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Application of dry powders of six plant species, as soil amendments, for controlling *Fusarium solani* and *Meloidogyne incognita* on pea in pots

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Abstract

Background: Application of organic amendments could improve soil properties as well as controlling of soil-borne pathogens. Soil amendments with dry powders of six plant species materials, *i.e.* caraway seeds, fennel seeds, garlic gloves, onion bulbs, pomegranate peel and spearmint leaves were separately applied for controlling *Fusarium solani* and *Meloidogyne incognita* on pea plants in pots. The control is untreated check pots for *Fusarium solani* and *Meloidogyne incognita*.

Results: The dry powder of pomegranate peel (as the rate of 10 g/1 kg soil)highly reduced the *Fusarium*- disease assessments (pre-emergence and post-emergence damping-off and root-rot diseases incidence), followed by spearmint leaves, caraway seeds, fennel seeds, garlic gloves and onion bulbs, respectively. The tested dry powder of plant species showed the nematicidal activity on *M. incognita* criteria, i.e. second juvenile (J_2) in soil and roots as well as galls and egg-masses in roots of pea. The spearmint leaves, onion bulbs and fennel seeds highly reduced the J_2 in soil and roots as well as galls and egg-masses. The pea plant growth parameters *i.e.* length of shoot, fresh & dry weights of shoot and fresh weight of roots, yield parameters, *i.e.* fresh and dry weight of pea pod and pod parameters as well as *Rhizobium* nodules number were increased in pea plants with reducing infestation with *F. solani* and *M. incognita*.

Conclusions: Soil amendments with dry powders of six plant species materials were used in this study reduced *F. solani* and *M. incognita* and improved pea plants

Keywords: Dry powder, *Fusarium solani*, Organic amendments, *Pisum sativum*, *Meloidogyne incognita*

Background

Pea plants (*Pisum sativum* L.) are the most important vegetables crop grew in many countries of the world as well as in Egypt, where it is rich in starch, protein, Vitamins and high in fiber (Pownall et al. 2010). *Fusarium solani* (*Fusarium* root rot disease) and *Meloidogyne incognita* (nematode root-knot disease) are among various soilborne pathogens which attack pea root systems (Anwar and Mcknery 2010). Application of organic amendments could improve soil properties as well as controlling of soilborne pathogens, where the non-sterilized vegetables waste-compost completely inhibited the mycelium growth of *Fusarium oxysporum* f.sp *radicis-lycopersici* in tomatoes, at the highest rates only (Kouki et al. 2012). There were several medicinal plants as caraway seeds containing R-carvone and D-limonene, fennel seeds containing fenchone, camphene, garlic gloves powder containing allicin, onion bulbs powder containing flavonoids, phytosterols and saponins, pomegranate peel contain tannins, terpenoids, alkaloids, flavonoids and

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glycoside and spearmint leaves contain Mint L-carvone, limonene which have nematicidal effect (Middleton et al. 2000; Youssef and El-Nagdi 2016).

The un-autoclaved water extracts of commercial composts also had inhibitory effects against *F. solani*, isolated from cucumber plants, in vitro tests. The compost amended soil could reduce the percentages of disease incidence and improve the growth parameters of cucumber plants in pot experiments (Sabet et al. 2013).The pomegranate peel aqueous extract inhibited the linear growth of *Fusarium oxysporum* and *F. solani* in vitro tests as well as pomegranate peel powder, when tested as seed or soil treatments, could decrease the pre- emergence and post-emergence of *Fusarium* damping-off disease in greenhouse experiments (Mohamad and Khalil 2015). Application of pomegranate peel aqueous extract could reduce of wilting incidence and improve of growth variables of tomato plants in vivo tests (Rongai et al. 2016). The olive oil cakes or castor bean reduced *Fusarium* root rot disease incidence and increased the growth parameters of eggplants in pots experiment (Abd-El-Khair et al. 2018). The compost tea, when combined with pomegranate peel powder, highly inhibited the growth of *F. oxysporum* in vitro tests. The combination also significantly reduced the wilting disease severity and increased the survival of lupine plants in field applications (Abou El-Nour Mona et al. 2020).

Application of aqueous or ethanol of stem extracts of *Rhizophora mucronata* showed more nematicidal effect against *Meloidogyne javanica* juveniles, than leaves extracts. Soil amended with dried powder of leaves or stem of *R. mucronata* controlled root-knot nematodes in plants of mash beans or okra, where the treatments also significantly increased the seeds germination and both length & weights of shoot and root of tested plants (Tariq et al. 2007). The municipal green wastes, olive pomace, spent mushroom substrates and sewage sludge, when applied as soil amendments, could significantly reduce *M. incognita* parameters in tomato roots. Soil amended olive pomace-based composts or composted mushroom substrate resulted the highest nematode suppression and significantly increased the plant growth of tomato plants (D'addabbo et al. 2011). Dry leaves of both fleabane (F) and sugar beets (S), mud sugar beet (M) as well as organic compost, as sugar cane residues (OC), alone or in combination with Bionema (B) were significantly reduced the *M. incognita* parameters. The combination of Bionema + Nile fertile was reduced numbers of J_2 nematode in soil as well as galls and egg-masses in roots, followed by B + M, B + OC, B + S and B + F, respectively and significantly increased the growth parameters of sugar beet (El-Nagdi et al. 2011). Soil amended with chopped or ground dry leaves of neem and castor leaves had maximum suppression against gall and eggs numbers of *M. javanica* in greenhouse, respectively (Lopes et al. 2011). Soil amended with fresh chopped leaves or dry leaves powder of *Datura stramonium*, *Peganum harmala* or *Tagetes minuta*, poultry and sheep manure reduced the nematode population and improved plant growth parameters in garlic. *P. harmala*, as dry leaves powder, was the most effective (Saeed 2015).The olive oil cakes or castor bean reduced nematode parameters of *M. incognita* and increased the growth parameters of eggplants in pots experiment (Abd-El-Khair et al. 2018). The soil amended with ground seeds of fennel & caraway or powdered leaves of basil significantly reduced the *M. incognita* parameters under greenhouse conditions. Basil waste was highly reduced numbers of J_2 and egg-masses of nematode, than fennel and caraway, respectively. The treatments highly improved growth and yield parameters of *M. incognita* infected pea plants (El-Nagdi et al. 2019).

The present study aimed to evaluate the antifungal and nematicidal activity of powdered materials of six plant species, *i.e.* caraway seeds (*Carum carvi*)), fennel seeds (*Foeniculum vierns*), garlic gloves (*Allium sativum*), onion bulbs (*Allium cepa*), pomegranate peels (*Punica granatum*) and spearmint leaves (*Mentha varidis*) for controlling of *Fusarium solani* and *Meloidogyne incognita* on pea plants in pots.

Methods

1.Dry plant materials

Six dry materials of plant species *i.e.* caraway seeds (*Carum carvi*), fennel seeds (*Foeniculum vierns*), garlic gloves powder (*Allium sativum*), onion bulbs powder (*Allium cepa*), pomegranate peel (*Punica granatum*) and spearmint leaves (*Mentha varidis*) were obtained from Governorate of Fauyoum of Egypt during 2018 season. Then, the plant materials were dried at room temperature. Seeds of fennel, caraway, pomegranate peels and Spearmint leaves were ground in a blender. A commercial powdered of garlic gloves (*Allium sativum*) and onion bulbs (*Allium cepa*) were applied. All plant species were applied as powder materials, for testing their antifungal and nematicidal activity.

2. *Fusarium* root-rot pathogen

Fusarium *solani* was isolated from naturally infected pea plants and then the pathogenic fungus was identified in Plant Pathology Department (PPD), National Research Centre (NRC), according to pathological, morphological

and cultural characters according to the key described by Ellis (1971) and Barnett and Hunter (1972).

3. ***Meloidogyne incognita* inoculum**

The root-knot nematode, *M. incognita*, was identified by using protocol described by Taylor and Sasser (1978) by using nematode adult female based on its perineal pattern morphological characteristics. The pure cultures of *M. incognita* were reared on eggplants by a single egg-mass of this nematode inoculated to susceptible eggplant cv. Baladi in a screen house at 30 ± 5 °C. Newly hatched second juvenile of nematode as inocula were applied.

4. **Pot experiment**

Seventy of plastic pots (there were 35 pots for Fusarium experiment and 35 pots for nematode experiment), each of it contains about 2 kg of solarized sandy-loam soil (1:1), were applied. The treatments of dry powder materials were as follows; caraway seeds, fennel seeds, garlic gloves, onion bulbs, pomegranate peel, spearmint leaves and untreated (without pathogen). Each pot soil was mixed well with each tested dry powdered plant materials, separately, at rate 10 g per 1 kg soil. Then, the pots were watered and left for one week. The pots were divided into two groups; each one contains 35 pots, the first group for *F. solani* and the second for *M. incognita*. Five pots were used as replicated for each treatment. Seeds of pea (cv. Concessa) surface sterilized in solution of sodium hypochlorite (1%) for 3 min., followed by three successive rinses in sterilized-distilled water. The excess water was removed by air drying. In the group A; the pots were inoculated with 7- days-old cultures *F. solani* adjusted to 10^8 propagules/g at the rate of 3% soil weight (W: W) and then, the pots were watered and left for one week. Five seeds were sown in each pot. In the group (B); five pea seeds were sown per pot. After seeds germination, the two plants were selected in each pot. The pots were inoculated with 1000 newly hatched J_2 of *M. incognita* in four holes made around the plant roots. The pots were arranged according to a complete randomized design on a bench of experimental greenhouse of PPD, NRC of Egypt.

Effect on disease assessments of *Fusarium solani*

Effect of dry powder of each caraway seeds, fennel seeds, garlic gloves, onion bulbs, pomegranate peels and spearmint leaves on disease assessments caused by *F. solani* was estimated. The pre-emergence and post- emergence of damping-off percentages were calculated after 15 and 45 days from sowing, respectively. The disease incidence (%) of root- rots and survived of healthy pea plants were recorded after 60 days of sowing.

$$\text{Pre - emergence (\%)} = \text{Number of non - germinated seeds/Total number of sown seeds} \times 100$$

$$\text{Post - emergence (\%)} = \text{Number of dead seedlings/Total number of sown seeds} \times 100 \quad \text{Survived plant (\%)} = \text{Number of survived plants/Total number of sown seeds} \times 100$$

Effect on *M. incognita* parameters

Three months after inoculation, the nematicidal effect of dry powder of each caraway seeds, fennel seeds, garlic gloves, onion bulbs, pomegranate peel and spearmint leaves against *M. incognita* criteria viz. J_2 number in soil as well as numbers of J_2, galls and egg-masses in pea roots (five roots /treatment) as well as the percentages of reduction were recorded.

Effect on plant growth and pod parameters

Effect of dry powder of each caraway seeds, fennel seeds, garlic gloves, onion bulbs, pomegranate peel and spearmint leaves on plant growth parameters of pea *i.e.*, length of shoot (cm), fresh & root weights (g) of shoot and fresh weight (g) of roots as well as pod parameters, *i.e.* fresh and dry weights (g) of pods were recorded with artificially infestation *F. solani* or *M. incognita*.

Statistical analysis

Results were analyzed by analysis of variance (ANOVA) using Computer Statistical Package Costat software (1990). User Manual Version 3.03, Barkley Co. The variation between treatments was detected using Duncan's multiple range test at 5% level of probability (Snedecor and Cochran 1999).

Results

Fusarium solani

Effect on disease assessments

The antifungal activity of dry powders of six plant species, *i.e.* caraway seeds, fennel seeds, garlic gloves, onion bulbs, pomegranate peel and spearmint leaves on *Fusarium* -disease assessments, in pots experiment, are listed in Table 1. The pomegranate peel highly increased the survival pea plants being 86.1%, followed by spearmint leaves (83.0%), caraway seeds (79.0%), fennel seeds

Table 1 Effect of dry powder plant materials on disease assessments of *Fusarium solani* as well as number of *Rhizobium* nodules in pea roots system in pots, under greenhouse conditions

Treatments[1] (dry powder)	Disease assessments (%)				Nodules no	
	Damping-off		Root rot incidence	Survival plants		
	Pre-emergence	Post-emergence				
					Log_{10}	Incr.%
Caraway seeds	9.4b[2]	10.7b	10.3bc	79.0ab	14	17
Fennel seeds	9.4b	13.9b	13.9bc	72.2bc	13	8
Garlic gloves	12.5b	14.3b	14.3bc	71.4bc	14	17
Onion bulb	12.5b	17.9ab	17.9b	64.2c	14	17
Pomegranate peel	6.3b	6.7b	7.2c	86.1a	13	8
Spearmint leaves	6.3b	7.2b	9.8bc	83.0ab	16	33
F. solani alone	31.3a	27.5a	31.7a	40.8d	12	–

[1] All treatments were done with artificial infection by *F. solani* alone

[2] Means followed by small letter are not significant according to Duncan's Multiple Range Test at $p \leq 0.05$

(72.2%), garlic gloves (71.4%) and onion bulbs (64.2%), respectively (Table 1).

Results revealed that the incidence of pre-emergence of damping-off disease was in the ranges of 6.3 to 12.5%, in treated pea plants, compared to 31.3% in pea plants treated with *F. solani* only. The dry powders of each pomegranate peel and spearmint leaves highly reduced the disease incidence to 6.3%, followed by each of caraway seeds & fennel seeds (9.4%) and each of garlic gloves & onion bulbs (12.5%), respectively. Results revealed that the post-emergence of damping-off disease incidence was in the ranges of 6.7 to 17.9%, than 27.5% in pea plants treated with *F. solani* only. The dry powder of pomegranate peel highly reduced the disease incidence to 6.7%, followed by spearmint leaves (7.2%), caraway seeds (10.7%), fennel seeds (13.9%), garlic gloves (14.3%) and onion bulbs (17.9%), respectively (Table 1).

The incidence of root rot disease in treated plants with dry powder of plant species was ranged from 7.2 to 17.9% in treated plants, compared to 31.7% in pea plants treated with *F. solani* only. The antifungal activity of tested dry powders were same trend as mentioned before, where the pomegranate peel highly reduced the root-rot incidence to 7.2%, followed by spearmint leaves (9.8%), caraway seeds (10.3%), fennel seeds (13.9%), garlic gloves (14.3%) and onion bulbs (17.9%), respectively. Results revealed that plant dry powders were increased the survival pea plants in the range of 71.4 to 86.1%, compared to survival plants being 40.8% with *F. solani* only.

Effect on plant growth and pod parameters

Effects of plant dry powders on growth parameters of pea plants *i.e.* length of shoot, fresh & dry weights of shoot and fresh weight of roots as well as yield parameters, *i.e.* fresh and dry weights of pea pods, with artificially infestation with *F. solani* in pot experiment, is shown in Table 2. The pomegranate peel highly increased being 58%, followed by onion bulbs (46%), garlic gloves (42%), fennel seeds (39%), caraway seeds (31%) and spearmint leaves (31%), respectively.

The plant dry powders increased the shoot length of treated plants in the ranges of 11 to 25% comparing *F. solani* treatment only. The pomegranate peel resulted the highest increases being 25%, followed by garlic gloves (21%), onion bulbs (19%), spearmint leaves (16%), fennel seeds (15%) and caraway seeds (11%), respectively. The fresh and dry weights of shoot of treated pea plants were in the ranges of 4 to 34% and 46 to 133% comparing with pathogen only. The pomegranate peel highly increased of each fresh and dry weights being 34 and 133%, followed by onion bulbs (24 & 127%), garlic gloves (15 & 106%), spearmint leaves (11 & 100%), fennel seeds (4 & 46%) and caraway seeds (9 & 73%). Results revealed that the fresh weight in treated pea roots ranged 31 to 58% comparing with pathogen only.

The plant dry powders increased the fresh pod of treated pea in the range of 60 to 110% comparing with pathogen only. The pomegranate peel has the highest increased being 110%, followed by onion bulbs (89%), garlic gloves (70%), caraway seeds (60%), fennel seeds (60%) and spearmint leaves (60%), respectively. The treatments also increased the dry weight of pea pod in the ranges of 35 to 91% comparing with pathogen only. The pomegranate peel also highly increased being 91%, followed by onion bulbs (87%), garlic gloves (61%), spearmint leaves (52%), fennel seeds (39%) and caraway seeds (35%), respectively (Table 2).

Table 2 Effect of dry powder plant materials on growth parameters of pea plants, artificially infected by *Fusarium solani* in pots, under greenhouse conditions

Treatments[1] (dry powder)	Plant growth parameters											
	Shoot parameters						Root fresh weight (g)		Pods parameters (g)			
	Length (cm)		Fresh weight (g)		Dry weight (g)				Fresh weight		Dry weight	
	cm	Inc.%	g	Inc.%	g	Inc.%	g	Inc.%	g	Inc.%	g	Inc.%
Caraway seeds	47.2d[2]	11	16.8de	4	4.8d	46	3.4b	31	5.9cd	60	3.1c	35
Fennel seeds	48.9cd	15	17.6ed	9	5.7c	73	3.6ab	39	5.9cd	60	3.2c	39
Garlic gloves	51.6b	21	18.5bc	15	6.8b	106	3.7ab	42	6.3c	70	3.7bc	61
Onion bulb	50.8b	19	20.0b	24	7.5a	127	3.8ab	46	7.0b	89	4.3ab	87
Pomegranate peel	53.2a	25	21.6a	34	7.7a	133	4.1a	58	7.8a	110	4.4a	91
Spearmint leaves	49.4c	16	17.8cde	11	6.6b	100	3.4b	31	5.9cd	60	3.5c	52
F. solani alone	42.6e	–	16.1e	–	3.3e	–	2.6c	–	3.7e	–	2.3d	–

[1] All treatments were done with artificial infection by *F. solani* alone

[2] Means followed by small letter are not significant according to Duncan's Multiple Range Test at $p \leq 0.05$

Meloidogyne incognita

Effect on nematode parameters

The nematicidal activity of plant dry powder, *i.e.* caraway seeds, fennel seeds, garlic gloves, onion bulbs, pomegranate peel and spearmint leaves against *M. incognita* parameters, *i.e.* J_2 in soil and J_2, galls and egg-masses in roots in pots are shown in Table 3. The dry powders reduced the J_2 numbers in soil in the ranges of 63 to 89% comparing with the untreated control (*M. incognita* alone). The spearmint highly increased the J_2 reduction in soil being 89%, followed by fennel seeds (88%), caraway seeds (86%), pomegranate peel (80%), onion bulbs (79%) and garlic gloves (63%), respectively. The treatments also reduced the J_2 number in roots in the ranges of 61 to 75% comparing with untreated control. The onion bulbs highly increased the percentages of root-J_2 reduction being 75%, followed by garlic gloves (72%), fennel seeds (69%), pomegranate peel (67%), caraway seeds (64%) and spearmint leaves (61%), respectively (Table 3).

The plant dry powders could reduce the galls number in roots in the ranges of 63 to 79% comparing with untreated control. The fennel seeds highly increased the percentages of galls reduction in pea roots being 79%, followed by garlic gloves (74%), pomegranate peel (74%), caraway seeds (68%), onion bulbs (63%) and spearmint leaves (63%), respectively. The treatments also reduced the egg-masses number in pea roots in the ranges of 67 to 83%, comparing with untreated control. The fennel seeds highly increased the percentages of egg-masses reduction in pea roots being 83%, followed by garlic gloves (75%), onion bulbs (75%), pomegranate peel (75%), caraway seeds (67%) and spearmint leaves (67%), respectively (Table 3).

Effect on plant growth and pod parameters

Effects of plant dry powders on tested pea plant growth parameters as well as pod parameters with artificially infestation with *M. incognita*, in pot experiment are shown in Table 4. The shoot length of treated pea plants was in the ranges of 10 to 26% comparing with nematode alone. The pomegranate peel highly increased the shoot length being 26%, followed by onion bulbs (20%), garlic gloves (18%), fennel seeds (14%), spearmint leaves (14%) and caraway seeds (10%), respectively. The shoot fresh and dry weights of treated pea plants were in the ranges of 9 to 36% and 17 to 59%, respectively. The pomegranate peel highly increased the shoot fresh and dry weights being 36 and 59%), followed by onion bulbs (24 & 55%), garlic gloves (17 & 35%), spearmint leaves (15 & 28%), fennel seeds (11 & 24%) and caraway seeds (9 & 17%), respectively. The fresh weight of pea roots was in the ranges of 14 to 46% comparing with pathogen only. The fennel seeds highly increased the root weight being 46%, followed by garlic gloves (43%), pomegranate peel (39%), onion bulbs (26%), garlic gloves (42%), spearmint leaves (29%) and caraway seeds (14%), respectively. The plant dry powders also increased the fresh pod in treated pea plants ranged from 71 to 141% comparing with untreated control. The pomegranate peel highly increased the fresh pod weight being 141%, followed by onion bulbs (129%), garlic gloves (109%), spearmint leaves (97%) fennel seeds (85%) and caraway seeds (71%), respectively. The dry weight of pea pod improved in the ranges of 23 to 104%. The pomegranate peel has highest increase of dry weight of pod being 104%, followed by onion bulbs (92%), garlic gloves (81%), fennel seeds (58%), spearmint leaves (50%) and caraway seeds (23%), respectively (Table 4).

Table 3 Effect of dry powder plant materials on *M. incognita* parameters and *Rhizobium* bacterial nodules number in pea roots system in pots, under greenhouse conditions

Treatments[1] (dry powder)	Nematodes parameters								Nodules no	
	J_2 in soil		J_2 in roots		Galls No		Egg-masses No			
	Log_{10}	Red. %	Log_{10}	Red. %	Log_{10}	Red. %	Log_{10}	Red. %	Log_{10}	Red. %
Caraway seeds	3.00c[2]	86	2.11b	64	0.78b	68	0.59b	67	15b	50
Fennel seeds	3.43b	88	2.04b	69	0.59d	79	0.26c	83	15b	50
Garlic gloves	3.43b	63	2.00b	72	0.69c	74	0.46b	75	15b	50
Onion bulb	3.19c	79	1.95c	75	0.84b	63	0.46b	75	12cd	20
Pomegranate peel	3.16c	80	2.00c	67	0.69c	74	0.46b	75	13c	30
Spearmint leaves	2.91c	89	2.15b	61	0.84b	63	0.59b	67	18a	80
M. incognita alone	3.86a	–	2.55a	–	1.28a	–	1.07a	–	10d	–

[1] All treatments were done with artificial infection by *M. incognita* alone

[2] Means followed by small letter are not significant according to Duncan's Multiple Range Test at $p \leq 0.05$

Table 4 Effect of dry powder plant materials on growth parameters of pea plants, artificially infected by *M. incognita* in pots, under greenhouse conditions

Treatments[1] (dry powder)	Shoot parameters						Root fresh weight		Pods weight			
	Length		Fresh weight		Dry weight				Fresh		Dry	
	cm	Inc.%	g	Inc.%	g	Inc.%	g	Inc.%	g	Inc.%	g	Inc.%
Caraway seeds	48.8bc[2]	10	17.9d	9	3.4c	17	3.2cd	14	5.8e	71	3.2cd	23
Fennel seeds	50.6b	14	18.2cd	11	3.6bc	24	4.1a	46	6.3de	85	4.1b	58
Garlic gloves	52.1b	18	19.1c	16	3.9b	35	4.0ab	43	7.1bc	109	4.7b	81
Onion bulb	53.2b	20	20.4b	24	4.5a	55	3.8ab	36	7.8ab	129	5.0a	92
Pomegranate peel	56.0a	26	22.3a	36	4.6a	59	3.9ab	39	8.2a	141	5.3a	104
Spearmint leaves	50.6b	14	18.8cd	15	3.7bc	28	3.6bc	29	6.7cd	97	3.9bc	50
M. incognita alone	44.3c	–	16.4e	–	2.9d	–	2.8d	–	3.4f	–	2.6d	–

[1] All treatments were done with artificial infection by *M. incognita* alone

[2] Means followed by small letter are not significant according to Duncan's Multiple Range Test at $p \leq 0.05$

Effect on *Rhizobium* nodules

The pots experiment revealed that the increase of *Rhizobium* nodules number was in the ranges of 8–33% in treated pea roots comparing with *F. solani* only. The spearmint leaves highly increased the *Rhizobium* nodules being 33%, followed by caraway seeds (17%), garlic gloves (17%), onion bulbs (17%), fennel seeds (8%) and pomegranate peel (8%), respectively (Table 1). Under artificially infestation with *M. incognita*, the number of *Rhizobium* nodules on pea roots was in the ranges of 20–80% comparing with untreated control. The spearmint leaves also highly increased the *Rhizobium* nodules being 80%, followed by caraway seeds (50%), fennel seeds, (50%), garlic gloves (50%), onion bulbs (20%) and pomegranate peel (30%), respectively (Table 2).

Discussion

Application of organic soil amendments could improve the physical & chemical properties, structure, temperature and humidity conditions of soil as well as nutrient contents for plants growth. The beneficial bacteria or fungi play an important role in suppressing the economically important soil borne disease (plant parasitic nematodes or pathogenic fungi).Organic amendments can provide an environmentally friendly alternative to chemical pesticide uses which are often expensive, limited available or environmentally hazardous (Renčo 2013). The use of organic amendments, a narrow C: N ratio, can improve soil fertility, whereas more efficiently can reduce the levels of nematode and could minimize the risks of increase levels of others soil-borne pathogens, where neem seeds powder has nematicidal activity in field or greenhouse (Agbenin 2004). Application of the leaves and stem of *Avicennia marina* or *Rhizophora mucronata*, as organic amendments, significantly controlled root rot fungi (*Fusarium* spp.) and root-knot nematode (*Meloidogyne javanica*) in potato in pots (Tariq et al. 2008). The olive pomace composts significantly increased soil chemical parameters as organic matter, where the nitrogen contents were at the highest rates (D'addabbo et al. 2011).

Our results revealed that the dry powders of tested plant species were differed in their antifungal or nematicdal activity against *Fusarium*-disease assessments or *M. incognita*-nematode parameters of *M. incognita* in potted pea plants, where the reduction differed according to treatment. The dry powders of pomegranate peel or spearmint leaves, resulted the highest reduction against incidence of pre- and post-emergence dapping-off as well as root rot diseases, than other plant dry powders when pea plants were artificially infested with *F. solani*. The obtained results are in agreement with those recorded by Borrego-Benjumea Ana et al. (2015), where soil amended with poultry manure or olive residue compost significantly reduced inoculum viability of *Fusarium oxysporum*, *F. proliferatum* and *F. solani* associated with asparagus roots when affected with crown and root rot diseases. The root severity disease symptoms significantly decreased, where *F. proliferatum* was lower severity, than *F. oxysporum* or *F. solani*. Soil amended with olive residue compost showed significantly asparagus plants fresh weight with *Fusarium* infection. Javaid and Rauf (2015) showed that the dry leaves of *Chenopodium album* significantly reduced disease incidence of basal rot in onion caused by *F. oxysporum* when incorporation at 3% (w/w). The chloroform, resulted from methanolic leaf extract, exhibited the best antifungal activity against fungal biomass. Therefore, the chloroform fraction or soil amendment with biomass of *C. album* dry leaves can apply as alternative of chemical fungicides for controlling basal rot disease in onions. Rongai et al. (2016) mentioned reduced the *Fusarium* population in soil as well as the compost tea in combination with pomegranate peel powder because of it has an important source of bioactive compounds which managed *Fusarium* wilt and increase in number of healthy tomato plants. It is cleared that pomegranate peel may be a promising as an environmentally safe alternative to fungicides by suppressing the most dangerous damping-off and wilt diseases (Abou El-Nour et al. 2020).

Under artificially infestation with *M. incognita*, the applied plant dry powders could reduce the nematode parameters, but no significant differences were recorded with most treatments. The dry powders of spearmint leaves, onion bulbs and fennel seeds had the highest nematicidal activity against of J_2 in soil & roots as well as galls & egg-masses. These results are in agreement with those recorded by Stirling and Eden (2008) and Youssef and El-Nagdi (2016–2017) on spearmint. They reported that soil amended with sugarcane residue, plus ammonium nitrate, enhanced microbial activity and decreased *M. incognita* populations when incorporated at 4 months before planting of capsicum. Soil amendments of olive pomace or composted mushroom substrate significantly reduced gall formation of *M. incognita* in tomato roots, whereas the composted municipal green wastes were more suppressive when combined with sewage sludge (D'addabbo et al. 2011). The bio-fumigation by mechanically incorporation of chopped brassicaceous plants into soil controlled soil-borne nematode. Bio-fumigant effect may due to the volatile or toxic of thiocyanates originated from the of secondary metabolites hydrolysis of glucoseinolate present in the *Brassica* tissues. The graminaceous plants such as sorghum and Sudan grass produce nematicidal cyanides via enzymatic hydrolysis of precursor cyanogenic glycoside/dhurrin. The allelopathic plant marigold produces α-terthienyl, which has shown

potential bio-fumigation effect against PPNs (Dutta et al. 2019).

Our results revealed that the dry powders of six plants species were increased the tested plant growth and pods parameters of pea plants in comparing pathogen alone, where the increase differed according to treatment. The leaves and stem of *Avicennia marina* or *Rhizophora mucronata*, as organic amendments, significantly increased the plant growth (length of shoot, weight of shoot, length of roots and weight of roots) of potato (Tariq et al. 2008). The compost of olive-waste was positively affected tomato growth, when combined with wastes of sheep wool. Soil amendments with composted mushroom substrate significantly increased the growth of plants, whereas composted municipal green waste was positively affected tomato growth in combination with sewage sludge (D'addabbo et al. 2011). The certain medicinal chopped plant green or dry leaves and their aqueous extracts of neem, Datura, camphor and oleander managed root knot nematode *M. incognita* criteria as well as plant growth parameters in eggplant and reduction differed according to treatment. The most plant growth parameters were increased by some treatments (Youssef and Lashein 2013).The powdered dry leaves of spearmint and sage alone or in combination were reduced *M. incognita* on cowpea and improving plant growth and yield criteria (El-Nagdi Wafaa et al. 2017).

Conclusions

Soil amendments with dry powders of six plant species, *i.e.* caraway seeds, fennel seeds, garlic gloves, onion bulbs, pomegranate peel and spearmint leaves were used in this study reduced *F. solani* and *M. incognita* criteria which subsequently improved plant growth and yield of pea plants. The pomegranate peel highly increased the survival pea plants infected by *F. solani* followed by spearmint leaves, caraway seeds, fennel seeds, garlic gloves and onion bulbs. The onion bulbs highly increased the percentages of nematode J_2 reduction, followed by garlic gloves, fennel seeds, pomegranate peel, caraway seeds and spearmint leaves. It is clear that the leaves and seeds of Egyptian plant species may have best control against *Fusraium* pathogen or root-knot nematode as well as improved plant growth and yield when applied in the field.

Abbreviations

M. incognita: *Meloidogyne incognita*; J_2: Second stage juveniles; *F. solani*: *Fusarium solani*; *F. oxysporum*: *Fusarium oxysporum*; *R. mucronata*: *Rhizophora mucronata*; F: Dry leaves of fleabane; M: Mud sugar beet; OC: Organic compost as sugar cane residues; B: Incombination with bionema; PPD: Plant Pathology Department; NRC: National Research Centre; ANOVA: Analysis of variance; COSTAT: Computer statistical package.

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Authors' contributions

H A E (The first author) suggested the idea of the research and design the experiment in green house, shared in writing the manuscript. W M A E (second author) carried out the manuscript in the green house, statistical analysis in data, shared in writing the manuscript. The two authors read and approved the final manuscript.

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Availability of data and materials

Soil amendments with dry powders of some plant species materials, are available for controlling *Fusarium solani* and *Meloidogyne incognita*.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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