55.50	3.30	3.50	3.85
C18	52.60	52.85	52.73	2.80	3.00	2.90
Mean M	57.47	60.06	---	3.31	3.88	---
LSD 0.05	6.698	3.091		0.476	0.324	

*soil amendment

The highest values were recorded due to using C_{15} (treatment of compost combined with phosphate rock and inoculated with *B. subtilis*) followed by C_{16} (compost + phosphate rock + *T. harzianum* treatment) with significant differences between them. The corresponding mean values were 61.10 & 66.13cm, for plant height; 3.60 & 4.60, for branches number/plant 19.20 & 21.50 gm for fruit weight 0.92/plant and, 97.02 & 93.50 on the average, respectively. For vitamin C. Compost + gypsum + *B. subtilis* (C12) gave moderate values in this respect followed by compost + gypsum + *T. harzianum* (C_{11}) and Compost + gypsium + AM fungi treatment (C_{10}). Meanwhile, addition of compost only without any amendments (C_1) gave the lowest plant height (55.08cm), branches no./plant (3.15), fruit weight (18.25), Fruit yield / plant (0.80 gm) and vitamin C (91.10). Generally, soil amendment with the tested compost treatments and spraying the foliar with compost extract caused a significant promotion to plant growth than spraying the foliar with compost extract only.

Table (6): Effect of interaction between compost extract, supplemented with bioagents, sulphur, phosphate rock and gypsum on fruit weight, fruit yield/plant and vitamin C during the two successive growing seasons.

Treatments	Mean of the two growing seasons								
	Application methods (M)								
	Fruit weight gm			Fruit yield/plant (kg)			Vitamin C		
	spray	A.+ spray	Mean (T)	spray	A.+ spray	Mean (T)	spray	A.+ spray	Mean (T)
C1	18.00	18.50	18.25	0.76	0.83	0.80	90.30	91.89	91.10
C2	18.20	18.80	18.50	0.77	0.85	0.81	91.50	93.71	92.61
C3	18.50	19.50	19.00	0.80	090	0.85	92.80	94.19	93.50
C4	18.50	20.00	19.25	0.81	0.92	0.87	93.05	95.62	94.34
C5	18.25	18.70	18.48	0.77	0.85	0.81	91.60	93.50	92.55
C6	18.30	19.00	18.65	0.79	0.90	0.85	92.00	94.85	93.43
C7	18.30	19.00	18.65	0.78	0.88	0.83	91.80	94.06	92.93
C8	18.20	18.90	18.55	0.78	0.87	0.83	91.68	94.65	93.17
C9	18.40	19.20	18.80	0.80	0.88	0.84	92.43	95.93	94.18
C10	18.30	19.00	18.65	0.80	0.87	0.84	92.00	94.46	93.23
C11	18.75	20.20	19.48	0.82	0.93	0.88	93.00	95.77	94.39
C12	19.00	20.50	19.75	0.85	0.95	0.90	93.25	96.87	95.06
C13	18.80	20.20	19.50	0.83	0.94	0.89	93.10	96.05	94.58
C14	18.80	20.75	23.78	0.85	0.94	0.90	93.20	95.80	94.50
C15	19.20	21.50	20.35	0.85	098	0.92	93.50	97.02	95.26
C16	19.00	21.00	20.00	0.87	0.97	0.92	93.35	96.95	95.15
C17	18.50	18.50	18.50	0.85	0.85	0.85	92.35	92.35	92.35
C18	17.00	16.50	16.75	0.75	0.65	0.70	90.10	88.10	89.10
Mean (M)	18.44	19.43	---	0.81	0.89	---	92.28	94.54	---
LSD at 0.05	T =1.15 M = 0.38 TM = 1.63			T = 0.03 M = 0.01 TM = 0.05			T = 2.34 M = 0.78 TM = 3.31		

The present results (Tables, 7 and 8) indicate that fresh & dry fruits, yield (kg/fed.) were significantly affected by the application of various compost treatments. The highest plant fresh weight, being 8.35 and 8.30 ton/fed., dry weight (577.27 and 574.07 kg/fed.), respectively for the fruits yield were obtained from C_{15} (treatment of compost + phosphate rock + *B. subtilis*) followed by C_{16} (compost + phosphate rock + *T. harzianum*). However the treatments of compost + gypsum + *B. subtilis* (C_{12}), compost + gypsum + *T. harzianum* (C_{13}) and compost + phosphate rock + AM fungi (C_{14}) showed moderate fresh and dry weights of fruits yield with significant differences among them. While application of compost only without any addition gave the lowest fresh and dry weights of fruits yield compared to the other treatments. The corresponding mean values of fresh weight were 7.10, 8.13 ton/fed and dry weight, being 496.77, and 573.97 kg/fed, respectively for fruits yield. On the other hand application of various compost treatments as soil amendments and spraying the pepper foliage by compost extract significantly increased the fresh and dry weights of fruits yield than spraying the pepper foliage by compost extract only.

Table (7): Effect of compost amended with sulphur, phosphate, gypsum and bioagents on fresh and dry weigh.

Treatment (T)	Mean of the two growing seasons					
	Application methods					
	Fresh weight (ton/fed.)			Dry weight (kg/fed.)		
	spray	A.+ spray	Mean (T)	spray	A.+ spray	Mean (T)
C1	7.10	8.13	7.62	496.77	573.97	530.37
C2	7.20	8.37	7.79	505.13	588.93	547.03
C3	7.47	8.57	8.02	513.77	599.07	556.42
C4	7.40	8.57	7.99	514.07	608.13	561.10
C5	7.27	8.40	7.84	507.67	588.07	547.87
C6	7.47	8.53	8.00	512.43	594.70	553.57
C7	7.40	8.50	7.95	511.33	593.60	552.47
C8	7.30	8.40	7.85	510.37	589.67	550.02
C9	7.33	8.43	7.88	510.47	592.13	551.30
C10	7.33	8.40	7.87	508.30	590.80	549.55
C11	7.50	8.63	8.07	515.43	608.83	562.13
C12	7.70	8.77	8.24	519.23	622.50	570.87
C13	7.63	8.77	8.20	518.23	619.67	568.95
C14	7.60	8.67	8.14	516.60	611.13	563.87
C15	7.80	8.90	8.35	522.60	631.93	577.27
C16	7.77	8.83	8.30	520.47	627.67	574.07
C17	7.27	8.30	7.79	500.97	582.73	541.85
C18	6.20	6.23	6.22	445.33	434.43	439.88
Mean (M)	7.37	8.41	---	508.29	592.11	---
LSD 0.05	T = 0.58 M = 0.19 TM = 0.82			T = 19.18 M = 6.39 TM = 27.12		

Table (8): Effect of compost amended with sulphur, phosphate, gypsum and bioagents on NPK uptake.

Treatments (T)	Mean of the two growing seasons								
	Application methods (M)								
	N Uptake (kg/fed.)			P Uptake (kg/fed.)			K Uptake (kg/fed.)		
	spray	A.+ spray	Mean (T)	spray	A.+ spray	Mean (T)	spray	A.+ Spray	Mean (T)
C1	5.87	7.03	6.45	1.00	1.17	1.09	4.79	5.10	4.95
C2	6.33	7.53	6.93	1.07	1.23	1.15	5.00	5.40	5.20
C3	6.63	7.93	7.28	1.13	1.33	1.23	5.25	5.73	5.49
C4	6.53	7.93	7.23	1.13	1.40	1.27	5.28	5.63	5.46+
C5	6.30	7.53	6.92	1.03	1.23	1.13	5.02	5.40	5.21
C6	6.47	7.93	7.20	1.10	1.30	1.20	5.15	5.57	5.36
C7	6.47	7.80	7.14	1.10	1.30	1.20	5.12	5.57	5.35
C8	6.37	7.63	7.00	1.07	1.27	1.17	5.14	5.53	5.34
C9	6.43	7.70	7.07	1.07	1.27	1.17	5.20	5.57	5.39
C10	6.43	7.63	7.03	1.07	1.27	1.17	5.17	5.53	5.35
C11	6.80	7.93	7.37	1.21	1.35	1.28	5.34	5.73	5.54
C12	7.07	8.63	7.85	1.27	1.47	1.37	5.32	5.80	5.56
C13	7.00	8.13	7.57	1.23	1.43	1.33	5.42	5.80	5.61
C14	6.80	8.03	7.42	1.23	1.40	1.32	5.30	5.73	5.52
C15	7.07	8.93	8.00	1.40	1.50	1.45	5.39	5.87	5.63
C16	7.07	8.80	7.94	1.27	1.50	1.39	5.39	5.87	5.63
C17	6.25	7.07	6.66	1.10	1.25	1.18	4.49	5.10	4.80
C18	5.13	5.17	5.15	0.83	0.87	0.85	3.92	5.40	4.66
Mean (M)	6.50	7.74	---	1.13	1.31	---	5.09	5.57	---
LSD at 0.05	T = 0.64 M = 0.21 TM = 0.90			T = 0.05 M = 0.01 TM = 0.06			T = 0.43 M = 0.14 TM = 0.60		

*soil amendment

Effect of compost on physical and chemical characteristics of soil

Data presented in Table (9) illustrate the effect of different compost treatments tested on some physical and chemical characteristics of soil at the end of the growing season. Generally, all different compost treatments either alone or in combination with bioagents, sulphur, phosphate rock and gypsum caused decrease in soil pH values as compared with control value. Soil pH value of 8.57 was recorded in the control whilst; minimum pH value (8.35) was recorded in C_{15} (compost + phosphate rock + *T. harzianum* treatment) followed by, C_{16} (treatment of compost + phosphate rock + *B. subtilis*), C_8 (treatment of compost + sulphur + AM fungi), (C_9 (treatment of compost +

sulphur +*B. subtilis*) and C_{14} (compost + phosphate rock +AM fungi). However, C_1 (treatment of compost), C_{11} (compost + gypsum + AM fungi treatment) and C_2(compost + AM fungi treatment) showed no significant differences among them in this respect.

The data revealed a relative increase in soil salinity (EC) as compared with control value (0.80 dS m^{-1}) due to using all compost applications. The highest values were obtained with C_2 (compost + sulphur treatment), C_8 (treatment of compost + sulphur + AM fungi) and C_9 (treatment of compost + sulphur + *B. subtilis*). The corresponding values were 0.73, 0.72 and 0.71 dS m^{-1} respectively, followed by C_{10} (compost + sulphur +*T. harzianum*), C_1 (compost treatment), C_7 (compost + *T. harzianum*), C_5 (compost + AM fungi) and C_6 (compost + *B. subtilis*) without significant differences among them while the lowest one was obtained with C_4 (treatment of compost + phosphate rock) being, 0.61 dS m^{-1}.

Organic carbon (OC) and organic matter (OM) contents of the soil were significantly increased with various compost treatments compared to the control treatment. The highest OC and OM contents were determined in compost + phosphate rock treatment (C_4) followed by C_9 (compost + sulphur + *B. subtilis*), C_{15} (compost + phosphate rock + AM fungi) without significant differences among them. The corresponding mean values for OC were 1.255, 1.196 and 1.196, respectively and for OM were 2.163, 2.063 and 2.063, respectively. While the lowest OC and OM contents were obtained due to treatment of compost only without any addition (C_1) followed by compost + *B. subtilis* treatment (C_6) and treatment of compost + AM fungi (C_5) without significant differences among them but are 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 due to using compost + phosphate rock + *B. subtilis* plots (C_{15}) followed by compost + phosphate rock (C_4), compost + phosphate rock + AM fungi (C_{14}), compost + phosphate rock + *T. harzianum* and compost + sulphur + *B. subtilis* (C_9) without significant differences among them. The corresponding mean values were 0.128, 0.124, 0.123, 0.119 and 0.119ppm, respectively. While the lowest one was recorded due to application of compost only without any addition (C_1), being 0.106 ppm. Regarding phosphorus, the highest values were recorded due to treatments addition of gypsum to compost, especially that inoculated with the tested bioagents, being, 15.98 ppm in compost + gypsum + *B. subtilis* treatment (C_{12}), 15.80 ppm due to treatment of compost + gypsum + *T. harzianum* (C_{13}) and 15.75ppm due to treatment of compost + gypsum + AM fungi (C_{11}) without significant differences among them. The lowest values were recorded with C_1 (treatment of compost only), T_8 (compost + AM fungi treatment) and C_7 (compost + *T. harzianum* treatment). On the other hand, the highest values of available K, were recorded with C_{12} (compost + gypsum + *B. subtilis* treatment), C_{15} (compost + phosphate rock + *B. subtilis* treatment), C_{11} (compost + gypsum +AM fungi), C_{16} (compost + Phosphate rock + *T. harzianum* treatment), C_{14} (compost +

phosphate rock + AM fungi treatment), C_9 (compost + sulphur + *B. subtilis*), C_4 (compost + phosphate rock treatment), C_{13} (compost + gypsum + *T. harzianum* treatment), C_{13} (compost + gypsum treatment), C_8 (compost + sulphur +AM fungi treatment), and C_{10} compost + sulphur + *T. harzianum* treatment) which lies in the same statistical group. Meanwhile the lowest values were recorded with C_1 plots (treatment of compost only).

Table 9: Effect of interaction between compost amended with sulphur, phosphate, gypsum and bioagents on some physical and chemical properties of soil in the two growing seasons.

Treatments	Mean of the two growing seasons							
	pH	EC	OC %	OM %	C/N ratio	Total N %	P (ppm)	K (ppm)
C1	8.48	0.66	1.112	1.916	10.52	0.106	13.53	252.97
C2	8.42	0.73	1.138	1.961	10.36	0.111	14.14	256.63
C3	8.47	0.63	1.151	1.984	10.18	0.113	15.21	276.37
C4	8.43	0.61	1.255	2.163	10.12	0.124	14.33	280.02
C5	8.46	0.65	1.122	1.934	10.29	0.109	13.61	253.70
C6	8.45	0.65	1.118	1.928	10.25	0.109	14.00	264.67
C7	8.45	0.66	1.165	2.009	10.51	0.111	13.62	261.74
C8	8.38	0.72	1.131	1.950	8.66	0.115	14.62	276.37
C9	8.38	0.71	1.196	2.063	10.04	0.119	15.00	282.91
C10	8.37	0.69	1.138	1.962	10.18	0.113	14.61	273.44
C11	8.47	0.64	1.132	1.951	10.20	0.111	15.75	286.61
C12	8.45	0.62	1.151	1.984	10.21	0.113	15.98	292.45
C13	8.45	0.63	1.145	1.974	10.13	0.113	15.80	279.29
C14	8.38	0.63	1.170	2.017	9.58	0.123	15.11	282.95
C15	8.35	0.62	1.196	2.063	9.44	0.128	15.37	292.45
C16	8.37	0.62	1.160	2.000	9.84	0.119	15.24	285.87
C17	8.56	0.80	1.032	1.780	12.24	0.084	10.01	230.31
C18	8.57	0.80	1.020	1.754	12.11	0.087	9.94	226.65
L.S.D at 0.05	0.09	0.06	0.04	0.08	0.39	0.014	1.31	19.04

Effect of compost on enzymatic activities:

Data presented in Table, 10 show the effect of the tested compost treatments on the defense related enzyme activities in the treated pepper plants compared to the untreated control. Overall, all tested treatments significantly increased the activity of defense related enzymes and phenols in pepper plants.

Combined treatments of compost with phosphate rock or gypsum inoculated with the tested bioagents resulted excess in the activity for peroxidase, polyphenoloxidase enzymes compared to the control treatment. Maximum increase in peroxidase and polyphenol oxidase activities was detected with compost + phosphate rock + *B. subtilis* treatment (C_{15}), being 1.893 and 0.734 % respectively. The lowest activity of these enzymes was detected in pepper plants received compost only without any additions (C_1).

Table 10: Effect of compost treatments on Peroxidase and Polyphenol oxidase activities.

Treatment	Enzyme activity Δ A /min/g fw	
	Peroxidase	Polyphenol oxidase
C1	0.682	0.348
C2	0.785	0.351
C3	1.003	0.414
C4	1.024	0.505
C5	0.832	0.371
C6	1.072	0.593
C7	1.041	0.579
C8	0.953	0.382
C9	0.997	0.396
C10	1.009	0.435
C11	1.010	0.472
C12	1.253	0.681
C13	1.121	0.645
C14	1.039	0.518
C15	1.893	0.734
C16	1.312	0.693
C17	1.734	0.712
C18	0.413	0.292
LSD at 0.05	0.070	0.039

Discussion

Compost use is one of the most important factors which contribute in increasing 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 diseases in some crops (Stone *et al.*, 2003 and Zaki *et al.*, 2011). The present study demonstrated that compost extracts alone or combined with sulpher, phosphate rock or gypsum inoculated with any of the tested bioagents suppressed conidial germination of *L. taurica in vitro* assay. The suppressive activity of microbial enriched compost extracts observed in this study is likely biological in nature. Previous accumulation of soluble nutrients from compost to compost extract during brewing time enhanced beneficial microorganisms in extract (Ingham, 2005), 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 pepper powdery mildew incidence and severity compared to the control under field conditions. Addition of phosphate rock to compost and inoculated with *B. subtilis* showed the highest efficacy in this concern. This result is in line with the reports of Segarra *et al.* (2009a, b). Brinton *et al.* (1996) reported that the principal active agents in compost extract appear to be the genera *Bacillus* and *Trichoderma* which caused inhibition of spore germination, antagonism and competition with pathogens and induced resistance against pathogens when sprayed onto 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) (Zhang *et al*., 1998; Litterick *et al.*, 2004 and Al Mughrabi *et al*., 2008) or suppressive physicochemical properties (improved nutrient status of the plant, toxic compounds or induced resistance) (Hoitink *et al*., 1997). 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 (Paula Júnior *et al.*, 2009). However, disease reduction was accompanied with a gradual increase in peroxidase and polyphenoloxidase activity contents. In the present study, soil amendment with the tested compost treatments and spraying the foliage with their compost extracts significantly strongly induced synthesis and accumulation of peroxidase, polyphenoloxidase that sprayed only by compost extracts. This result is in agreement with reports of (Nwogbaga & Iwuagwu (2015) and Siddiqui *et al*. (2009) who reported that compost extracts increase peroxidase, polyphenoloxidase, 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 are responsible for induction of systemic resistance (Segarra *et al.*, 2009b). Also, the compost was rich in inorganic salts, organic carbon and phenols, which can affect pathogen growth and phyllosphere microorganisms (Segarra *et al*., 2009a).

Our results showed a general increase in both plant growth characteristics (plant height, number of branches / plant, fruit yield / plant, fruit fresh due to due to using tested compost treatments as soil amendments and compost extracts as foliar spray either alone or amended with sulphur, phosphate rock or gypsum inoculated with the tested bioagents compared with 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 (Donn *et al.*, 2014 and Nadjet *et al.*, 2014).

Sulphur gave the lowest effect in this regard either when applied alone or mixed with the tested bioagents to compost treatments. This result is in agreement with the report of Magarey *et al.* (2002) who reported that sulphur is toxic to most fungi including many of the antagonistic to *Uncenula necator*. Also Sulphur is a multi site fungicide which inhibits the production or activity of the range of enzymes.

Compost amended with phosphate rock and inoculated with bioagents recorded the. highest effect compared to the other treatments. Addition of phosphate supplementing microorganisms as *B. subtilis*, *T. harzianum* and AM fungi influenced phosphate rock solubility and stimulated pepper roots to absorb more P from the soil and its transporting towards shoots, resulting in stimulating the overall plant growth as compared to each treatment alone. Phosphorus is a responsible element about structural of the membrane system of the cell, the mitochondria and chloroplast (Akande *et al.*, 2008a).The methods of promoting the quality of phosphate rock and its agronomic efficiency include composting with organic manures (Adediran & Sobulo, 1997).Combination of poultry manure or cow dung with phosphate rock significantly improved release of P and performance of crops (Akande *et al.*, 2005 and Akande *et al.*, 2008b).The microbial activities stimulated nutrients uptake and plant growth may be due to hormones such as auxin or gibberellic acid production as declared by Contreras-Cornejo *et al.* (2016). The arbuscular mycorrhizal fungi (AMF) compose a symbiotic relationship with the roots of most plants by increasing plant phosphate (P) uptake and growth, while plants provide the AM fungi with exudates for metabolism (Smith et al., 2003). Gypsum is a moderately soluble source of the essential plant nutrients, calcium and sulphur, and can improve overall plant growth. Our results showed that application of different treatments of compost tested to soil cultivated with pepper 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 value is in agreement with Moreno *et al*. (1997) who mentioned that the reduction in pH results at the end of the growing season due to the root exudates, the release of NH4+ and the nitrification process which takes place during the course of plant growing period. CO_2 released into soil atmosphere due to decomposition of organic wastes can be converted into carbonic acid (H_2CO3) by reacting with water (H2O) and decreases soil pH (Chang *et al.,* 1991 and Sağlam, 1997). Dahdoh and Hassan (1997) 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*. (1996), who pronounced that increasing organic manure addition increased nutrient availability in the soil due to moreover amounts of available nutrients released from the decomposed organic manure. Rodriguez-*Vila et al.* (2016) confirmed that organic amendments sustain soil properties by rising organic matter, nutrient content, and microbial activity and thus increase crop growth and yield.

Therefore, this study can support the usefulness of inoculation of compost with any of the tested bioagents and soil amendment with compost on spraying the pepper plants with compost extract to control powdery mildew and improve production of pepper plants as well as improve soil fertility.

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إستخدام الكمبوست في مكافحة البياض الدقيقي على الفلفل و تأثيره على الإنتاجية

فرج محمد فرج[1] ، محمد بسيونى طه[2] ، سعيد محمد كامل[1] ،و احمد جمعة محمد[3]

1- معهد بحوث أمراض النباتات ، مركز البحوث الزراعية ، الجيزة ، مصر
2- معهد بحوث الاراضى والمياة والبيئة ،مركز البحوث الزراعية ، الجيزة ، مصر
3- معهد بحوث البساتين ، مركز البحوث الزراعية ، الجيزة ، مصر

تم تقييم كفاءة الكمبوست (حطب الذرة المعامل بسماد الغنم) مع الكبريت وصخر الفوسفات والجبس وبعض العوامل الحيوية مثل (*Bacillus subtilis,* *Trichoderma harzianum* ،و بعض فطرايات الميكروهيزا) لمكافخه البياض الدقيقي على الفلفل تحت الظروف الحقلية. أجريت التجارب تحت ظروف العدوى الطبيعية في المزرعة التجريبية لمحطة بحوث البساتين في سدس. مركز البحوث الزراعيه - بمحافظة بني سويف. تم استخدام طريقتين مختلفتين للتطبيق ، معاملة التربة و الرش الورقى أومعاملة الرش فقط علي المجموع الخضري لتقليل الاصابه بمرض البياض الدقيقي على الفلفل وتحسين إنتاجيته ، وكذلك زيادة خصوبة التربة. سببت كل معاملات الكومبوست المختبره انخفاضاً في الأوراق المصابة والشدة المرضيه للبياض الدقيقي ، بالإضافة إلى زيادة المحصول مقارنة بالمعاملة الكنترول . من ناحية أخرى ، أدت الاضافه الارضيه والرش لنباتات الفلفل خلال موسم النمو مع الكمبوست و الخلط مع *Trichoderma harzianum* إلى انخفاض كبير في شدة المرض مع زيادة معنويه كبيرة في محصول الفلفل مقارنة بمعامله الكنترول. بالإضافة إلى ذلك ، فإن خلط الكمبوست مع *Bacillus subtilis* أعطت أفضل النتائج في مكافحه البياض الدقيقي فى الفلفل.