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Seaweeds as an alternative to chemical pesticides for the management of root diseases of sunflower and tomato

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Summary

With the rising popularity of organic farming, due to adverse effect of chemicals, the seaweed fertilizer industry is growing rapidly worldwide. Seaweeds act as natural plant growth stimulator and enable the plants to withstand drought, disease or frost. Root diseases of tomato and sunflower caused by root rotting fungi, *Fusarium* spp., *Rhizoctonia solani* and *Macrophomina phaseolina,* and root knot nematode, *Meloidogyne* spp., are the major constraints in tomato and sunflower production. In our studies, ethanol and water extracts of several seaweeds showed significant nematicidal activity against *Meloidogyne javanica.* In this study, efficacy of three seaweeds *Spatoglossum variabile, Melanothamnus afaqhusainii* and *Halimeda tuna* was compared with a fungicide Topsin-M and a nematicide carbofuran both in screen house and under field condition. Seaweed and pesticides showed more or similar suppressive effect on root pathogens of tomato and sunflower by reducing fungal root infection and nematode's galls on roots and nematode's penetration in roots. However, mixed application of *S. variabile* with carbofuran caused maximum reduction in nematode's penetration in roots and produced greater fresh shoot weight, root length and maximum yield of tomato under field condition. Seaweeds offer a non-chemical means of disease control, which would also protect our environment from the use of hazardous chemicals.

Introduction

Global utilization of seaweed is a multi-billion dollar industry. Research and utilization of marine algae have increased markedly from last several decades (JIMENEZ-ESCRIG and SANCHEZ-MUNIZ, 2000). A number of products based on algae have been developed and applied in many fields like foods, pharmaceuticals, cosmetics and nutritional supplements (SMIT, 2004). Much of this is based on farming of edible species or on the production of agar, carrageen and alginate. Perhaps the longest established, most widespread and most proven effective use of seaweed is as a fertilizer (CHAPMAN and CHAPMAN, 1980; HATTORI, 1999). The high fiber content of seaweed acts as a soil conditioner and assists moisture retention, while the mineral content is a useful fertilizer and source of trace elements (MAT-ATKO, 1992). They also contain bio-control properties and contain many organic compounds and growth regulators such as auxins, gibberellins and precursor of ethylene and betaine which affect plant growth. Seaweed extracts have been reported to increase plant resistance to pests and diseases, plant growth, yield and quality (JOLIVET et al., 1991; MAT-ATKO, 1992; SHYAMALI et al., 1982).

Management of soil-borne plant pathogens, including parasitic nematodes, is one of the single greatest challenges facing modern agriculture worldwide. The importance of soil-borne pathogens in modern agriculture systems is made especially clear by the current rush worldwide to find alternatives to methyl bromide for pre-plant treatment of soils used to produce certain high-value crops. Losses caused by plant parasitic nematodes are estimated about US $100 billion annually (SAIFULLAH et al., 2007), whereas fungal pathogens including species of *Fusarium, Phytophthora, Rhizoctonia, Pythium, Verticillium* and *Macrophomina phaseolina* caused billions dollar losses each year. Most soilborne pathogens are difficult to control by conventional strategies such as the use of resistant cultivars and synthetic fungicides (WELLER et al., 2002). Moreover the effect of synthetic fungicides on the environment and on human health are leading to significant changes in the use of fungicides for the management of plant disease (PERKINS and PATTERSON, 1997). As a consequence there is an increased emphasis on ways to minimize the use of pesticides (MAAS and GALLETTA, 1997). In our previous study, several seaweeds collected from Karachi coast have shown effective control of root rotting fungi like *Macrophomina phaseolina, Rhizoctonia solani, Fusarium* species and root knot nematode (*Meloidogyne* spp.,) on various crops (SULTANA et al., 2007; 2008; 2009). In this study, efficacy of some seaweeds was examined alone or with common pesticides Topsin-M (fungicide) and carbofuran (nematicide) both in screen house and under field condition in suppressing the soilborne diseases and growth of sunflower (*Helianthus annuus* L.) and tomato (*Lycopersicon esculentum* Mill.).

Materials and methods

Seaweeds *Melanothamnus afaqhusainii*, *Spatoglossum variabile* and *Halimeda tuna* collected from Buleji Beach, Karachi were used in these experiments individually or with commercial pesticides, Topsin-M (fungicide) and carbofuran (nematicide) to compare the efficacy of these seaweeds with common commercial pesticides. The experiments were conducted both under screen house and field conditions using sunflower and tomato as test plants.

Screen house experiment

Dry powder of seaweeds was mixed with sandy loam soil (pH 8.1) to give a concentration of 1.0% w/w. The soil was naturally infested with 3-7 sclerotia of *Macrophomina phaseolina* g^{-1} of soil as determined by wet sieving and dilution plating (SHEIKH and GHAFFAR, 1975), 2-6% colonization of *Rhizoctonia solani* on sorghum seeds used as baits (WILHELM, 1955) and 3,000 cfu g^{-1} of soil (cfu = colony forming units) of a mixed population of *Fusarium oxysporum* and *F. solani* as determined by soil dilution (NASH and SNYDER, 1962). One kg of amended soil was transferred to clay pots (12 cm diam.). The pots were watered daily to allow the decomposition of the organic substrate. After three weeks, four equal size seedlings of tomato (*Lycopersicon esculentum* Mill.) variety Roma, raised in steam sterilized soil were transplanted after root treatment with aqueous suspension of Topsin-M (200 ppm) for 15 minutes, whereas carbofuran (at 0.05 g/kg soil) was applied after nematode inoculation. A set of seaweeds and pesticides separately were also kept for comparison. The pots without seaweeds and /or pesticides served as control. The pots were kept randomized on a screen house bench at 50% WHC (water holding capacity) with four replicates of each treatment (KEEN and RACZKOWSKI, 1921). The seedlings were inoculated with *Meloidogyne javanica* eggs/juveniles at 2000 eggs/second stage juveniles per pot after one week of seedlings establishment. Whereas in case of sunflower six seeds were sown in each pots and 20 ml of Topsin-M (200 ppm) suspension was drenched per pots. After one week of germination only four seedlings were kept and excess were removed and inoculated with nematode suspension similar to tomato experiment.

To determine the efficacy of seaweeds and pesticides on the root pathogens and plant growth, plants were uprooted after six weeks of nematode inoculation. Observations were made on plant height, fresh shoot weight, root length and root weight. Nematode infection was determined by counting the numbers of galls per root system (TAYLOR and SASSER, 1978). To determine nematode penetration and infection by root-infecting fungi, roots from each plant were cut into 1-cm long pieces and five pieces of tap roots from each plant were used for assessment of fungal infection. The remaining roots were mixed thoroughly, and 1-gram sub-sample was wrapped in muslin cloth and dipped in boiling 0.25% acid fuchsin stain for 3-5 minutes. Roots were left in the stain to cool, and then washed under tap water to remove excess stain. Roots were transferred to vials containing glycerol and water (1:1 v:v) with a few drops of lactic acid. Roots were macerated in an electric blender for 45 seconds and the resulting suspension was suspended in 50 ml water. Numbers of juveniles and females in five 5 ml sub samples were counted with the aid of dissecting microscope and numbers of nematode/g root were calculated (SIDDIQUI and EHTESHAMUL-HAQUE, 2001). To determine the incidence of fungal infection, 1-cm long root pieces from tap roots (five pieces from each plant) were surface disinfested with 1% Ca $(OCl)_2$ solution and plated onto potato dextrose agar amended with penicillin (100,000 units/l) and streptomycin (0.2 g/l). After incubation for 5 days at 28 °C, colonies of *Macrophomina phaseolina*, *Rhizoctonia solani* and species of *Fusarium* were recorded. The experiment was conducted twice. Data were subjected to analysis of variance (ANOVA) and means were separated using the least significant difference (LSD) according to GOMEZ and GOMEZ, 1984).

Field Experiments

Dry powder of seaweeds *M. afaqhusainii*, *S. variabile* and *H. tuna* were mixed in sandy loam soil at 70 g per two meter rows and watered 2-3 days interval to allow the organic matters to decompose. The soil had a natural infestation of 6-18 sclerotia/g of soil of *Macrophomina phaseolina*, 5-12% colonization of *Rhizoctonia solani* on sorghum seeds used as baits and 2800cfu/gm of soil of mixed population of *Fusarium oxysporum* and *F. solani*. After two weeks of seaweed decomposition, three-week-old tomato seedlings of equal size, raised in steam sterilized soil were transplanted in each row at 12 seedlings per row. In another set, Topsin-M (200 ppm) at 200 ml/ 2 meter row and carbofuran (1 g/ 2 m row) were applied in seaweed amended and non-amended soil. After one week of seedling transplantation, each row was inoculated with aqueous suspension of *Meloidogyne javanica* eggs/juveniles at 4000/ two meter row. Each treatment was replicated four times and plants were watered 2-3 days intervals depending upon requirement of plants. Effect of seaweed and pesticides on soilborne pathogens, growth and yield of tomato were recorded after 10 weeks of nematode inoculation. Effect of seaweeds on root rotting fungi and root knot nematode was determined as described above except addition of data on nematode's population in soil. Nematode's population in soil around roots was determined by Baermann funnel method (SCHINDLER, 1961). In case of sunflower, 30 seeds were sown in each row and seedlings were inoculated with nematode suspension after one week of germination. Observations were recorded after 6 weeks of nematode inoculation.

Results

Screen house Experiment

Sunflower

On sunflower application of *S. variabile* alone or *H. tuna* with Topsin-M or carbofuran caused complete inhibition of *Macrophomina phaseolina* infection on sunflower roots. Seaweeds alone or with pesticides also significantly reduced *Fusarium solani* infection (Tab. 1). Application of seaweeds with pesticides also caused a suppressive effect on nematode by reducing the nematode's penetration in roots (Tab. 1). Seaweed soil amendment showed a positive effect on plant growth by enhancing the plant height (Tab. 2).

Tab. 1: Effect of green (*Halimeda tuna*), brown (*Spatoglossum variabile*) and red (*Melanothamnus afaqhusainii*) seaweeds on the infection of *Macrophomina phaseolina, Rhizoctonia solani* and *Fusarium solani* and *Meloidogyne javanica* on sunflower roots under screen house condition.

Treatments	*M. phaseolina*	*R. solani*	*F. solani*	No.of knots/ root system	Juveniles/females/ g root
	Infection %				
Control	31.2	25	43.7	15.5	13.2
Topsin-M	0	12.5	18.7	4.9	1.6
Carbofuran	12.5	12.5	12.5	10.5	4.9
H. tuna at 1% w/w (A)	12.5	31.2	25	8.7	8.2
S. variabile at 1% w/w (B)	0	12.5	18.7	8.5	3.3
M. afaqhusainii at 1% w/w (C)	18.7	18.7	25	3.8	4.9
Topsin-M + A	0	6.2	6.2	9.8	2.7
Carbofuran + A	0	43.7	37.5	7.9	1.6
Topsin-M + B	6.2	6.2	18.7	7.6	3.3
Carbofuran + B	6.2	43.7	12.5	7.4	3.3
Topsin-M + C	12.5	25	25	9.1	1.6
Carbofuran + C	12.5	12.5	37.5	7.4	1.6
$LSD_{0.05}$ for fungi = Treatments = 11.9[1], Pathogens = 5.9[2]				**ns**	**10.6**

[1]Mean values in column showing differences greater than LSD values are significantly different at p< 0.05.
[2]Mean values in rows for fungi showing differences greater than LSD values are significantly different at p< 0.05.

Tab. 2: Effect of green (*Halimeda tuna*), brown (*Spatoglossum variabile*) and red (*Melanothamnus afaqhusainii*) seaweeds on the growth of sunflower under screen house condition.

Treatments	Plant height (cm)	Fresh shoot weight (g)	Root length (cm)	Fresh root weight (g)
Control	20.2	3.8	12.1	0.48
Topsin-M	23.4	2.9	12.5	0.52
Carbofuran	26.3	3.5	13.1	0.69
H. tuna at 1% w/w (A)	28.1	3.5	9.1	0.63
S. variabile at 1% w/w (B)	27.3	4.6	12.4	1.02
M. afaqhusainii at 1% w/w (C)	25.9	3.2	10.1	0.74
Topsin-M + A	25.7	3.6	9.3	0.66
Carbofuran + A	28.8	3.7	8.5	0.99
Topsin-M + B	25.0	3.6	9.7	0.51
Carbofuran + B	31.7	3.7	11.4	0.48
Topsin-M + C	27.5	4.1	12.0	0.70
Carbofuran + C	26.2	3.3	9.9	0.68
$LSD_{0.05}$	**5.1[1]**	**ns**	**ns**	**0.39[1]**

[1]Mean values in column showing differences greater than LSD values are significantly different at $p < 0.05$.
ns = non-significant

Tab. 3: Effect of green (*Halimeda tuna*), brown (*Spatoglossum variabile*) and red (*Melanothamnus afaqhusainii*) seaweeds on the infection of *Macrophomina phaseolina, Rhizoctonia solani, Fusarium solani* and *Meloidogyne javanica* on tomato roots under screen house condition.

Treatments	*M. phaseolina*	*R. solani*	*F. solani*	No.of knots/ root system	Juveniles/females/ g root
	Infection %				
Control	6.2	25	37.5	71.5	398
Topsin-M	6.2	6.2	18.7	32.9	381
Carbofuran	0	0	12.5	33.4	261
H. tuna at 1% w/w (A)	6.2	6.2	12.5	28.7	389
S. variabile at 1% w/w (B)	0	6.2	12.5	18.5	246
M. afaqhusainii at 1% w/w (C)	0	6.2	31.2	41.5	294
Topsin-M + A	0	0	0	21.2	149
Carbofuran + A	0	6.2	25	19.1	166
Topsin-M + B	0	6.2	18.7	18.3	258
Carbofuran + B	0	0	0	30.7	297
Topsin-M + C	6.2	6.2	12.5	22.3	253
Carbofuran + C	0	0	12.5	10.8	259
$LSD_{0.05}$ for fungi = Treatments = 8.7[1], Pathogens = 4.3[2]				**42.3[2]**	**192[2]**

[1]Mean values in column showing differences greater than LSD values are significantly different at $p < 0.05$.
[2]Mean values in rows for fungi showing differences greater than LSD values are significantly different at $p < 0.05$.

Tomato
Application of seaweeds alone and or with Topsin-M and carbofuran also showed a suppressive effect on root rotting fungi *Rhizoctonia solani* and *Fusarium solani*. *Halimeda tuna* with Topsin-M and *S. variabile* with carbofuran caused complete suppression of *M. phaseolina*, *R. solani* and *F. solani* on tomato roots (Tab. 3). Seaweeds alone and or with pesticides also caused a suppressive effect on nematode by reducing the number of galls on roots. Application of *H. tuna* with Topsin-M and carbofuran caused better protection of roots from nematode invasion than applied separately (Tab. 3). Greater plant height and fresh shoot weight was achieved by the mixed application of *S. variabile* and Topsin-M (Tab. 4). Whereas *H. tuna* produced maximum root length.

Field Experiment
Sunflower
Seaweed alone and/or with pesticides, Topsin-M and carbofuran caused a suppressive effect on root rotting fungi of sunflower by reducing the infection of *Macrophomina phaseolina*, *Fusarium solani* and *Rhizoctoni solani* (Tab. 5). Seaweed application alone or with Topsin-M and carbofuran also produced an adverse effect

Tab. 4: Effect of green (*Halimeda tuna*), brown (*Spatoglossum variabile*) and red (*Melanothamnus afaqhusainii*) seaweeds on the growth of tomato under screen house condition.

Treatments	Plant height (cm)	Fresh shoot weight (g)	Root length (cm)	Fresh root weight (g)
Control	19.65	3.56	9.65	1.95
Topsin-M	17.87	3.19	5.6	1.92
Carbofuran	19.67	3.41	18.9	2.05
H. tuna at 1% w/w (A)	21.14	3.6	21.1	2.2
S. variabile at 1% w/w (B)	26.9	5.92	19.6	4.2
M. afaqhusainii at 1% w/w (C)	21.47	5	6.4	3.4
Topsin-M +A	23.2	5	5	2.73
Carbofuran +A	24.1	3.87	5.5	2.36
Topsin-M + B	27.7	6.9	5.2	4.4
Carbofuran + B	24.5	6.75	12.1	3.6
Topsin-M + C	22.87	4.9	5.6	2.9
Carbofuran + C	19.12	3.9	6.2	2.3
$LSD_{0.05}$	**5.01[1]**	**1.66[1]**	**7.85[1]**	**1.82[1]**

[1]Mean values in column showing differences greater than LSD values are significantly different at $p< 0.05$.

Tab. 5: Effect of green (*Halimeda tuna*), brown (*Spatoglossum variabile*) and red (*Melanothamnus afaqhusainii*) seaweeds on the infection of *Macrophomina phaseolina, Rhizoctonia solani, Fusarium solani* and *Meloidogyne javanica* on sunflower roots under field condition.

Treatments	*M. phaseolina*	*R. solani*	*F. solani*	No. of knots/ root system	Juveniles/ females/g root	Nematodes/ 100 g soil
	Infection %					
Control	18.7	12.5	12.5	59.6	14	30.5
Topsin-M	0	6.2	0	35.2	11.5	20
Carbofuran	6.2	12.5	0	38.6	7	32
H. tuna at 1% w/w (A)	0	0	0	12.0	9	28
S. variabile at 1% w/w (B)	0	18.7	0	47.8	6	20
M. afaqhusainii at 1% w/w (C)	18.7	12.5	25	10.6	7	40
Topsin-M + A	6.2	12.5	0	27.3	8	40
Carbofuran + A	0	18.7	12.5	17.7	14	16
Topsin-M + B	6.2	0	0	16.5	10	36
Carbofuran + B	6.2	6.2	6.2	27.4	9	32
Topsin-M + C	0	0	0	19.2	8	20
Carbofuran + C	0	0	0	21.3	4	28
$LSD_{0.05}$ for fungi = Treatments = 11.9[1], Pathogens = 5.9[2]				**30.8[1]**	**8.8[1]**	**ns**

[1]Mean values in column showing differences greater than LSD values are significantly different at $p< 0.05$.
[2]Mean values in rows showing differences greater than LSD values are significantly different at $p< 0.05$.

on root knot disease (Tab. 5). Maximum reduction in nematode's penetration in roots was achieved by the mixed application of *M. afaqhusainii* and carbofuran. Maximum fresh shoot weight was produced by *S. variabile* used alone (Tab. 6).

Tomato

Seaweed soil amendment, alone or with Topsin-M and carbofuran caused a suppressive effect on root rotting fungi *Rhizoctonia solani* and *Fusarium solani* infecting tomato roots. No infection of *F. solani* was observed where *S. variabile* and *M. afaqhusainii* used alone or where *M. afaqhusainii* used with Topsin-M and *H. tuna* applied with carbofuran (Tab. 7). Seaweed also showed inhibitory effect on *Meloidogyne javanica.* Highest reduction in neamtode's penetration in roots was achieved by the mixed application of *S. variabile* and carbofuran (Tab. 7). Soil amendment with seaweeds alone or with pesticides caused a positive effect on plant growth by enhancing the plant height, fresh shoot weight, root length and yield. Maximum plant height was achieved where *S. variabile* was used with Topsin-M, whereas with carbofuran *S. variabile* produced greater fresh shoot weight and root length. *Spatoglossum variabile* also produced highest yield (in terms of number and by weight of fruits) of tomato used either with Topsin-M or carbofuran (Tab. 8).

Tab. 6: Effect of green (*Halimeda tuna*), brown (*Spatoglossum variabile*) and red (*Melanothamnus afaqhusainii*) seaweeds on the growth of sunflower under field condition.

Treatments	Plant height (cm)	Fresh shoot weight (g)	Root length (cm)	Fresh root weight (g)
Control	71.7	48.0	10.9	10.1
Topsin-M	101	90.8	9.4	8.5
Carbofuran	67.9	55.9	10.4	8.5
H. tuna at 1% w/w (A)	58.2	58.8	13.7	8.1
S.variabile at 1% w/w (B)	87.7	101.1	12.4	19.7
M. afaqhusanii at 1% w/w (C)	62.1	46.0	10.6	7.0
Topsin-M + A	72.0	58.2	14.1	20.3
Carbofuran + A	76.3	77.3	11.6	6.3
Topsin-M + B	67.9	69.0	11.7	5.7
Carbofuran + B	71.0	37.8	10.2	7.3
Topsin-M + C	91.1	85.7	8.9	5.5
Carbofuran + C	75.1	74.5	11.9	8.1
$LSD_{0.05}$	**28.1[1]**	**50.4[1]**	**ns**	**11.1[1]**

[1]Mean values in column showing differences greater than LSD values are significantly different at $p< 0.05$.
ns = non-significant

Tab. 7: Effect of green (*Halimeda tuna*), brown (*Spatoglossum variabile*) and red (*Melanothamnus afaqhusainii*) seaweeds on the infection of *Macrophomina phaseolina, Rhizoctonia solani, Fusarium solani* and *Meloidogyne javanica* on tomato roots under field condition.

Treatments	*M. phaseolina*	*R. solani*	*F. solani*	No. of knots/ root system	Juveniles/females/ g root	Nematodes/ 100 g
	Infection %					
Control	6.2	56.2	43.7	19.7	85.8	44.8
Topsin-M	0	6.2	12.5	9.6	59.9	21.4
Carbofuran	6.2	18.7	6.2	13.3	114.8	9.9
H. tuna at 1% w/w (A)	6.2	12.5	25	8.6	29.9	8.3
S. variabile at 1% w/w (B)	0	12.5	0	9.2	63.1	8.9
M. afaqhusainii at 1% w/w (C)	0	12.5	0	16	79.7	9.9
Topsin-M + A	12.5	31.2	12.5	6.8	53.2	9.9
Carbofuran + A	0	12.5	0	11.6	71.2	9.9
Topsin-M + B	6.2	18.7	6.2	12.3	38.1	12.4
Carbofuran + B	12.5	31.2	18.7	8.7	14.1	9.1
Topsin-M + C	6.2	6.2	0	12.1	46.4	4.1
Carbofuran + C	0	12.5	6.2	11.2	31.3	11.6
$LSD_{0.05}$ for fungi = Treatments = 12.4[1], Pathogens = 6.2[2]				**9.2[1]**	**54.4[1]**	**ns**

[1]Mean values in column showing differences greater than LSD values are significantly different at $p< 0.05$.
[2]Mean values in rows showing differences greater than LSD values are significantly different at $p< 0.05$.

Discussion

Marine biosphere is an untapped reservoir of agrochemically potent compounds. Seaweed has been used as a fertilizer for many years and are the most widely used biostimulant in agriculture management (HATTORI, 1999). In this study, seaweeds like *Spatoglossum variabile, Halimeda tuna,* and *Melanothamnus afaqhusainii,* showed more or less similar suppressive effect on root rotting fungi and root knot nematode to chemical fungicides (Topsin-M) and nematicide (carbofuran). Considerable evidence has been accumulated in recent years to support and identify the benefits associated with the use of seaweed in crop production systems. Seaweed extracts have been reported to increase plant resistance to pests and diseases, plant growth, yield and quality (JOLVET et al, 1991; PARDEE et al.,, 2004; VERKLEIJ, 1992). Application of seaweed to plants can result in decreased levels of nematode attack (ARA et al., 1997; WU et al., 1997; 1998). Seaweeds contain elaborate secondary metabolites that play a significant role in the defense of the host against predators and parasites which offer a potential novel approach to control population of plant parasitic nematodes (PARACER et al.,

Tab. 8: Effect of green (*Halimeda tuna*), brown (*Spatoglossum variabile*) and red (*Melanothamnus afaqhusainii*) seaweeds on the growth and yield of tomato under field condition.

Treatments	Plant height (cm)	Fresh shoot weight (g)	Root length (cm)	Fresh root weight (g)	No. of fruits/ 4 plant	Weight of fruits/ 4 plant (g)
Control	34.8	28.4	23.8	3.5	13.7	152.5
Topsin-M	42.0	33.7	24.2	4.8	20.0	308.7
Carbofuran	35.4	18.7	21.5	3.9	14.7	292.5
H. tuna at 1% w/w (A)	42.4	43.1	22.4	5.0	21.5	317.5
S. variabile at 1% w/w (B)	39.3	22.3	25.2	9.4	22.5	407.5
M. afaqhusainii at 1% w/w (C)	38.8	28.4	22.3	4.9	20.5	348.7
Topsin-M + A	33.7	30.9	19.0	3.8	13.0	175
Carbofuran + A	39.0	56.2	27.0	7.5	23.2	447.5
Topsin-M + B	46.4	62.4	27.0	7.5	28.0	490
Carbofuran + B	43.5	89.3	30.3	8.1	28.5	523
Topsin-M + C	43.3	43.7	29.4	6.6	22.5	412.5
Carbofuran + C	40.1	55.6	25.6	6.2	22.5	361.2
$LSD_{0.05}$	**7.5[1]**	**25.6[1]**	**5.9[1]**	**ns**	**9.6[1]**	**201.2[1]**

[1]Mean values in column showing differences greater than LSD values are significantly different at $p< 0.05$.
ns = non-significant

1987; JACOBS et al., 2003). In a large number of marine algae, antimicrobial activities are attributed to the presence of acrylic acid. Seaweeds contain 1-aminocyclopropane-1-carboxylic acid (ACC), which has antimicrobial activity (NELSON and VAN STANDEN, 1985). Whereas WU et al, (1997) suggested that betains of the brown alga *Ascophyllum nodosum* caused a reduction of *M. javanica* and *M. incognita* infection on tomato.

In this study, seaweeds showed more or less similar suppressive effect on root rotting fungi and root knot nematode like chemical pesticides, Topsin-M (fungicides) and carbofuran (nematicide). However, mixed application of *S. variabile* with carbofuran caused maximum reduction in nematode's penetration in roots and produced greater fresh shoot weight, root length and maximum yield of tomato under field condition, which is in agreement with our previous study (SULTANA et al., 2009).

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