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BIOFUMIGATION FOR CONTROLLING FUSARIUM CROWN ROT AND HEAD BLIGHT OF WHEAT

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ABSTRACT

Fusarium species are capable of causing various diseases in wheat, such as Fusarium crown rot (FCR) and Fusarium head blight (FHB). We used *Fusarium pseudograminearum* **(**OK465188**)** for evaluating the impact of four biofumigant plants (Cabbage, Turnip, Rocket, and Radish) on the vegetative growth, pathological and yield characteristics of five wheat cultivars (Misr1, Misr3, Giza171, Sakha95, and Sids14), in comparison to a control treatment for controlling crown rot and head blight of wheat. Greenhouse experiments have demonstrated the effectiveness of biofumigation for controlling FCR and FHB diseases of wheat during two growing seasons. These results approved that biofumigation is a promising and environmentally friendly approach for managing FCR and FHB diseases in wheat.

INTRODUCTION

Wheat infections can significantly impact crops yield through harvest losses, storage losses, and reduced crop quality. The extent of these losses is influenced by various factors, including the type and abundance of pathogens, environmental conditions, and the genetic resistance or tolerance of wheat cultivars to specific diseases. Fusarium diseases, particularly Fusarium crown rot (FCR), pose a significant threat to wheat production in Egypt. These diseases can lead to substantial losses in both yield and crop quality for various economically important plant species, including cereals. The first signs of Fusarium crown rot (FCR) appear as a chocolate brown discoloration on the lower part of the stem, typically affecting the first to third internodes (sections between stem joints). This discoloration becomes visible after peeling back the leaf sheaths at the base of the tiller (stem with its attached leaves). Diagnosis of FCR often involves examining the opened stem internodes for the presence of pink fungal growth (mycelium) inside (**Cook, 2010**). Also, variations in the disease-causing potential (pathogenic diversity) among different fungal isolates associated with FCR were identified by **Smiley *et al*. (2005)**. **Selim *et al*. (2021)** identified *Fusarium pseudograminearum* as a significant pathogen causing crown rot in wheat crops in Egypt. This finding adds to the growing list of fungal pathogens associated with this destructive disease. *Fusarium nygamai* has been documented as a pathogen affecting various crops, including wheat, rice, sugar beet, and lentils. Previous studies have

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reported its presence in wheat roots and stalks (**Besharati *et al*., 2017**) and its association with root rot in wheat (Iraq), rice (Sardinia), sugar beet (China), and lentils (Pakistan). Additionally, *F. nygamai* has been implicated in crown rot of wheat in China.

In Montana a study was conducted to compare the disease-causing abilities (pathogenicity) of Fusarium species on hard red spring and durum wheat varieties. The study found that *F. culmorum* was most responsible for seedling blight, while *F. pseudograminearum* and *F. graminearum* were more likely to cause crown rot (**Dyer *et al*., 2007**).

Fusarium head blight (FHB) is a significant disease affecting wheat production globally. This disease is primarily caused by various Fusarium species, such as *F. pseudograminearum, F. avenaceum, F. culmorum, and F. graminearum* (**Smiley *et al*., 2005; Ali and Mahmoud, 2019**). Although *F. graminearum* is the primary pathogen associated with Fusarium head blight (FHB) in North America, the specific Fusarium species responsible for FHB can vary depending on the region. For instance, in Egypt, *F. graminearum* has been identified as the main culprit (**Mahmoud, 2016**), whereas in Canada, it is just one of several Fusarium species contributing to FHB (**Dexter *et al*., 1997**). **Li *et al*. (2010**) suggested that Fusarium head blight and crown rot are caused by the same Fusarium pathogens. This study aimed to identify and characterize the fungal pathogens associated with crown rot in wheat using morphological and cultural techniques. Additionally, the study sought to determine the pathogenicity of *Fusarium nygamai*, a specific Fusarium species, in causing crown rot in wheat crops in North Sinai. Furthermore, the study aimed to evaluate the efficacy of biofumigation using five different biofumigant species in improving the growth and pathological characteristics of five wheat cultivars infected with *Fusarium nygamai* under both in vitro and greenhouse conditions in North Sinai, Egypt.

MATERIALS AND METHODS

Greenhouse Experiment

Isolate of *Fusarium pseudograminearum*

We obtained an isolate of *Fusarium pseudograminearum* from Plant Pathology Department, Faculty of Desert and Environmental Agriculture, Matrouh University with GenBank accession number OK465188 for evaluating the biofumigation, biocontrol, and solarization compared with some fungicides and their effect for controlling *Fusarium pseudograminearum*.

Plant material

The study utilized four biofumigant plants: cabbage (*Brassica oleracea var. oleracea*), turnip (*Brassica rapa var. rapa*), rocket (*Eruca sativa*), and radish (*Raphanus raphanistrum subsp. sativus*). For the greenhouse experiment, five wheat cultivars were selected: Misr1, Misr3, Giza171, Sakha95, and Sids14. Seeds for these cultivars were obtained from the Agriculture Research Centre in Giza, Egypt.

Preparing Greenhouse for Biofumigation Experiment

Four biofumigant species; cabbage, turnip, rocket, and radish-were evaluated as potential soil biofumigants to control fungal pathogens. These biofumigants were tested in sterilized soil. Four pots were planted with seeds for each biofumigant species on September 3rd and 5th during two separate growing seasons. Standard agricultural practices were followed throughout the growth period. At maturity (December 9th), the biofumigant plants were incorporated back into their respective pots by chopping and mixing them into the soil. The soil was then thoroughly irrigated. To capture the gases released during biodegradation, each pot was covered with a transparent plastic film for 21 days Fig. 1.

Fig. 1. A: incorporating four Brassicaceae plants into the soil at maturity stage, B*:* *Fusarium pseudograminearum* inoculation on autoclaved barely medium, C, D: Pots of Biofumigation treatments

Soil infestation

Plastic pots with a diameter of 20 cm were used, each filled with 2 kg of sterilized sandy soil. One week after planting Brassica crops, the soil was inoculated with *Fusarium pseudograminearium* by adding a 1 cm disc of the fungus to 250 ml flasks containing 100 grams of sterilized barley. The inoculated flasks were then used to infest the pots with the fungus at a rate of 5% of the soil weight. Wheat seeds were planted in the inoculated soil 24 hours after incorporating the Brassica crops. Pathological, growth and yield characteristics were measured:

Plant height (cm)

It was determined as the distance in centimeters from the soil surface to the plant apex.

Infected spike percentage

(Infected spike number/total spike number) ×100

Disease incidence

(Infected plants / Total plants number) × 100

Disease severity

FCR severity was determined by using a crown rot rating (CRR) scale of 1 to 4 for the first internode of each plant, where: 1 = 0–25%; 2 = 25–50%; 3 = 50–75%; and 4 = 75–100% of the internode discolored as described by **Hogg *et al*. (2007)**.

Weight of total plants: Mean number of the total weight of plants in each pot.

Design and Statical Analysis

All data were analyzed using SPSS software (v16.0). Two-way ANOVA Mean ± SD (n= 3) tested main and interaction effects, followed by Duncan's test for significant differences among means ($P \leq 0.05$). Treatments were replicated four times in each experiment and arranged in a completely randomized design (CRD).

RESULTS AND DISCUSSION

Greenhouse Experiments

Effect of biofumigation treatments and wheat cultivars on pathological characteristics

Data in Table 1 showed the highly significant interaction effect between five cultivars and four treatments compared to control (untreated) on pathological characteristics in the first and second seasons after 90 days.

In season (2021/2022)

Disease incidence had recorded the highest value (100.00) with cabbage, turnip, rocket, radish, and control treatments on cultivar Misr1.

Disease incidence had recorded the highest value (100.00) with Cabbage, Turnip and Radish and control treatments on cultivar Misr2.

Disease incidence had recorded the highest value (100.00) with Cabbage, Turnip and Radish treatments, but the lowest value (85.69) was recorded by Rocket treatment on cultivar Sids14.

Disease incidence had recorded the highest value (100.00) with Cabbage, Turnip and Radish treatments, but the lowest value (62.47) was recorded by Rocket treatment on cultivar Sakha95.

Disease incidence recorded the highest value (100.00) with Cabbage Turnip and Radish treatments, but the lowest value (89.99) was recorded by Rocket treatment on cultivar Giza171.

Disease severity recorded the highest value (1.75) with radish treatment, but the lowest value (1.00) was recorded by Turnip and Rocket treatments on cultivar Misr1.

Disease severity recorded the highest value (1.75) with Cabbage treatment. However, the lowest value (1.00) was recorded by Rocket treatment on cultivar Misr2.

Disease severity recorded the highest value (2.33) with Cabbage treatment. But the lowest value (1.17) was recorded by Rocket treatment on cultivar Sids14.

Disease severity recorded the highest value (2.33) with Cabbage treatment. However, the lowest value (1.67) was recorded by turnip and Rocket treatments on cultivar Sakha95.

Disease severity recorded the highest value (2.17) with Cabbage treatment. But the lowest value (1.25) was recorded by Rocket treatment on cultivar Giza171.

Rotten crown length recorded the highest value (2.58 cm) with cabbage and control treatment. However, the lowest value (1.67 cm) was recorded by turnip and rocket treatments on cultivar Misr1.

Rotten crown length recorded the highest value (2.04 cm) with cabbage treatment. However, the lowest value (0.50 cm) was recorded by rocket treatment on cultivar Misr2.

Rotten crown length recorded the highest value (2.92 cm) with cabbage treatment. However, the lowest value (1.29 cm) was recorded by turnip treatment on cultivar Sids14.

Rotten crown length recorded the highest value (2.75 cm) with cabbage treatment. However, the lowest value (1.67 cm) was recorded by turnip treatment on cultivar Sakha95.

Rotten crown length recorded the highest value (2.83 cm) with cabbage treatment. However, the lowest value (1.50 cm) was recorded by turnip treatment on cultivar Giza171.

Rotten Crown length recorded the highest results for biofumigation by rocket treatment on cultivars; Misr1, Misr2, Sids 14, Sakha95, and Giza171 as (2.58, 2.04, 2.58, 2.75, and 2.83 cm) while the lowest results recorded for biofumigation by turnip in cultivars; Misr 1, Sids 14, Sakha 95 as

Table 1. The effects of interaction between five wheat cultivars and four biofumigation plants on pathological characteristics of wheat plants cultivated in soil infested with *Fusarium pseudograminearum* in both seasons (2021 & 2022) after 90 days

Cultivars	Treatments	FHB symptoms		FCR Crown root index					
		Season 2021/2022	Season 2022/2023	Season 2021/2022			Season 2022/2023		
		Infected spike %	Infected spike %	Disease incidence %	Disease severity*	rotten crown length (cm)	Disease incidence %	Disease severity *	rotten crown length (cm)
Misr1	**Bio-cabbage**	0.00	0.00	100.00	1.25	2.58	88.88	1.83	2.17
	Bio-turnip	0.00	0.00	100.00	1.00	1.67	66.79	1.17	1.83
	Bio-rocket	0.00	0.00	100.00	1.00	1.67	33.28	1.00	1.56
	Bio-radish	0.00	0.00	100.00	1.75	1.83	75.16	1.50	2.06
	Control	0.00	0.00	100.00	1.92	3.00	100.00	1.89	3.94
Misr2	**Bio-cabbage**	71.39	71.64	100.00	1.75	2.04	88.88	1.50	1.83
	Bio-turnip	0.00	0.00	100.00	1.08	0.71	88.88	1.17	1.75
	Bio-rocket	0.00	0.00	100.00	1.00	0.50	55.52	1.11	0.67
	Bio-radish	37.63	37.58	100.00	1.33	1.75	88.73	1.50	1.78
	Control	100.00	100.00	100.00	2.08	2.58	100.00	2.17	2.83
Sids14	**Bio-cabbage**	49.92	49.92	100.00	2.33	2.58	100.00	2.00	1.83
	Bio-turnip	0.00	0.00	100.00	1.83	1.29	100.00	1.78	1.58
	Bio-rocket	0.00	0.00	85.69	1.17	1.33	100.00	1.72	1.19
	Bio-radish	0.00	0.00	100.00	1.75	2.00	100.00	1.83	1.92
	Control	-	-	100.00	2.92	3.50	100.00	2.83	3.06
Sakha95	**Bio-cabbage**	66.64	100.00	100.00	2.33	2.75	100.00	2.83	2.67
	Bio-turnip	0.00	0.00	100.00	1.67	1.67	100.00	1.56	1.67
	Bio-rocket	0.00	0.00	62.47	1.67	1.71	99.63	2.06	2.08
	Bio-radish	49.92	0.00	100.00	1.92	2.00	100.00	2.33	2.00
	Control	100.00	100.00	100.00	3.75	3.54	100.00	3.50	4.11
Giza171	**Bio-cabbage**	66.64	83.12	100.00	2.17	2.83	100.00	1.78	2.44
	Bio-turnip	37.44	29.99	100.00	1.50	1.50	100.00	1.44	1.83
	Bio-rocket	37.44	33.43	89.99	1.25	1.75	100.00	1.44	1.50
	Bio-radish	49.92	50.25	100.00	1.42	1.83	100.00	1.17	2.33
	Control	100.00	100.00	100.00	2.33	5.33	100.00	2.33	5.44

Mean values of Pathological characters (cm)

*** Hogg *et al*. (2007).**

(1.67, 1.29 and 1.67 cm) but biofumigation with rocket was recorded by cultivars; (Misr1 and Misr2) however Giza171 was recorded by biofumigation with Radish.

Disease incidence recorded the highest results with all treatments with all cultivars while the lowest results were recorded for biofumigation by rocket treatment in cultivars; sids14, Sakha95, and Giza171 as (85.69, 62.47, 89.99%), respectively.

Disease severity resulted the highest value for Rocket treatment on cultivars; Misr1, Misr2, Sids14, Sakha95, and Giza171 as (1.00, 1.00, 1.17, 1.67, 1.25), respectively after 120 days of planting.

Infected spikes percentage recorded the highest value (0%) with cabbage, turnip, rocket, radish, and control treatments on cultivar Misr1.

Infected spikes percentage recorded the highest value (71.39 %) with Cabbage treatment. However, the lowest value (0 %) was recorded by Turnip and Rocket treatments on cultivar Misr2.

The infected spikes percentage recorded the highest value (49.92 %) with Cabbage treatment. but the lowest value (0 %) was recorded by Turnip, Rocket, and Radish treatment on cultivar Sids14.

The infected spikes percentage recorded the highest value (66.64 %) with Cabbage treatment. But the lowest value (0 %) was recorded by Turnip and rocket treatments on cultivar Sakha95.

The infected spikes percentage recorded the highest value (66.64 %) with Cabbage treatment. but the lowest value (37.44 %) was recorded by Turnip and Rocket treatments on cultivar Giza171.

In season (2022/2023)

Disease incidence recorded the highest value (88.88%) with Cabbage treatment but the lowest value (33.28%) was recorded by Rocket treatment on cultivar Misr1.

Disease incidence recorded the highest value (88.88%) with Cabbage and Turnip treatments. However, the lowest value (55.52%) was recorded by Rocket treatment on cultivar Misr2.

Disease incidence recorded the highest value (100.00%) with Cabbage, Turnip, Rocket and Radish treatments on cultivar Sids14.

Disease incidence recorded the highest value (100.00%) with Cabbage, Turnip, and Radish treatments. However, the lowest value (99.63%) was recorded by Rocket treatment on cultivar Sakha95.

Disease incidence recorded the highest value (100.00%) with Cabbage, Turnip, Rocket, and Radish treatments on cultivar Giza171.

Disease severity recorded the highest value (1.83) with Cabbage treatment. However, the lowest value (1.00) was recorded by Rocket treatment on cultivar Misr1.

Disease severity recorded the highest value (1.50) with Cabbage and Radish treatments. However, the lowest value (1.11) was recorded by Rocket treatment on cultivar Misr2.

Disease severity recorded the highest value (2.00) with Cabbage treatment. However, the lowest value (1.72) was recorded by Rocket treatment on cultivar Sids14.

Disease severity recorded the highest value (2.83) with Cabbage treatment. However, the lowest value (1.56) was recorded by turnip treatment on cultivar Sakha95.

Disease severity recorded the highest value (1.78) with Cabbage treatment. But the lowest value (1.11) was recorded by Radish treatment on cultivar Giza171

Rotten crown length recorded the highest value (2.17 cm) with cabbage treatment.

However, the lowest value (1.56 cm) was recorded by Rocket treatment on cultivar Misr1.

Rotten crown length recorded the highest value (1.83 cm) with cabbage treatment. However, the lowest value (0.67 cm) was recorded by rocket treatment on cultivar Misr2.

Rotten crown length recorded the highest value (1.92 cm) with Radish treatment. But rocket treatment on cultivar Sids14 recorded the lowest value (1.19 cm).

Rotten crown length recorded the highest value (2.67 cm) with Cabbage treatment. But turnip treatment on cultivar Sakha95 recorded the lowest value (1.67 cm).

Rotten crown length recorded the highest value (2.44 cm) with Cabbage treatment. However, the lowest value (1.50 cm) was recorded by Rocket treatment on cultivar Giza171.

Rotten Crown length recorded the highest results for biofumigation by cabbage treatment with cultivars; Misr1, Misr2, Sakha95, and Giza171 as (2.17, 1.83, 2.67 and 2.44 cm) but biofumigation by Radish treatment with cultivar; Sids14 (1.92 cm) while the lowest value (1.56, 0.67, 1.19 and 1.50 cm) was recorded with cultivars; Misr1, Misr2, Sids14, and Giza171 but biofumigation with Turnip was recorded by cultivar Sakha 95 as (1.67 cm).

Disease incidence recorded the highest results for control treatment on cultivars; Misr1, Misr2, Sakha95 as (100%) while the lowest results recorded for biofumigation by rocket in cultivars; Misr1, Misr2, Sakha95 as (33.28, 55.52, 99.63%).

Disease severity resulted in the highest value for control treatment on cultivars; Misr1, Misr2, Sids14, Sakha95, and Giza171 as (1.89, 2.17, 2.83, 3.50, 2.33) while, biofumigation by rocket in cultivars; Misr1, Misr2, Sids14, Giza171 as (1.00, 1.11, 1.72, 1.44) after 120 days of planting. But Turnip recorded the least with Sakha 95 as 1.56)

The infected spikes percentage recorded the highest value (0%) with cabbage, turnip, rocket, radish, and control treatments on cultivar Misr1.

The infected spikes percentage recorded the highest value (71.64%) with Cabbage treatment. However, the lowest value (37.58%) was recorded by Radish treatment on cultivar Misr2.

The Iinfected spikes percentage recorded the highest value (49.92%) with Cabbage treatment. However, the lowest value (0%) was recorded by Turnip, Rocket, and Radish treatments on cultivar Sids14.

The infected spikes percentage recorded the highest value (100.00%) with Cabbage treatment. However, the lowest value (0%) was recorded by Turnip, Rocket, and Radish treatments on cultivar Sakha95.

The infected spikes percentage recorded the highest value (83.12%) with Cabbage treatment. However, the lowest value (29.99%) was recorded by Turnip treatment on cultivar Giza171.

Effect of biofumigation plants and wheat cultivars on plant height

Data in Table 2 showed the highly significant interaction effect between five cultivars and four treatments compared to control (untreated) on Plant height in the first and second seasons after 120 days.

In season (2021/2022)

Plant height recorded the highest value (47.33 cm) with Turnip treatment, while the lowest value (41.00 cm) with Cabbage treatment on cultivar Misr1.

Plant height recorded the highest value (54.00 cm) with Rocket treatment, while the lowest value (38.83 cm) with Cabbage treatment on cultivar Misr2.

Plant height recorded the highest value (40.5 cm) with rocket treatment, while the lowest value (34.17 cm) with Cabbage treatment on cultivar Sids14.

Table 2. The effects of interaction between five wheat cultivars and four biofumigation plants on plant height of wheat plants cultivated in soil infested with *Fusarium pseudograminearum* in both season (2021 & 2022) after 120 days

Mean values of vegetative characters (cm)			
Cultivars	**Treatments**	**Season 2021/2022**	**Season 2022/2023**
		Plant height	**Plant height**
Misr1	**Bio-cabbage**	41.00	38.70
	Bio-turnip	43.67	42.33
	Bio-rocket	47.33	46.17
	Bio-radish	42.83	42.90
	Control	35.33	35.20
Misr2	**Bio-cabbage**	38.83	34.08
	Bio-turnip	44.83	43.58
	Bio-rocket	54.00	45.16
	Bio-radish	44.33	42.50
	Control	30.50	30.00
Sids14	**Bio-cabbage**	34.17	31.80
	Bio-turnip	40.17	43.33
	Bio-rocket	40.50	38.50
	Bio-radish	35.67	36.40
	Control	28.33	27.55
Sakha95	**Bio-cabbage**	34.00	31.47
	Bio-turnip	41.33	33.80
	Bio-rocket	42.33	39.30
	Bio-radish	38.00	40.90
	Control	24.90	26.81
Giza171	**Bio-cabbage**	45.83	44.17
	Bio-turnip	51.67	51.70
	Bio-rocket	53.33	53.10
	Bio-radish	50.17	47.00
	Control	34.67	37.88
L.S.D(0.05)		**	**

Plant height recorded the highest value (42.33 cm) with Rocket treatment, while the lowest value (34.00 cm) with Cabbage treatment on cultivar Sakha95.

Plant height recorded the highest value (53.33 cm) with Rocket treatment, while the lowest value (45.83 cm) with Cabbage treatment on cultivar Giza171.

Plant height recorded the best results of biofumigation with Rocket treatment on cultivars Misr1, Misr2, Sids14, Sakha95, and Giza171 as (47.33, 54.00, 40.50, 42.33, 53.33 cm) while Control treatment resulted the least results after 120 days of planting.

In season (2022/2023)

Plant height recorded the highest value (46.17 cm) with Turnip treatment, while the lowest value (38.70 cm) with Cabbage treatment on cultivar Misr1 after 120 days.

Plant height recorded the highest value (45.16 cm) with Rocket treatment, while the lowest value (34.08 cm) with Cabbage treatment on cultivar Misr2 after 120 days.

Plant height recorded the highest value (43.33 cm) with Turnip treatment, while the lowest value (31.80 cm) with Cabbage treatment on cultivar Sids14 after 120 days.

Plant height recorded the highest value (40.90 cm) with Radish treatment, while the lowest value (33.80 cm) with Turnip treatment on cultivar Sakha95 after 120 days.

Plant height recorded the highest value (53.10 cm) with Rocket treatment, while the lowest value (44.17 cm) with Cabbage treatment on cultivar Giza171 after 120 days.

Plant height recorded the best results of biofumigation with Rocket treatment on cultivars Misr1, Misr 2 and Giza171 as (46.17, 45.16 and 53.10 cm) but biofumigation with Turnip and biofumigation with Radish resulted the best on cultivars Sids14 and Sakha 95 as (43.33 and 40.90 cm), respectively. While control treatment resulted the least results after 120 days of planting.

Biofumigation treatments had a highly significant effect on improving the vegetative growth and led to enrich plant height and leaves number. Similar results were obtained by other researchers (**Smolinska *et al*., 2003; Matthiessen and Kirkegaard, 2006; Mazzola *et al*., 2007; Oka *et al*. 2007; Baysal-Gurel *et al*., 2009; Hansen and Keinath, 2013**).

Effect of biofumigation plants and wheat cultivars on weight of total plants

Data in Tables 3 presented the highly significant interaction effect between five cultivars and four treatments compared to control (untreated) on weight of total plants in the first and second seasons after 120 days.

In season (2021\2022)

The weight of total plants had recorded the highest value (1.23) with Rocket treatment. But the lowest value (1.11kg) was recorded by Cabbage treatment on cultivar Misr1.

The weight of total plants had recorded the highest value (1.20 kg) with Rocket treatment. But the lowest value (0.74 kg) was recorded by Cabbage treatment on cultivar Misr2.

The weight of total plants had recorded the highest value (1.19 kg) with Rocket treatment. But the lowest value (0.55 kg) was recorded by Cabbage treatment on cultivar Sids14.

The weight of total plants had recorded the highest value (1.75 kg) with Rocket treatment. But the lowest value (0.41 kg) was recorded by Radish treatment on cultivar Sakha95.

The weight of total plants had recorded the highest value (1.53 kg) with Rocket treatment. But the lowest value (1.05 kg) was recorded by Cabbage treatment on cultivar Giza171.

Table 3. The effect of interaction between four wheat cultivars and four biofumigation plants on yield and its components characteristics of wheat plants cultivated in soil infested with *Fusarium pseudograminearum* in both seasons (2021 & 2022) after 120 days

Mean values of Yields its components kg			
Cultivars	**Treatments**	**Season 2021/2022**	**Season 2022/2023**
		Weight of total plants	**Weight of total plants**
Misr1	**Bio-cabbage**	1.11	1.05
	Bio-turnip	1.22	1.09
	Bio-rocket	1.23	1.24
	Bio-radish	1.12	0.99
	Control	0.93	0.79
Misr2	**Bio-cabbage**	0.74	0.64
	Bio-turnip	1.19	1.15
	Bio-rocket	1.20	1.88
	Bio-radish	1.01	1.17
	Control	0.81	0.50
Sids14	**Bio-cabbage**	0.55	0.72
	Bio-turnip	0.82	1.27
	Bio-rocket	1.19	1.06
	Bio-radish	0.66	0.59
	Control	0.46	0.45
Sakha95	**Bio-cabbage**	0.53	0.53
	Bio-turnip	1.09	1.04
	Bio-rocket	1.75	1.04
	Bio-radish	0.41	0.92
	Control	0.46	0.53
Giza171	**Bio-cabbage**	1.05	1.12
	Bio-turnip	1.42	1.50
	Bio-rocket	1.53	1.32
	Bio-radish	1.37	1.44
	Control	0.64	0.62
L.S.D(0.05)		**	**

The weight of total plants recorded the highest rate (1.23, 1.20, 1.19, 1.75 and 1.53 kg) for Rocket biofumigation treatment with cultivars; Misr1, Misr2, Sids14, Sakha 95, and Giza171, respectively.

In season (2022\2023)

The weight of total plants had recorded the highest value (1.24 kg) with Rocket treatment. But the lowest value (0.99 kg) was recorded by Radish treatment on cultivar Misr1.

The weight of total plants had recorded the highest value (1.88 kg) with Rocket treatment. But the lowest value (0.64 kg) was recorded by Cabbage treatment on cultivar Misr2.

The weight of total plants had recorded the highest value (1.27 kg) with Turnip treatment. But the lowest value (0.59 kg) was recorded by Radish treatment on cultivar Sids14.

The weight of total plants had recorded the highest value (1.04 kg) with Rocket and Radish treatments. But the lowest value (0.53 kg) was recorded by Cabbage treatment on cultivar Sakha95.

The weight of total plants had recorded the highest value (1.50 kg) with Turnip treatment. But the lowest value (1.22 kg) was recorded by Cabbage treatment on cultivar Giza171.

The weight of total plants recorded the highest levels (1.24, 1.88 and 1.44 kg) for Rocket biofumigation by cultivars Misr1, Misr2, and Giza171, respectively. and (1.72 and 1.04 kg) for Turnip biofumigation with cultivars Sids14 and Sakha95, respectively.

Many studies highlighted that glucosinolates act as natural biofumigants and biofumigation is a chemical-free method for soil disinfection. This process can modify the physical, chemical, and biological properties of the soil, ultimately contributing to the suppression of pathogens (**Zukalová *et al*., 2003; Kirkegaard and Matthiessen, 2004; Cohen *et al*., 2005; Matthiessen and Kirkegaard, 2006; Stark *et al*., 2008 and Larkin *et al*., 2010; Swetha *et al*., 2020**).

From data presented in Table 1 these findings align with the observations of **Koike and Subbarao (2000**) concluded that utilizing broccoli residues as a biofumigant plant for managing Verticillium wilt of cauliflower was effective in reducing disease incidence and severity compared to the control group in field conditions. **Kirkegaard *et al*. (2003)** discovered that Brassica crops were the most effective method among those tested for reducing crown rot infection in wheat. **Motisi *et al*. (2009)** successfully employed biofumigant plants as a biological control measure for sugar beet root rot in field conditions. **Readford (2015)** demonstrated that rotating crops with Brassica species successfully decreased the quantity of crown rot inoculum compared to a fallow treatment during the growing season in field trials in northern New South Wales.

Drakopoulos *et al*. (2020) demonstrated that certain biofumigant plants can reduce mycotoxin production by *Fusarium graminearum*, the primary culprit behind Fusarium head blight in wheat. Furthermore, Elsayed, *et al*. (2022) reported success in reducing head blight disease incidence in Egyptian wheat crops using biofumigation with Brassica plants.

Data presented in Table 2 showed that plant height recorded the best results of biofumigation with Rocket treatment on cultivars Misr1, Misr2, Sids14, Sakha95, and Giza171 as (47.33, 54.00, 40.50, 42.33, 53.33 cm) while control treatment resulted the least results after 120 days of planting in the first season but in the second season plant height recorded the best results of biofumigation with Rocket treatment on cultivars Misr1, Misr 2 and Giza171 as (46.17, 45.16 and 53.10 cm) but biofumigation with turnip and biofumigation with radish resulted the best on cultivars Sids14 and Sakha 95 as (43.33 and 40.90 cm), respectively. While control treatment resulted the least results after 120 days of planting.

Data obtained in Table 3 showed the results of total weight plants recorded the highest rate (1.23, 1.20, 1.19, 1.75 and 1.53 kg) for Rocket biofumigation treatment with cultivars; Misr1, Misr2, Sids14, Sakha95, and Giza171, respectively in the first season. While, in the second season Weight of total plants recorded the highest levels (1.24, 1.88 and 1.44 kg) for Rocket biofumigation by cultivars; Misr1, Misr2, and Giza171, respectively and (1.72 and 1.04 kg) for Turnip biofumigation with Cultivars; Sids14 and Sakha95, respectively.

The findings of this study are consistent with those of **Hansen and Keinath (2013)**, who observed that Brassica treatments significantly improved pepper yields, comparable to other methods. **Sarhan *et al*. (2020)** found that biofumigation treatments led to an increase in plant height, which positively influenced chickpea yield components under field conditions. **Oka *et al.* (2007)** found that green manure application not only helps to prevent diseases but also promotes plant growth and productivity. **Sarhan *et al.* (2020)** investigated the effectiveness of biofumigation using mustard and canola seed meals to control the soil-borne pathogens were found to increase crop yields in greenhouse and field experiments. **Oka *et al*. (2007)** discovered that applying green manure to the soil not only helps to manage diseases but also promotes plant growth and productivity. This suggests that green manure is a beneficial practice for improving overall crop health and yield. Several studies (**Smolinska *et al*., 2003; Matthiessen and Kirkegaard, 2006; Mazzola *et al*., 2007**) have found that using Brassica species as green manure can suppress soil-borne pathogenic fungi, leading to improved plant growth and yield. This beneficial effect is attributed to the release of volatile biocidal compounds, primarily isothiocyanates (ITCs), produced by hydrolyzed Brassica species in the soil.

Matthiessen and Kirkegaard (2006) suggested that the suppression effects of incorporating cruciferous residues into the soil could be attributed to indirect effects on pathogens, such as changes in the populations of antagonistic organisms, as well as the impact of compounds released from the plant tissues.

In contrast to the findings of other studies, **Hartz *et al*. (2005)** found that using overwintering mustard cover crops did not consistently affect soil-borne disease control or tomato fruit productivity in six field trials. Also, **Baysal-Gurel *et al*. (2009)** found that biofumigation did not significantly impact the total or marketable tomato yields. Their study revealed no notable differences in tomato yields between plots with and without cover crops.

Conclusion

Biofumigation can be considered as an effective method for controlling FCR and FHB of wheat caused by *F. pseudograminearum*. This eco-friendly practice may be effectively integrated with other fungal control strategies, such as crop rotation, the use of resistant varieties, and other techniques, in both organic and conventional agricultural systems as a control strategy for this important disease of wheat.

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الملخص العربي

التدخين الحيوي للتحكم في مرض عفن التاج ولفحة السنبلة في القمح

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تسبب فطريات الفيوزاريوم عدة أمراض لنباتات القمح، مثل عفن التاج ولفحة السنبلة الفيوزاريومى. وقد حصلنا على عينة من الفيوزاريوم سودوجرامينيريوم OK465188 لتقييم فعالية أربع نباتات تدخين حيوى (الكرنب، اللفت، الجرجير، والفجل) على النمو الخضري، والخصائص المرضية والمحصولية لخمسة أصناف من القمح (مصر ١، مصر ٣، الجيزة ١٧١، سخا ٩٥، وسدس ١٤) مقارنة بمعاملة التحكم للسيطرة على عفن التاج ولفحة السنبلة للقمح. أثبتت تجارب الصوب فعالية التدخين الحيوي في السيطرة على مرض عفن التاج الفيوزاريومي ولفحة السنبلة الفيوزارمى للقمح خلال موسمين زراعيين. وقد أكدت هذه النتائج أن التدخين الحيوي هو نهج واعد وصديق للبيئة لإدارة مرض عفن التاج ولفحة السنبلة الفيوزاريومي في القمح.

الكلمات الاسترشادية: نباتات التدخين الحيوي، لفحة السنبلة الفيوزاريومي، عفن التاج الفيوزاريومي، أصناف القمح.

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