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The Use of Bread Yeast as a Biocontrol Agent for Controlling Seed-Borne Fungi of Faba Bean

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Abstract: Present objective was to study this phenomenon on the common seed-borne fungi of faba bean in soil amended with composted organic wastes and infested with the most commonly isolated fungi from *Vicia faba* seed. *In vitro* studies showed that the yeast was effective in reducing the linear growth of *Cephalosporium* sp., *F. verticillioides*, *F. oxysporum*,. *F. solani*, *R. solani* and *V. dahliae*. Pre- and post-emergence damping-off caused by *Cephalosporium* sp., *F. verticillioides*, *F. oxysporum*, *F. solani*, *R. solani* and *V. dahliae* was reduced significantly when seeds of faba bean were coated with a water suspension (10^9 cfu mL^{-1}) of the yeast before sowing in soil supplemented with compost type (1) (prepared by Mansoura manufacturer with organic waste from city garbage) or type (2) (consisted of 1 ton of horticultural waste and 100 kg sheep manure). Soil was artificially infested with the fungi isolated from faba bean seeds. The above treatment significantly increased plant growth parameters including height, shoot and root length, number of branches/plant, number of pods/plant, pod weight/plant, fresh weight and dry weight. Photosynthetic pigments (chlorophyll A, chlorophyll B and carotenoids) were also increased by the treatments. Total phenols content in the treated plant leaves was higher than in the control plants.

Key words: *Saccharomyces cerevisiae*, bread yeast, biological control, faba bean, composted organic materials

INTRODUCTION

Vicia faba, which has several common names (broad bean, fava bean, faba bean, horse bean, field bean, tic bean), is a species of bean (Fabaceae) native to North Africa and Southwest Asia and is extensively cultivated elsewhere.

This crop is subjected to numerous injuries and stresses which interfere with growth and development. Many fungi are serious pathogens on flowers and seeds, reducing seed yield both qualitatively and quantitatively. Other fungi, including saprophytes and very weak parasites, may lower seed quality. The most common seed-borne fungi on faba bean are: *Ascochyta fabae*, the cause of leaf and pod spot; *Botrytis cinerea*, the cause of grey mould; *Botrytis fabae*, the cause of chocolate spot; *Fusarium* sp., the cause of foot rot and wilts and *Rhizoctonia solani*, the cause of damping-off of seedlings. Seed abortion, shrunken seeds, reduction in seed size, seed rot, seed necrosis, seed discoloration, reduction in germination capacity and physiological alterations in seed are caused by these pathogens (Neergaard, 1979).

Certain yeasts possess many features which make them favourable as biocontrol agents (Wilson and Wisniewski, 1989). Gianluca *et al.* (2006) isolated antagonistic yeasts from the epiphytic flora associated with grape berries. The yeasts showed biological control of *Aspergillus carbonarius* and *A. niger*, which produce Ochratoxin A in grape. Lassois *et al.* (2008) reported the antagonistic activity of two yeast strains, *Pichia anomala* and *Candida oleophila*, on the parasitic complex of banana crown rot.

Composts have been found to be effective as biocontrol agents of various plant pathogens under field conditions (Keener *et al*., 2000). Ioanna *et al*. (2008) found that no chemical control method was adequate to control the soil-borne fungus *Verticillium dahliae*. Management strategies were focused on preventive measures, utilizing microbes to suppress *V. dahliae*. Eggplants grown in sterilized or non-sterilized compost were transplanted to soil infested with *V. dahliae* microsclerotia, amended or not with sterilized or non-sterilized compost. The most effective treatments were those that included non-sterilized compost; therefore, the observed suppression of *V. dahliae* could be attributed to microbial agents.

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Several microbes were isolated from the root system of eggplants grown in the compost and tested *in vitro* against *V. dahliae*. Two bacterial strains were identified as members of the *Pseudomonas fluorescens* complex and two fungal isolates of *Fusarium oxysporum* were selected for further evaluation under glasshouse conditions. The ability of the microbial agents to reduce the percentage of diseased leaves compared to the control treatment was demonstrated.

This study was undertaken to evaluate the effect of bread yeast in suppressing the most common seed-borne pathogens of faba bean in the presence of soil amended with composted organic household wastes and yard trimmings.

MATERIALS AND METHODS

Isolation and identification of yeast: *Saccharomyces cerevisiae* (Meyen ex E.C. Hansen) was isolated on malt extract agar medium (MEA), identified in the Microbiology Department, Faculty of Agriculture, Mansoura University and tested for its antagonistic effects against the following seed-borne fungi of faba bean: *Cephalosporium* sp., *F. oxysporum*, *F. solani*, *F. verticillioides*, *R. solani* and *V. dahliae*.

***In vitro* agar plate bioassays:** The isolated yeast was assayed *in vitro* for inhibition of the six pathogenic fungi. Initial inhibition assays were conducted on PDA plates with single streaks of yeast drawn across the plate's centers. After 2-3 days growth at 20-25°C, PDA discs of 0.5 cm diameter were taken from the margins of growing pathogen colonies and placed on either sides of the yeast streaks at a distance of 30 mm, then incubated for an additional 4-6 days at 20-25°C. The distance was measured from the fungal colony center to its edge nearest the yeast streak. This was compared to the growth of a non-streaked control to determine the degree of inhibition of pathogen growth (Wang *et al*., 2003). Three replicates were used for each pathogen.

Effect of *S. cerevisiae* combined with composted organic materials on the seed-borne pathogenic fungi of faba bean plants under greenhouse conditions: Two types of compost were used; Compost (1) which was prepared by Mansoura manufacturer for organic manure from city garbage and Compost (2) which consisted of 1 ton of horticultural waste and 100 kg sheep manure. Chemical and physical analyses of these composts were performed at the Mansoura manufacturer for compost (1) and at the Faculty of Agriculture, Mansoura University for compost (2). The results are shown in Table 1.

Table 1: Chemical and physical analysis of the two types of compost

Parameters	Compost type (1)	Compost type (2)
Moisture content (%)	48.20	42.20
Total N (%)	1.05	0.96
Total P (%)	0.19	0.23
Total K (%)	0.91	0.98
Organic carbon (%)	44.82	25.49
C/N ratio	24:1	15:10
pH	8.4	7.50
EC (dS m^{-1})	1.85	1.78

An experiment was conducted to determine the effect of the composted organic materials enriched with the yeast *S. cerevisiae* on the six pathogenic fungi. *S. cerevisiae* was applied as a seed dressing to the faba bean seeds. Three flasks containing two-days-old liquid cultures of *S. cerevisiae* were used. Seeds were coated with an adhesive material (acacia gum) before treatment. Yeast-coated seeds contained about 10^9 cfu $seed^{-1}$ (Weller and Cook, 1983).

Eighteen plastic pots (25 cm diameter) containing sterilized sandy loam soil were used for each fungus. Three replicates (pots) were used for each treatment as follows:

- Control (non-amended soil, non-treated seeds)
- Compost type (1) treated soil, non-treated seeds
- Compost type (2) treated soil, non-treated seeds
- Yeast (non-amended soil, *S. cerevisiae* treated seeds)
- Compost type (1) treated soil, *S. cerevisiae* treated seeds
- Compost type (2) treated soil, *S. cerevisiae* treated seeds

Each type of compost was added to the pots at the rate of 25 g/pot. The treatments were inoculated separately with each fungal preparation at the rate of 5% (w/w). Pots were kept in a greenhouse for 7 days at 22±5°C to allow the fungi to adapt before sowing seeds. During that period, the soil was moistened when necessary. Seeds were coated with a yeast suspension taken from 3-days-old liquid cultures. Five seeds were planted in each pot. Control pots were prepared similarly but were pathogen-free.

The numbers of pre- and post-emergence damping off and stunted seedlings, as well as healthy plants, were recorded after 15, 30 and 45 days. Growth parameters including plant height (cm), root length (cm), shoot length (cm), number of branches (branch/plant), number of pods (pod/plant), pod weight (g), fresh weight (g) and dry weight (g) were recorded after 60 days. Photosynthetic pigments (mg g^{-1} fresh weight) and total phenols (mg catechol/100 g fresh weight) were measured.

Estimation of photosynthetic pigments content: The spectrophotometric method recommended by

Metzner *et al.* (1965) was used in this investigation. A definite weight of fresh leaves was homogenized immediately after harvesting in 5 mL cold aqueous acetone (85%), kept overnight in a refrigerator and then centrifuged. The supernatant, which contained the pigments, was diluted with cold aqueous acetone to an appropriate volume for spectrophotometric measurements. The extract was measured against blanks of pure 85% acetone solution at three wavelengths: 452, 644 and 663 nm. The concentration of each pigment, chlorophyll A (Chl. A), chlorophyll B (Chl. B) and carotenoids (Carot.), was determined by using the following equations:

$$\text{Chl. A} = 10.3\ E_{663}\text{-}0.918\ E_{644}$$

$$\text{Chl. B} = 19.7\ \text{E644-3.87 E663}$$

$$\text{Carot.} = 4.2\ \text{E452-(0.0264 Chl. a} + 0.426\ \text{Chl. b)}$$

Estimation of total phenols content: Total phenols were determined using the Folin-Ciocalteau reagent (Singleton and Rossi, 1965). To determine the calibration curve, 1 mL aliquots of 0.02, 0.04, 0.06, 0.08 and 1.00 mg mL^{-1} ethanolic catechol solutions were combined with 0.5 mL Folin-Ciocalteau reagent. After 3 min, 2 mL (200 g L^{-1}) sodium carbonate was added and the contents were mixed thoroughly. The final color change was measured calorimetrically at 650 nm using a SPEKOL11 Carl Zeiss photometer and the calibration curve was drawn.

Fresh leaf samples (2 g) were homogenized in 80% aqueous ethanol at room temperature and centrifuged in cold at 10,000 rpm for 15 min and the supernatant was saved. The residues were re-extracted twice with 80% ethanol and the supernatants were pooled, put in evaporating dishes and evaporated to dryness at room temperature. Residues were dissolved in 5 mL of distilled water. One hundred microlitres of this extract was diluted to 3 mL with water and mixed with the same amount of reagents as described above. The color was developed and absorbance measured after 60 min. The results were expressed as mg catechol/100 g fresh weight material. All determinations were replicated three times. Total content of phenolic compounds in plant ethanolic extracts was calculated as catechol equivalents by the following equation:

$$T = \frac{c \times V}{m} \times 100$$

Where:

T: Total content of phenolic compounds, in mg of catechol/100 g of fresh weight material

c: The concentration of catechol established from the calibration curve, in mg mL^{-1}

V: The volume of extract in mL

m: The weight of pure plant ethanolic extract in g

Statistical analysis: Data were subjected to analysis of variance by Duncan's multiple range tests using SAS version 6.11 (Duncan, 1995).

RESULTS

Effect of *S. cerevisiae* isolated yeast from compost on seed-borne pathogenic fungi of faba bean plants under greenhouse conditions: The following pathogenic fungi were used in this investigation: *Cephalosporium* sp., *F. verticillioides*, *F. oxysporum*, *F. solani*, *R. solani* and *V. dahliae*.

***In vitro* agar plate bioassays:** Data presented in Table 2 show the degree of fungal inhibition due to the effect of isolated yeast; *Cephalosporium* sp. had linear growth of 1.35 cm, *F. verticillioides* had 0.97 cm, *F. oxysporum* had 0.77 cm, *F. solani* had 1.80 cm, *R. solani* had 0.97 cm and *V. dahliae* had 0.87 cm.

Effect of *S. cerevisiae* combined with tested composts on faba bean seeds grown in pathogen-infested soil under greenhouse conditions: Faba bean seeds coated with *S. cerevisiae* were grown in soil supplemented with compost type (1) or type (2). Soil was infested with the fungal isolates. The results showed decreases in pre- and post-emergence damping-off and stunted seedlings (Table 3-5).

Data in Table 3 show that seed treatment with *S. cerevisiae* significantly reduced the amount of pre-emergence damping-off due to the presence of following fungi in soil: *F. oxysporum* and *F. solani* (50.00%), *F. verticillioides* (25.00%), *R. solani* (33.32%) and *V. dahliae* (25.00%).

Data in Table 4 show that the treatment in which compost type (1) was added to soil and seeds were coated

Table 2: Antagonistic effect of isolated yeast on linear growth of tested pathogenic fungi *in vitro*

Fungus	Linear growth (cm)	Inhibition (%)
Control	2.75a [x]	0.00
Cephalosporium sp.	1.35bc	50.90
F. oxysporum	0.77c	72.00
F. solani	1.80b	34.55
F. verticillioides	0.97c	64.73
R. solani	0.97c	64.73
V. dahliae	0.87c	68.36

Control: No antagonist yeast. [x]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

Table 3: Effect of *S. cerevisiae* on seedling survival of faba bean plants grown in pathogen-infested soil under greenhouse conditions

	Pre-emergence damping-off (%)			Post-emergence damping-off (%)			Stunted seedlings (%)		
Fungus	Control	Yeast	Reduction (%)	Control	Yeast	Reduction (%)	Control	Yeast	Reduction (%)
Non-infested soil	6.67c[x]	0.00e	100.00	6.67b	0.00b	0.00	6.67b	6.67a	0.00
Cephalosporium sp.	13.33bc	13.30cd	0.00	20.00ab	13.33ab	33.35	33.33a	26.67a	20.00
F. verticillioides	53.33a	40.00a	25.00	6.67b	6.67ab	0.00	26.67ab	20.00a	25.00
F.oxysporum	13.33c	6.67de	50.00	20.00ab	20.00a	0.00	20.00ab	13.33a	33.35
F. solani	40.00ab	20.00bc	50.00	26.67ab	13.33ab	50.00	13.33ab	13.33a	0.00
R. solani	40.00ab	26.67b	33.32	33.33a	20.00a	40.00	20.00ab	13.33a	33.35
V. dahliae	26.67bc	20.00bc	25.00	6.67b	6.67ab	0.00	33.33a	20.00a	40.00

Control: Healthy seeds planted as non-coated seeds. Yeast: Healthy yeast-coated seeds planted in pathogen-infested soil. Reduction (%) = Yeast-Control/Control×100. [X]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

Table 4: Effect of compost type (1) combined with *S. cerevisiae* on seedling survival of faba bean plants grown in pathogen-infested-soil under greenhouse conditions

	Pre-emergence damping-off (%)			Post-emergence damping-off (%)			Stunted seedlings (%)		
Fungus	Control	*S. cerevisiae* +Compost (1)	Reduction (%)	Control	*S. cerevisiae* +Compost (1)	Reduction (%)	Control	*S. cerevisiae* +Compost (1)	Reduction (%)
Non-infested soil	6.67c	0.00b	100.00	6.67b	0.00a	100.00	6.67b	0.00a	100.00
Cephalosporium sp.	13.33bc	6.67ab	50.00	20.00ab	6.67a	66.65	33.33a	6.67a	80.00
F. verticillioides	53.33a	20.00a	62.50	6.67b	6.67a	0.00	26.67ab	6.67a	75.00
F. oxysporum	13.33c	6.67ab	50.00	20.00ab	13.33a	33.35	20.00ab	13.33a	33.35
F. solani	40.00ab	20.00a	50.00	26.67ab	0.00a	100.00	13.33ab	0.00a	100.00
R. solani	40.00ab	13.33ab	66.68	33.33a	13.33a	60.00	20.00ab	6.67a	66.65
V. dahliae	26.67bc	13.33ab	50.00	6.67b	6.67a	0.00	33.33a	13.33a	60.00

Control: Healthy seeds planted in non-treated soil and non-coated seeds. *S. cerevisiae* +compost 1: Healthy yeast coated seeds planted in pathogen-infested and compost type (1) treated soil. Reduction (%) = *S. cerevisiae* +compost type (1)-Control/Control×100. [X]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

Table 5: Effect of compost type (2) combined with *S. cerevisiae* on seedling survival of faba bean plants grown in pathogen-infested soil under greenhouse conditions

	Pre-emergence damping-off (%)			Post-emergencedamping-off (%)			Stunted seedlings (%)		
Fungus	Control	*S. cerevisiae* +Compost (1)	Reduction (%)	Control	*S. cerevisiae* +Compost (1)	Reduction (%)	Control	*S. cerevisiae* +Compost (1)	Reduction (%)
Non-infested soil	6.67c[x]	0.00a	100.00	6.67b	0.00a	100.00	6.67b	0.00a	100.00
Cephalosporium sp.	13.33bc	6.67a	50.00	20.00ab	6.67a	66.65	33.33a	6.67a	80.00
F. verticillioides	53.33a	6.67a	88.00	6.67b	0.00a	100.00	26.67ab	6.67a	66.65
F. oxysporum	13.33c	6.67a	50.00	20.00ab	0.00a	100.00	20.00ab	0.00a	100.00
F. solani	40.00ab	6.67a	83.32	26.67ab	6.67a	75.00	13.33ab	6.67a	50.00
R. solani	40.00ab	6.67a	83.32	33.33a	0.00a	100.00	20.00ab	13.33a	33.35
V. dahliae	26.67bc	6.67a	75.00	6.67b	6.67a	0.00	33.33a	6.67a	80.00

Control: Healthy seeds planted in non-treated soil (non-coated seeds). *S. cerevisiae* +compost (2): Healthy yeast-coated seeds planted in pathogen-infested and compost type (2) treated soil. Reduction (%) = *S. cerevisiae* +compost type (2)-Control/Control×100. [X]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

with *S. cerevisiae* significantly reduced pre-emergence damping-off caused by *R. solani* (66.68%), *Cephalosporium* sp. (50.00%), *F. verticillioides* (62.50%), *F. oxysporum* (50.00%), *F. solani* (50.00%) and *V. dahliae* (50.00%).

Data in Table 5 show that the addition of compost type (2) with *S. cerevisiae* significantly reduced pre-emergence damping-off caused by *F. verticillioides* (88.00%), *Cephalosporium* sp. (50.00%), *F. oxysporum* (50.00%), *F. solani* (83.32%), *R. solani* (83.32%) and *V. dahliae* (75.00%).

Data in Table 3 show that seed treatment with *S. cerevisiae* significantly reduced post-emergence damping-off caused by *F. solani* (50.00%), *Cephalosporium* sp. (33.35%) and *R. solani* (40.00%). *F. verticillioides*, *F. oxysporum* and *V. dahliae* were not affected by the yeast.

Data in Table 4 show that compost type (1) in the presence of *S. cerevisiae* significantly reduced post-emergence damping-off caused by *F. solani* (100%), *Cephalosporium* sp. (66.65%), *F. oxysporum* (33.35%) and *R. solani* (60.00%). *F. verticillioides* and *V. dahliae* were resistant to the antagonistic properties of *S. cerevisiae*.

Data in Table 5 show that compost type (2) in the presence of *S. cerevisiae* significantly reduced post-emergence damping-off caused by *F. verticillioides*, *F. oxysporum* and *R. solani* (100%) compared with other pathogenic fungi: *Cephalosporium* sp. (66.65%), *F. solani* (75.00%) and *V. dahliae* did not react to *S. cerevisiae*.

Data in Table 3 show that seed treatment with *S. cerevisiae* significantly reduced the number of stunted seedlings due to *V. dahliae* (40.00%), *Cephalosporium* sp. (20.00%), *F. verticillioides* (25.00%), *F. oxysporum* (33.35%) and *R. solani* (33.35%). *F. solani* was not affected by *S. cerevisiae*.

Data in Table 4 show that compost type (1) in the presence of *S. cerevisiae* significantly reduced the number of stunted seedlings caused by *F. solani* (100%), as compared with *Cephalosporium* sp. (80.00%), *F. verticillioides* (75.00%), *F. oxysporum* (33.35%), *R. solani* (66.65%) and *V. dahliae* (60.00%).

Data in Table 5 show that compost type (2) added to soil in the presence of seed coated with *S. cerevisiae* significantly reduced the number of stunted seedlings caused by *F. oxysporum* (100%), as compared with *Cephalosporium* sp. (80.00%), *F. verticillioides* (66.65%), *F. solani* (50.00%), *R. solani* (33.35%) and *V. dahliae* (80.00%).

Effect of *S. cerevisiae* combined with tested composts on the growth parameters of faba bean plants grown in pathogen-infested soil under greenhouse conditions: In this experiment faba bean seeds coated with *S. cerevisiae* and grown in soil amended with compost type (1) and (2) showed an increase in various growth parameters (plant height, shoot length, root length, number of branches/plant, number of pods/plant, pod weight/plant, fresh weight and dry weight) when compared with non-coated seeds (Table 6-8).

Plant height (cm): Data in Table 6 show an increase in plant height in the treatment where *S. cerevisiae* was used and soil was infested with *R. solani*, with an average height of 88.46 cm, while *Cephalosporium* sp. averaged 79.60 cm, *F. verticillioides* 78.50 cm, *F. oxysporum* 84.33 cm, *F. solani* 82.23 cm and *V. dahliae* 79.10 cm.

Data in Table 7 show an increase in plant height in the treatment where compost type (1) was added to the soil and seeds were coated with *S. cerevisiae* in soil infested with *R. solani*, with an average height of 92.76 cm, while *Cephalosporium* sp. averaged 86.26 cm, *F. verticillioides* 92.26 cm, *F. oxysporum* 87.86 cm, *F. solani* 86.66 cm and *V. dahliae* 88.00 cm.

Data in Table 8 show an increase in plant height in the treatment where compost type (2) was added to the soil and seeds were coated with *S. cerevisiae* in soil infested with *F. oxysporum*, with an average height of 91.80 cm, while *Cephalosporium* sp. averaged 83.50 cm, *F. verticillioides* 95.00 cm, *F. solani* 91.33 cm, *R. solani* 87.70 cm and *V. dahliae* 88.00 cm.

Shoot length (cm): Data in Table 6 show an increase in shoot length in the treatment where faba bean seeds coated with *S. cerevisiae* were sown in soil infested with *R. solani*. The average length was 64.66 cm, while *Cephalosporium* sp. averaged 57.60 cm, *F. verticillioides* 60.00 cm, *F. oxysporum* 61.00 cm, *F. solani* 59.56 cm and *V. dahliae* 59.00 cm.

Data in Table 7 show that the treatment of compost type (1) and *S. cerevisiae* in the presence of *R. solani* significantly increased shoot length to an average

Table 6: Effect of *S. cerevisiae* on growth parameters of faba bean plants grown in pathogen-infested soil under greenhouse conditions

	Growth parameters											
	Plant height (cm)			Shoot length (cm)			Root length (cm)			No. of branches		
Fungus	Control	*S. cerevisiae*	Increase (%)	Control	*S. cerevisiae*	Increase (%)	Control	*S. cerevisiae*	Increase (%)	Control	*S. cerevisiae*	Increase (%)
Non-infested soil	64.30a	91.33a	42.03	45.30a	67.00a	47.90	19.00a	24.33a	28.05	1.86a	2.96a	59.14
Cephalosporium sp.	55.56bc	79.60b	43.27	42.80ab	57.60a	34.58	12.76b	22.00bc	72.41	1.67a	2.33a	39.52
F. verticillioides	59.63ab	78.50b	31.65	45.30a	60.00a	32.45	14.33ab	18.50bc	29.10	1.83a	2.16a	18.03
F. oxysporum	54.30bc	84.33ab	55.30	38.70b	61.00a	57.62	15.60ab	23.33a-c	49.55	1.67a	2.00a	19.76
F. solani	58.33bc	82.23ab	40.97	41.56ab	59.56a	43.31	16.76ab	22.66a-c	42.24	1.77a	2.66a	50.28
R. solani	52.93c	88.46ab	67.13	38.33b	64.66a	68.69	14.60ab	23.80ab	35.20	1.33a	2.33a	75.19
V. dahliae	57.60bc	79.10b	37.33	44.30a	59.00a	33.18	13.30b	20.10a-c	51.12	1.43a	2.63a	83.92

	Growth parameters											
	No. of pods (pods/plant)			Pod weight (g)			Fresh weight (g)			Dry weight (g)		
Fungus	Control	*S. cerevisiae*	Increase (%)	Control	*S. cerevisiae*	Increase (%)	Control	*S. cerevisiae*	Increase (%)	Control	*S. cerevisiae*	Increase (%)
Non-infested soil	4.67a	6.66a	42.61	14.73a	16.00a	8.62	60.30a	65.00a	7.80	18.86a	19.60a	3.92
Cephalosporium sp.	2.33bc	4.33a	85.84	6.10bc	7.40a-c	21.31	31.37c	38.10de	21.45	6.63c	10.53d	58.82
F. verticillioides	3.33ab	6.33a	90.00	9.40b	12.00ab	27.66	30.00c	50.20bc	67.33	7.40bc	13.10b-d	77.00
F. oxysporum	4.33a	5.00a	15.47	6.00bc	10.86ab	81.00	33.60bc	52.23ab	55.45	14.80ab	16.96ab	14.59
F. solani	2.00bc	5.00a	100.00	3.60cd	8.00a-c	122.22	34.60bc	44.10cd	27.46	7.80bc	11.20cd	43.59
R. solani	1.33c	4.00a	200.00	5.00bc	8.10a-c	62.00	45.17ab	50.66bc	12.15	9.26bc	15.66-c	69.11
V. dahliae	2.00bc	5.00a	150.00	6.00bc	6.66bc	11.00	34.90bc	52.00ab	49.00	8.90bc	10.00d	12.36

Control: Non-coated seeds. *S. cerevisiae*: Yeast-coated seeds planted in pathogen-infested soil. Increase (%) = *S. cerevisiae*-Control/Control×100. [x]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

Table 7: Effect of compost type (1) combined with *S. cerevisiae* on growth parameters of faba bean plants grown in pathogen-infested soil under greenhouse conditions

	Growth parameters											
	Plant height (cm)			Shoot length (cm)			Root length (cm)			No. of branches		
Fungus	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)
Non-infested soil	64.30a	97.86a	52.19	45.30a	71.00a	56.73	19.00a	26.86a	41.36	1.86a	3.20a	72.04
Cephalosporium sp.	55.56bc	86.26b	55.26	42.80ab	66.93a-c	56.38	12.76b	19.33b	51.49	1.67a	2.66a-c	59.28
F. verticillioides	59.63ab	92.26ab	54.72	45.30a	68.26a-c	50.68	14.33ab	24.00ab	67.48	1.83a	2.93ab	60.11
F. oxysporum	54.30bc	87.86b	61.80	38.70b	63.20bc	63.30	15.60ab	24.66ab	58.08	1.67a	2.33bc	39.52
F. solani	58.33bc	86.66b	48.57	41.56ab	61.83c	48.77	16.76ab	24.83ab	48.15	1.77a	2.86ab	61.58
R. solani	52.93c	92.76ab	75.25	38.33b	68.80ab	79.49	14.60ab	23.96ab	64.11	1.33a	2.53a-c	90.22
V. dahliae	57.60bc	88.00b	52.78	44.30a	61.46c	38.74	13.30b	26.60a	84.96	1.43a	2.86ab	100.00

	Growth parameters											
	No. of pods (pods/plant)			Pod weight (g)			Fresh weight (g)			Dry weight (g)		
Fungus	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)
Non-infested soil	4.67a	6.00a	28.48	14.73a	18.66a	26.68	60.30a	72.13a	19.62	18.86a	24.00a	27.25
Cephalosporium sp.	2.33bc	4.66a	100.00	6.10bc	14.00b	129.50	31.37c	53.06b	69.14	6.63c	10.00c	50.82
F. verticillioides	3.33ab	5.33a	60.00	9.40b	14.00b	48.93	30.00c	68.00a	126.67	7.40bc	14.90ab	101.35
F. oxysporum	4.33a	5.66a	30.72	6.00bc	12.00b	100.00	33.60bc	57.06b	69.82	14.80ab	17.43ab	17.77
F. solani	2.00bc	5.00a	150.00	3.60cd	11.33b	214.72	34.60bc	43.00c	24.28	7.80bc	12.00bc	53.85
R. solani	1.33c	5.66a	325.56	5.00bc	12.93b	158.60	45.17ab	70.50a	56.08	9.26bc	16.83ab	81.75
V. dahliae	2.00bc	6.00a	200.00	6.00bc	14.73ab	145.50	34.90bc	43.23c	23.87	8.90bc	14.70ab	65.17

Control: Non-coated seeds planted in non-treated soil. Compost (1) + *S. cerevisiae*: Healthy yeast-coated seeds planted in pathogen-infested and compost type (1) treated soil. Increase (%) = Compost (1)+ *S. cerevisiae*-Control/Control×100. [X]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

Table 8: Effect of compost type (2) combined with *S. cerevisiae* on growth parameters of faba bean plants grown in pathogen-infested soil under greenhouse conditions

	Growth parameters											
	Plant height (cm)			Shoot length (cm)			Root length (cm)			No. of branches		
Fungus	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)
Non-infested soil	64.30a	96.30a	49.77	45.30a	68.70a	51.66	19.00a	31.23a	64.37	1.86a	3.23a	73.66
Cephalosporium sp.	55.56bc	83.50a	50.29	42.80ab	65.13ab	52.17	12.76b	19.00b	48.90	1.67a	2.66ab	59.28
F. verticillioides	59.63ab	95.00a	59.32	45.30a	65.33ab	44.22	14.33ab	29.66a	106.98	1.83a	3.23a	76.50
F. oxysporum	54.30bc	91.80a	69.06	38.70b	64.46ab	66.56	15.60ab	27.33a	75.19	1.67a	2.66ab	59.28
F. solani	58.33bc	91.33a	56.57	41.56ab	64.46ab	55.10	16.76ab	26.86a	60.26	1.77a	2.73ab	54.24
R. solani	52.93c	87.70a	65.69	38.33b	66.00a	72.19	14.60ab	27.60a	89.04	1.33a	2.73ab	105.26
V. dahliae	57.60bc	88.00a	52.78	44.30a	60.00b	35.44	13.30b	28.00a	110.53	1.43a	2.73ab	90.90

	Growth parameters											
	No. of pods (pods/plant)			Pod weight (g)			Fresh weight (g)			Dry weight (g)		
Fungus	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)
Non-infested soil	4.67a	5.66a	21.20	14.73a	15.60a	5.90	60.30a	80.33a	33.21	18.86a	25.00a	2.56
Cephalosporium sp.	2.33bc	5.00a	114.59	6.10bc	11.06a-c	81.31	31.37c	48.53bc	54.40	6.63c	10.53bc	58.82
F. verticillioides	3.33ab	5.33a	60.00	9.40b	13.70ab	45.74	30.00c	66.00ab	120.00	7.40bc	14.70bc	98.65
F. oxysporum	4.33a	5.00a	15.47	6.00bc	12.60ab	110.00	33.60bc	66.20ab	97.02	14.80ab	20.50ab	38.51
F. solani	2.00bc	5.66a	183.00	3.60cd	12.20ab	238.89	34.60bc	40.00c	15.60	7.80bc	10.20bc	30.77
R. solani	1.33c	5.33a	300.00	5.00bc	10.00bc	100.00	45.17ab	56.30b	24.64	9.26bc	15.80b	70.63
V. dahliae	2.00bc	5.66a	183.00	6.00bc	12.70ab	111.67	34.90bc	49.50bc	41.83	8.90bc	12.86bc	44.49

Control: Non-coated seeds planted in non-treated soil. Compost (2) + *S. cerevisiae*: Healthy yeast-coated seeds planted in pathogen-infested and compost type (2) treated soil. Increase (%) = Compost (2) + *S. cerevisiae*-Control/Control×100. [X]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

68.80 cm, while *Cephalosporium* sp. averaged 66.93 cm, *F. verticillioides* 68.26 cm, *F. oxysporum* 63.20 cm, *F. solani* 61.83 cm and *V. dahliae* 61.46 cm.

Data in Table 8 show that the treatment of compost type (2) in the presence of *S. cerevisiae* significantly increased average shoot length where soil was infested with *R. solani* to 66.00 cm, while *Cephalosporium* sp. averaged 65.13 cm, *F. verticillioides* 65.33 cm, *F. oxysporum* 64.46 cm, *F. solani* 64.46 cm and *V. dahliae* 60.00 cm length.

Root length (cm): Data in Table 6 show an average increase in root length in the treatment where *S. cerevisiae* was used and soil infested with *Cephalosporium* sp. of 22.00 cm, while *F. verticillioides* averaged 18.50 cm, *F. oxysporum* 23.33 cm, *F. solani* 22.66 cm, *R. solani* 23.80 cm and *V. dahliae* 20.10 cm.

Data in Table 7 show an average increase in root length of faba bean plants grown in soil supplemented with compost type (1) when seeds were coated with *S. cerevisiae* and soil was infested with *V. dahliae* of 26.60 cm, while *Cephalosporium* sp. averaged 19.33 cm, *F. verticillioides* 24.00 cm, *F. oxysporum* 24.66 cm, *F. solani* 24.83 cm and *R. solani* 23.96 cm.

Data in Table 8 show an average increase in root length in the treatment where compost type (2) combined with *S. cerevisiae* was used with soil infested with V. dahliae of 28.00 cm, while *Cephalosporium* sp. averaged 19.00 cm, *F. verticillioides* 29.66 cm, *F. oxysporum* 27.33 cm, *F. solani* 26.86 cm and *R. solani* 27.60 cm.

Number of branches (branches/plant): Data in Table 6 show an increase in the average number of branches in the treatment where *S. cerevisiae* was used and soil infested with *V. dahliae* of 2.63 branches/plant, while *Cephalosporium* sp. averaged 2.33 branches/plant, *F. verticillioides* 2.16 branches/plant, *F. oxysporum* 2.00 branches/plant, *F. solani* 2.66 branches/plant and *R. solani* 2.33 branches/plant.

Data in Table 7 show an increase in the average number of branches in the treatment where compost type (1) combined with *S. cerevisiae* was used in soil infested with *V. dahliae* of 2.86 branches/plant, while *Cephalosporium* sp. averaged 2.66 branches/plant, *F. verticillioides* 2.93 branches/plant, *F. oxysporum* 2.33 branches/plant, *F. solani* 2.86 branches/plant and *R. solani* 2.53 branches/plant.

Data in Table 8 show an increase in the average number of branches in the treatment where soil was supplemented with compost type (2), *S. cerevisiae* was used and the soil infested with *R. solani* of 2.73 branches/plant, while *Cephalosporium* sp. averaged 2.66 branches/plant, *F. verticillioides* 3.23 branches/plant, *F. oxysporum* 2.66 branches/plant, *F. solani* 2.73 branches/plant and *V. dahliae* 2.73 branches/plant.

Number of pods (pods/plant): Data in Table 6 show an increase in the average number of pods in the treatment where *S. cerevisiae* was used and soil infested with *R. solani* of 4.00 pods/plant, while *Cephalosporium* sp. averaged 4.33 pods/plant, *F. verticillioides* 6.33 pods/plant, *F. oxysporum* 5.00 pods/plant, *F. solani* 5.00 pods/plant and *V. dahliae* 5.00 pods/plant.

Data in Table 7 show an increase in the average number of pods in the treatment of compost type (1) and *S. cerevisiae* with *R. solani* infested soil of 5.66 pods/plant, while *Cephalosporium* sp. averaged 4.66 pods/plant, *F. verticillioides* 5.33 pods/plant, *F. oxysporum* 5.66 pods/plant, *F. solani* 5.00 pods/plant and *V. dahliae* 6.00 pods/plant.

Data in Table 8 show an increase in the average number of pods in the treatment where compost type (2) and *S. cerevisiae* were used in soil infested with *R. solani* of 5.33 pods/plant, whild *Cephalosporium* sp. averaged 5.00 pods/plant, *F. verticillioides* 5.33 pods/plant, *F. oxysporum* 5.00 pods/plant, *F. solani* 5.66 pods/plant and *V. dahliae* 5.66 pods/plant.

Pod weight (g/plant): Data in Table 6 show an increase in average total pod weight in the treatment where *S. cerevisiae* was used and soil infested with *F. solani* of 8.00 g/plant, while *Cephalosporium* sp. averaged 7.40 g, *F. verticillioides* 12.00 g, *F. oxysporum* 10.86 g, *R. solani* 8.10 g and *V. dahliae* 6.66 g.

Data in Table 7 show an increase in the average total pod weight in the treatment where compost type (1) and *S. cerevisiae* were used with soil infested with *F. solani* of 11.33 g/plant, while *Cephalosporium* sp. averaged 14.00 g, *F. verticillioides* 14.00 g, *F. oxysporum* 12.00 g, *R. solani* 12.93 g and *V. dahliae* 14.73 g.

Data in Table 8 show an increase in average total pod weight in the treatment where compost type (2) and *S. cerevisiae* were used in soil infested with *V. dahliae* of 12.70 g/plant, while *Cephalosporium* sp. averaged 11.06 g, *F. verticillioides* 13.70 g, *F. oxysporum* 12.60 g, *F. solani* 12.20 g and *R. solani* 10.00 g.

Fresh weight (g/plant): Data in Table 6 show an average increase in the fresh weight of faba bean plants in the treatment where *S. cerevisiae* was used and soil infested with *F. verticillioides* of 50.20 g, while *Cephalosporium* sp. averaged 38.10 g, *F. oxysporum* 52.23 g, *F. solani* 44.10 g, *R. solani* 50.66 g and *V. dahliae* 52.00 g.

Data in Table 7 show an average increase in fresh weight in the treatment where compost type (1) and *S. cerevisiae* were used with soil infested with

F. verticillioides of 68.00 g, while *Cephalosporium* sp. averaged 53.06 g, *F. oxysporum* 57.06 g, *F. solani* 43.00 g, *R. solani* 70.50 g and *V. dahliae* 43.23 g.

Data in Table 8 show an average increase in fresh weight in the treatment where compost type (2) and *S. cerevisiae* were used in soil infested with *F. verticillioides* of 66.00 g, while *Cephalosporium* sp. averaged 48.53 g, *F. oxysporum* 66.20 g, *F. solani* 40.00 g, *R. solani* 56.30 g and *V. dahliae* 49.50 g.

Dry weight (g/plant): Data in Table 6 show an increase in average dry weight in the treatment where *S. cerevisiae* was used and soil infested with *F. verticillioides* of 13.10 g, while *Cephalosporium* sp. averaged 10.53 g, *F. oxysporum* 16.96 g, *F. solani* 11.20 g, *R. solani* 15.66 g and *V. dahliae* 10.00 g.

Data in Table 7 show an increase in average dry weight in the treatment where compost type (1) and *S. cerevisiae* were used in soil infested with *F. verticillioides* of 14.90 g, while *Cephalosporium* sp. averaged 10.00 g, *F. oxysporum* 17.43 g, *F. solani* 11.20 g, *R. solani* 16.83 g and *V. dahliae* 14.70 g.

Data in Table 8 show an increase in average dry weight in the treatment where compost type (2) and *S. cerevisiae* were used in soil infested with *F. verticillioides* of 14.70 g, while *Cephalosporium* sp. averaged 10.53 g, *F. oxysporum* 20.50 g, *F. solani* 10.20 g, *R. solani* 15.80 g and *V. dahliae* 12.86 g.

Effect of *S. cerevisiae* separately and combined with each compost on photosynthetic pigments and total phenols content of faba bean plants grown in fungi infested soil under greenhouse conditions.

Faba bean seeds coated with *S. cerevisiae* separately, as well as combined with compost type (1) and type (2) treated soil, were grown in soil infested with each fungus. The plants showed an increase in photosynthetic pigments (chlorophyll A, chlorophyll B and carotenoids) and total phenols content when compared with the control (Table 9-11).

Data in Table 9 show that chlorophyll A content increased when *S. cerevisiae*-coated seeds were planted in soil infested with *R. solani* by 70.11%, while the increase was 32.43% with *F. solani*, 17.69% with *Cephalosporium* sp., 15.87% with *F. verticillioides*, 14.84% with *F. oxysporum* and 11.28% with *V. dahliae*.

Data in Table 10 show that chlorophyll A content increased in the *S. cerevisiae*+compost type (1) treatment in soil infested with *R. solani* by 65.52%, while the increase was 39.64% with *F. solani*, 19.23% with *Cephalosporium* sp., 15.87% with *F. verticillioides*, 13.28% with *F. oxysporum* and 12.78% with *V. dahliae*.

Data in Table 11 show that chlorophyll A content increased in the *S. cerevisiae*+compost type (2) treatment in soil infested with *R. solani* by 72.41%, while the increase was 30.63% with *F. solani*, 20.00% with *Cephalosporium* sp., 19.84% with *F. verticillioides*, 13.53% with *V. dahliae* and 13.28% with *F. oxysporum*.

Data in Table 9 show that chlorophyll B content increased when *S. cerevisiae*-coated seeds were planted in soil infested with *R. solani* by 73.53%, while the increase was 24.04% with *Cephalosporium* sp., 18.81% with *F. verticillioides*, 12.50% with *F. oxysporum*, 51.80% with *F. solani* and 11.93% with *V. dahliae*.

Data in Table 10 show that chlorophyll B content increased in the *S. cerevisiae*+compost type (1) treatment in soil infested with *R. solani* by 73.53%, while the increase was 51.80% with *F. solani*, 24.04% with *Cephalosporium* sp., 18.81% with *F. verticillioides*, 12.50% with *F. oxysporum* and 11.93% with *V. dahliae.*

Data in Table 11 show that chlorophyll B content increased in the *S. cerevisiae*+compost type (2) treatment in soil infested with *R. solani* by 85.29%%, while the increase was 48.19% with *F. solani*, 26.92% with *Cephalosporium* sp., 26.92% with *F. oxysporum*, 14.85% with *F. verticilloides and 11.93% with V. dahliae*.

Data in Table 9 show that carotenoids content increased when *S. cerevisiae*-coated seeds were planted in soil infested with *R. solani* by 68.42%, while the increase was 35.05% with *F. solani*, 11.11% with *Cephalosporium* sp., 9.01% with *V. dahliae*, 5.08% with *F. oxysporum* and 5.00% with *F. verticillioides*.

Data in Table 10 show that carotenoids content increased in the *S. cerevisiae*+compost type (1) treatment in soil infested with *R. solani* by 77.63%, while

Table 9: Effect of *S. cerevisiae* on photosynthetic pigments and total phenols content of faba bean plants grown in pathogen-infested soil under greenhouse conditions

	Chl A (mg g^{-1} fresh wt.)			Chl B (mg g^{-1} fresh wt.)			Carotenoids (mg g^{-1} fresh wt.)			Total phenols (mgcat/100 g fresh wt.)		
Fungus	Control	*S. cerevisiae*	Increase	Control	*S. cerevisiae*	Increase	Control	*S. cerevisiae*	Increase	Control	*S. cerevisiae*	Increase
Non-infested soil	1.44a	1.60a	11.11	1.16a	1.31a	12.93	1.25a	1.50a	20.00	98.94e	112.10d	13.30
Cephalosporium sp.	1.30b	1.53ab	17.69	1.04b	1.29ab	24.04	1.17a	1.30b	11.11	116.85d	129.19bc	10.56
F. verticillioides	1.26b	1.46ab	15.87	1.01b	1.20b-d	18.81	1.20a	1.26b	5.00	113.13d	114.35cd	1.08
F. oxysporum	1.28b	1.47ab	14.84	1.04b	1.17cd	12.50	1.18a	1.24b	5.08	127.23c	149.10a	17.19
F. solani	1.11c	1.47ab	32.43	0.83c	1.26a-c	51.80	0.97b	1.31b	35.05	133.00bc	147.31a	10.76
R. solani	0.87d	1.48ab	70.11	0.68d	1.18cd	73.53	0.76c	1.28b	68.42	178.95a	190.62a	6.52
V. dahliae	1.33ab	1.48ab	11.28	1.09ab	1.22b-d	11.93	1.22a	1.33b	9.01	138.33b	142.94ab	3.33

Control: Non-coated seeds. *S. cerevisiae*: Healthy yeast-coated seeds planted in pathogen-infested soil. Increase (%) = *S. cerevisiae*-Control/Control x 100. [X]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

Table 10: Effect of compost type (1) combined with *S. cerevisiae* on photosynthetic pigments and total phenols content of faba bean plants grown in pathogen-infested soil under greenhouse conditions

	Chl A (mg g^{-1} fresh wt.)			Chl B (mg g^{-1} fresh wt.)			Carotenoids (mg g^{-1} fresh wt.)			Total phenols (mgcat/100 g f resh wt.)		
Fungus	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)	Control	Compost (1) +*S. cerevisiae*	Increase (%)
Non-infested soil	1.44a	1.67a	15.97	1.16a	1.36a	17.24	1.25a	1.49a	19.20	98.94e	114.57bc	15.80
Cephalosporium sp.	1.30b	1.55ab	19.23	1.04b	1.32ab	26.92	1.17a	1.43ab	22.22	116.85d	146.70a	25.55
F. verticillioides	1.26b	1.46b	15.87	1.01b	1.16d	14.85	1.20a	1.30cd	8.33	113.13d	126.19b	11.54
F. oxysporum	1.28b	1.45b	13.28	1.04b	1.32ab	26.92	1.18a	1.42a-c	20.24	127.23c	149.09a	17.18
F. solani	1.11c	1.55ab	39.64	0.83c	1.23cd	48.19	0.97b	1.30cd	34.02	133.00bc	151.95a	14.25
R. solani	0.87d	1.44b	65.52	0.68d	1.26bc	85.29	0.76c	1.35bc	77.63	178.95a	190.56a	6.49
V. dahliae	1.33ab	1.50b	12.78	1.09ab	1.22cd	11.93	1.22a	1.37bc	12.30	138.33b	149.40a	8.00

Control: Non-coated seeds. Compost (1) + *S. cerevisiae*: Healthy yeast-coated seeds planted in compost (1) treated soil. Increase (%) = Compost (1)+ *S. cerevisiae*-Control/Control×100. [X]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

Table 11: Effect of compost type (2) combined with *S. cerevisiae* on photosynthetic pigments and total phenols of faba bean plants grown in pathogen-infested soil under greenhouse conditions

	Chl A (mg g^{-1} fresh wt.)			Chl B (mg g^{-1} fresh wt.)			Carotenoids (mg g^{-1} fresh wt.)			Total phenols (mgcat/100 g fresh wt.)		
Fungus	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)	Control	Compost (2) +*S. cerevisiae*	Increase (%)
Non-infested soil	1.44a	1.60a	11.11	1.16a	1.36a	17.24	1.25a	1.45a	16.00	98.94e	124.47c	25.80
Cephalosporium sp.	1.30b	1.56ab	20.00	1.04b	1.16b	11.54	1.17a	1.34ab	14.53	116.85d	143.00c	22.38
F. verticillioides	1.26b	1.51ab	19.84	1.01b	1.20b	18.81	1.20a	1.35ab	12.50	113.13d	170.39a-c	50.61
F. oxysporum	1.28b	1.45b	13.28	1.04b	1.20b	15.38	1.18a	1.35ab	14.40	127.23c	156.75bc	23.20
F. solani	1.11c	1.45b	30.63	0.83c	1.25ab	50.60	0.97b	1.31bc	35.05	133.00bc	195.08ab	46.68
R. solani	0.87d	1.50ab	72.41	0.68d	1.26ab	85.29	0.76c	1.29bc	69.74	178.95a	203.68a	13.82
V. dahliae	1.33ab	1.51ab	13.53	1.09ab	1.23b	12.84	1.22a	1.34ab	9.83	138.33b	169.12a- c	22.26

Control: Non-coated seeds. Compost (2) + *S. cerevisiae*: Healthy yeast-coated seeds planted in compost (2) treated soil. Increase (%) = Compost (2)+ *S. cerevisiae*-Control/Control×100. [X]Mean within a column followed by the same letter(s) is not significantly different according to Duncan's multiple range tests

the increase was 34.02% with *F. solani*, 22.22% with *Cephalosporium* sp., 20.24% with *F. oxysporum*, 12.30% with *V. dahliae* and 8.33% with *F. verticillioides*.

Data in Table 11 show that carotenoids content increased in the *S. cerevisiae*+compost type (2) treatment in soil infested with *R. solani* by 69.74%, while the increase was 35.05% with *F. solani*, 14.53% with *Cephalosporium* sp., 14.40% with *F. oxysporum*, 12.50% with *F. verticilloides* and 9.83% with *V. dahliae*.

Data in Table 9 show that total phenols content increased when *S. cerevisiae*-coated seeds were planted in soil infested with *F. oxysporum* by 17.19%, while the increase was 10.76% with *F. solani*, 10.56% with *Cephalosporium* sp., 6.52% with *R. solani*, 3.33% with *V. dahliae* and 1.08% with *F. verticillioides*.

Data in Table 10 show that total phenols content increased in the *S. cerevisiae*+compost type (1) treatment in soil infested with *Cephalosporium* sp. by 25.55%, while the increase was 17.18% with *F. oxysporum*, 14.25% with *F. solani*, 11.54% with *F. verticillioides*, 8.00% with *V. dahliae* and 6.49% with *R. solani*.

Data in Table 11 show that total phenols content increased in the *S. cerevisiae*+compost type (2) treatment in soil infested with *F. verticilloides* by 50.61%, while the increase was 46.68% with *F. solani*, 22.38% with *Cephalosporium* sp., 22.26% with *V. dahliae*, 22.20% with *F. oxysporum* and 13.82% with *R. solani*.

DISCUSSION

The present study shows that the application of yeast as a bio-control agent affected all tested fungi *in vitro*. The percentage of inhibition reached 72% with *Fusarium oxysporum* when compared with the other pathogenic fungi and the control. These results are in agreement with Hassanein *et al*. (2002), who reported that yeasts were effective producers of antifungal metabolites. In addition, it was found that isolates of actinomycetes produced chitinase and β-1, 3 glucanase and caused extensive plasmolysis and cell wall lysis of *Cephalosporium maydis in vitro*. Since the cell wall of *C. maydis* consists largely of chitin and β-glucanase (Bartnicki-Garcia and Lippman, 1982), there is a voluminous body of literature on the ability of actinomycetes and fungi to parasitize spores, hyphae and other fungal structures. Many of these observations are linked with plant disease bio-control (Jeffries and Young, 1994; Van de Boogert and Deacan, 1994; Davanlou *et al*., 1999).

Weller (1988), Lee *et al*. (1991), Yuan and Crawford (1995), Valois *et al*. (1996), El-Tarabily *et al*. (1997), Youssef *et al*. (2001) and Gianluca *et al.* (2006) reported also that a microorganism that colonizes roots is ideal for use as a biocontrol agent against soil-borne diseases and, consequently, improving plant growth. Yeasts applied for the control of plant pathogens were found to produce proteinaceous killer toxins lethal to susceptible yeast and fungi strains (Hodgson *et al*., 1995; Abranches *et al*., 1997; Marquina *et al*., 2002; Santos *et al*., 2004).

Results obtained from this study showed that the addition of yeast as an antagonist improved disease suppression due to the compost and decreased disease severity (pre- and post-emergence damping-off and stunted seedlings). This result is supported by the finding of Postma *et al.* (2003) in which they concluded that the antagonist may enrich composts to increase the reliability of the beneficial effects of compost in disease suppressiveness.

In this study, the treatment of compost plus yeast increased plant growth. This result is supported by Kleifield and Chet (1992) and El-Mehalawy *et al*. (2004) who reported that the growth increase caused by rhizosphere microorganisms depended mainly on the ability of those microorganisms to survive and develop in the rhizosphere. In addition, several plant-microbe interactions were developed which benefited plant growth through different mechanisms, such as the production of plant regulators, siderophores, phosphate solubilization, nutrient uptake and availability (Hoflich and Kuhn, 1996; Gupta *et al*., 1998; Bowen and Rovira, 1999).

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