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Solarization of Commercial Peat in Transparent Polyethylene Bags and its Effect on Survival of Some Plant Pathogenic Fungi

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Abstract. Two experiments were held to test the effect of solarization as a disinfestation non-chemical method of peat moss, a potential source of pathogenic fungal inocula. Solarization took place in spring and summer, 2004, of transparent polyethylene bags filled with artificially infested sphagnum peat moss with *Pythium aphanidermatum* and *Fusarium oxysporum.* Average daily maximum temperatures of solarized bags at five cm deep reached 51 and 54.2ºC in the spring and summer experiments, an increase of 16.8 and 16.9ºC, respectively, over temperatures of non solarized shaded bags. In the summer experiment, all tested pathogens were completely eliminated within two days at both depths, surface at 0-7.5 cm and inner layer of peat moss, 7.5-15 cm. In the spring experiment, however, *F. oxysporum* survived solarization better than *P. aphanidermatum.* It took six and eight days to eliminate the former at the surface and inner layer of the peat moss bags, respectively. The latter, on the other hand, took two and six days to be eliminated, respectively. The number of both fungi was significantly not affected in the shaded bags with a fluctuation in the population. Solarization of peat moss in clear plastic bags is a very efficient, economical, safe and easy method to eradicate plant pathogenic fungi even at cooler seasons.

Introduction

Peat is a common plant growth medium used as a substitute for soil. It is a perfect medium for seed germination and transplanting of seedlings and can be

used alone or mixed with other media such as vermiculite or perlite. However, commercial peat or peat-based propagation mixes has been reported to be a potential source of pathogenic fungal inocula[1-6].

Kim *et al.*[5], noted that 52 samples of commercial horticultural peat, all contained pathogenic *Fusarium* spp., 15 contained pathogenic *Pythium aphanidermatum* and *P. irregulare*, but none contained *Rhizoctonia solani* or *Verticillium* spp. El-Meleigi *et al.*[3] isolated pathogenic *Fusarium* spp., *Trichoderma* spp. and *Pythium* spp. from 100, 100 and 40% of the ten tested samples of German peat moss exported to Saudi Arabia, respectively. When cucumber seeds were germinated in peat moss mixture, 18% of the seedlings showed damping off.

Disinfestation of potting mixes, either by applying pesticides[7, 8] or by dry or steam heat[7, 9-11], for eradication of pathogenic microorganisms, is a common agricultural practice in nurseries and greenhouses. The application of these methods is expensive, and sometimes expenses outweighed benefits.

Solarization of field[12, 13] or greenhouse soils[14, 15] is a widespread method for controlling soilborne plant diseases. It is achieved by mulching wet soil with a transparent polyethylene sheets during the hot season. The main purpose of this method is to entirely or partially eliminate soilborne plant pathogenic fungi, bacteria, nematodes, insects, and weeds[12, 13, 16-18]. Direct high thermal effect below the plastic sheets is the main mechanism in elimination of these pests[17, 19-21].

Solarization of potting mixes containing peat was studied by some researchers for elimination of primary inocula of many plant pathogenic fungi[22, 23]. This method eradicated *Pythium myriotylum*, *Phytophthora nycotianae* and *Sclerotium rolfsii* the causal agent of root rot diseases of nursery ornamental plants[22]. In another study by Kaewruang *et al.*[23], solarization of potting mixes in clear plastic bags controlled root rot of gerbera caused by *Phytophthora cryptogea*, *Fusarium oxysporum* and *Rhizoctonia solani.*

Pythium aphanidermatum and *Fusarium oxysporum* were isolated from controlled environment greenhouses grown cucumber and tomato plants showing basal stem rot and crown stem rot, respectively in the western region of Saudi Arabia[24]. The source of inocula was suspected to be introduced through the widely used commercial German peat moss[3] that has been mixed with pure sand as a plant growth medium.

The objective of this study is to determine the effect of solarization of artificially inoculated commercial German sphagnum peat moss in clear plastic bags on survival of *Pythium aphanidermatum* (Edson) Fitsp. and *Fusarium oxy-*

sporum Schlechtend.: Fr. F. sp. Radicis- lycopersici W.R. Jarvis & Shoemaker through time in two solarization dates.

Materials and Methods

Preparation of Propagules

Oospores of *Pythium aphanidermatum* were produced on a semi solid Vegetable Oil Nitrate Agar (VONA) culture media containing 3 ml vegetable oil, 1.5 g $NaNo_3$, 1 g KH_2PO_4, 0.5 g $MgSO_4$. $7H_2O$, a trace of thiamine-HCl and 3 g agar in 1000 ml distilled water[36]. The fungus was obtained from a diseased mature cucumber plant (*Cucumis sativus* L.) causing basal stem rot in a controlled environment greenhouse in Hada-Sham. *Fusarium oxysporum*, however, was isolated from an infected tomato plant showing crown rot in Hada-Sham controlled environment greenhouse. Conidia were produced on V-8 Juice Agar (V-8JA) medium containing 20% V-8 juice, v/v, 2% agar, and 0.3% CaCO3[25].

Oospore suspension of 100 plates of *P. aphanidermatum* was prepared as described by Sunboul[24]. For *F. oxysporum*, conidia of 40 plates were collected by applying 15 ml of sterile water/plate and the surface of the agar was scraped with sterile spatula. Suspension of each fungus alone, then was added to 100 g dry autoclaved ground peat moss and left on a sheet of clean paper on the lab bench to dry at room temperature. Inoculants were put in plastic bags and stored in the refrigerator until needed.

Solarization of Peat Moss

Two experiments were held in a complete randomized plot design with factorial arrangement [2 dates (spring and summer) × 2 solarization treatments (solarized and shaded) × 6 sampling times (0, 1, 2, 4, 6 and 8 days) × 2 sampling depth 0-7.5 and 7.5-15 cm)]. Both experiments were held in the nursery of King Abdulaziz University in Jeddah at 14-22 April, and 15-23 August, 2004. German sphagnum peat moss (~ 20% moisture content) was artificially infested with each inoculant of *P. aphanidermatum* and *F. oxysporum*, previously prepared, in separate bags and mixed thoroughly in a 500 l cement mixer for 25 min to insure homogeneity of the mixture. Tap water was added to the mix until reached to 50% (w/w). Peat moss was filled in a 200 µ thick, 60 × 90 cm transparent polyethylene bags, with a total of 20 kg for each bag. Each treatment included three replicates, with a total of six bags for each fungus. The bags were sealed tightly by a packing tape. Half of the peat moss bags were exposed to the sun (solarized) and the other half were placed under the shade (non-solarized) to serve as a control.

To measure the temperature inside the plastic bags of both solarized and non-solarized, a soil temperature thermometer was inserted at 5, 10 and 15 cm deep

from the surface. Air temperatures were recorded in the shade at 1.5 m height from the surface of the soil. Bags were turned over daily to insure equal exposure to solar radiation for each side. Maximum and minimum temperatures were recorded daily at 6:30 am and 3:00 pm.

Enumeration of Fungi

Samples of peat moss were withdrawn at 0, 1, 2, 4, 6 and 8 days after the beginning of solarization, three samples per bag, using a soil auger and then pooled and mixed in plastic bags then air dried in the lab. Population densities of *P. aphanidermatum* and *F. oxysporum* were determined by the serial dilution method using a semi selective medium, Potato dextrose agar amended with 200 mg/l streptomycin sulfate, 40 mg rose bengal and 100 mg quintozene (PCNB)[25]. Data were statistically analyzed using MSTAT program.

Results

Maximum temperatures in solarized peat bags were recorded at five cm deep reaching 51ºC in the spring date (14-22 April/2004) and 56ºC in the summer date (15-23 August/2004) Fig. 1.Average maximum daily temperatures were 51 and 54.2ºC in solarized peat bags, respectively. In non-solarized bags, maximum daily average temperatures reached 34.2 and 37.3ºC in the spring and summer date, respectively. This means an increase of 16.8 and 16.9ºC due to solarization, respectively.

Analysis of variance is presented in Table 1. It is obvious that population densities of *P. aphanidermatum* was significantly affected at $P \leq 0.01$ level by solarization and time of sampling and at $P \leq 0.05$ level by the date of solarization. However, population density of *F. oxysporum* was significantly affected at the $P \leq 0.01$ level by solarization, the date of solarization and sampling time. Population densities of either pathogen were not affected significantly at any level by the depth of samples. The interaction of the different treatments also is shown in Table 1.

Solarization of peat moss in clear polyethylene bags was very effective in completely eliminating all tested pathogens within two days in the summer of solarization experiment as compared to shaded peat bags, Fig. 2(B), 3(B). In the spring experiment, however, eradication of both fungi took longer time than in the summer experiment, Fig. 2 & 3. Propagules of *Pythium aphanidermatum* were completely eradicated in two days at 0-7.5 cm deep, compared to six days in deeper depths at 7.5-15 cm in spring date, Fig. 2(A). *Fusarium oxysporum*, on the other hand, was more tolerant to high temperatures than *P. aphanidermatum* (Fig. 2A and 3A). *F. oxysporum* was not detected after six days from

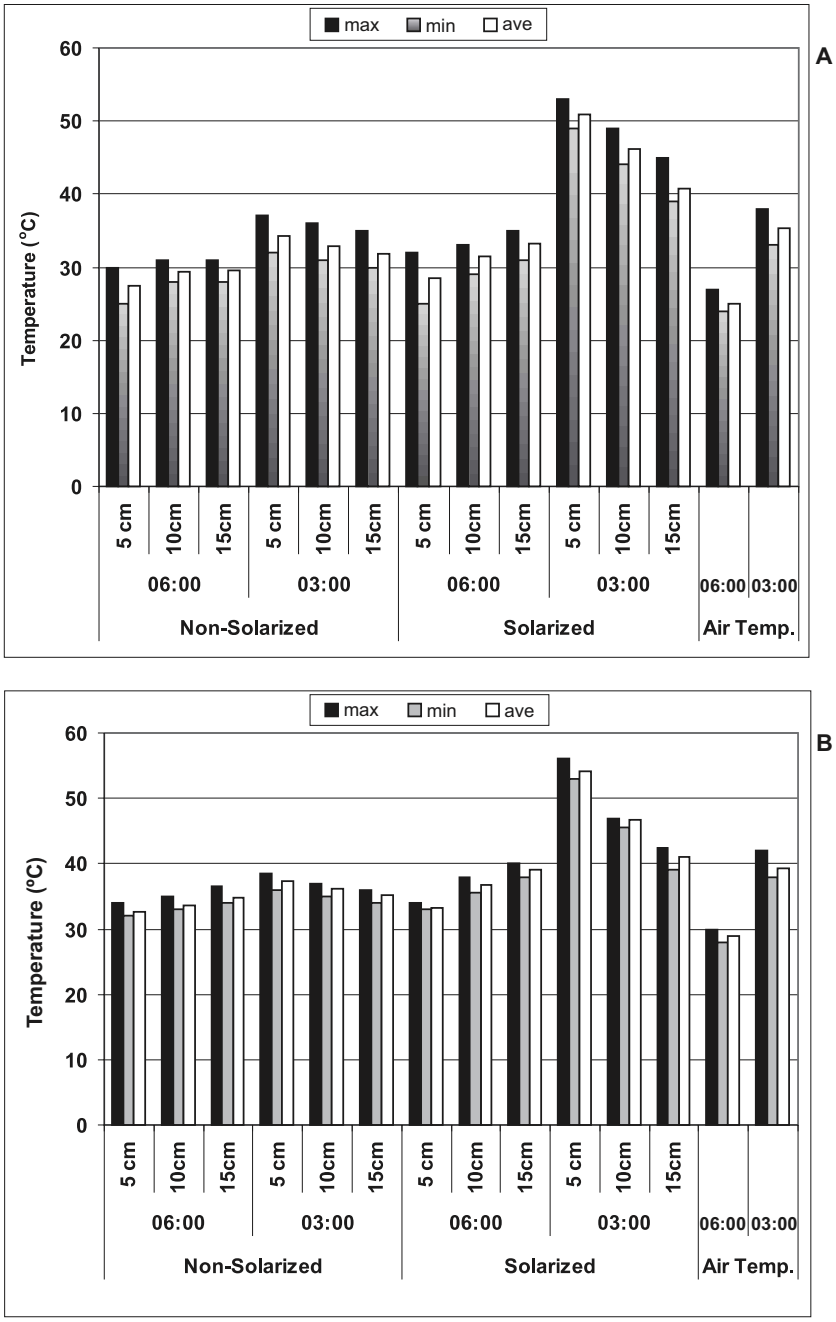

Fig. 1. Daily average temperatures of non-solarized and solarized peat moss at 5, 10 and 15 cm deep in clear plastic bags at 6:00 am and 3:00 pm from 14-22 April (A) and from 15-23 August 2004 (B). Air temperatures were also recorded at 6:00 am and 3:00 p.m.

the 7.5 cm top layer of the peat bags, Fig. 3(A). At deeper depths (7.5-15 cm), however, the fungus was not detected after eight days.

Table 1. Analysis of variance of the effect of solarization of peat moss bags at two dates 14-22 April and 15-23 Aug., 2004, six sampling times at 0, 1, 2, 4, 6 and 8 days and at two depths at 0-7.5 and 7.5-15 cm on population density of *P. aphani dermatum* and *F. oxysporum.*

Source of variation	DF	Mean	
		P. apha.	***F. oxy.***
Date of solarization (D)	1	1.8×10^{5}*	1.4×10^{11}**
Solarization (S)	1	3.5×10^{7}**	1.7×10^{11}**
D*S	1	6.9×10^{5}**	3.0×10^{10}**
Time of sampling (T)	5	1.7×10^{6}**	6.9×10^{9}**
D*T	5	1.8×10^{5}**	2.2×10^{9}**
S*T	5	2.1×10^{6}**	1.1×10^{10}**
D*S*T	5	8.1×10^{4}	5.3×10^{9}**
Depth of samples (P)	1	1.6×10^{5}	1.6×10^{8}
D*P	1	5.3×10^{4}	1.4×10^{7}
S*P	1	1.1×10^{4}	1.2×10^{9}*
D*S*P	1	8.2×10^{3}	1.8×10^{9}**
T*P	1	3.2×10^{4}	9.5×10^{8}**
D*T*P	5	5.1×10^{4}	7.7×10^{8}**
S*T*P	5	5.5×10^{4}	5.1×10^{8}*
D*S*T*P	5	1.2×10^{4}	3.0×10^{8}
Error	94	4.0×10^{4}	2.1×10^{8}

*Significant at P = 0.05
**Significant at P = 0.01

Population densities of both fungal pathogens fluctuated through time in non-solarized bags with no major change as compared to solarized bags, Fig. 2 & 3. In summer experiment, the number of propagules of *P. aphanidermatum* was increased ~ 10 and 32% in the peat samples withdrawn from 0-7.5 and 7.5-15 cm, respectively, after eight days of solarization (Fig. 2). The number of propagules of *F. oxysporum* recovered from 0-7.5 and 7.5-15 cm in the shaded bags was increased ~ 21 and 13% after eight days in the spring date as compared to 20% decrease and 8% increase in the summer date, respectively, Fig. 3.

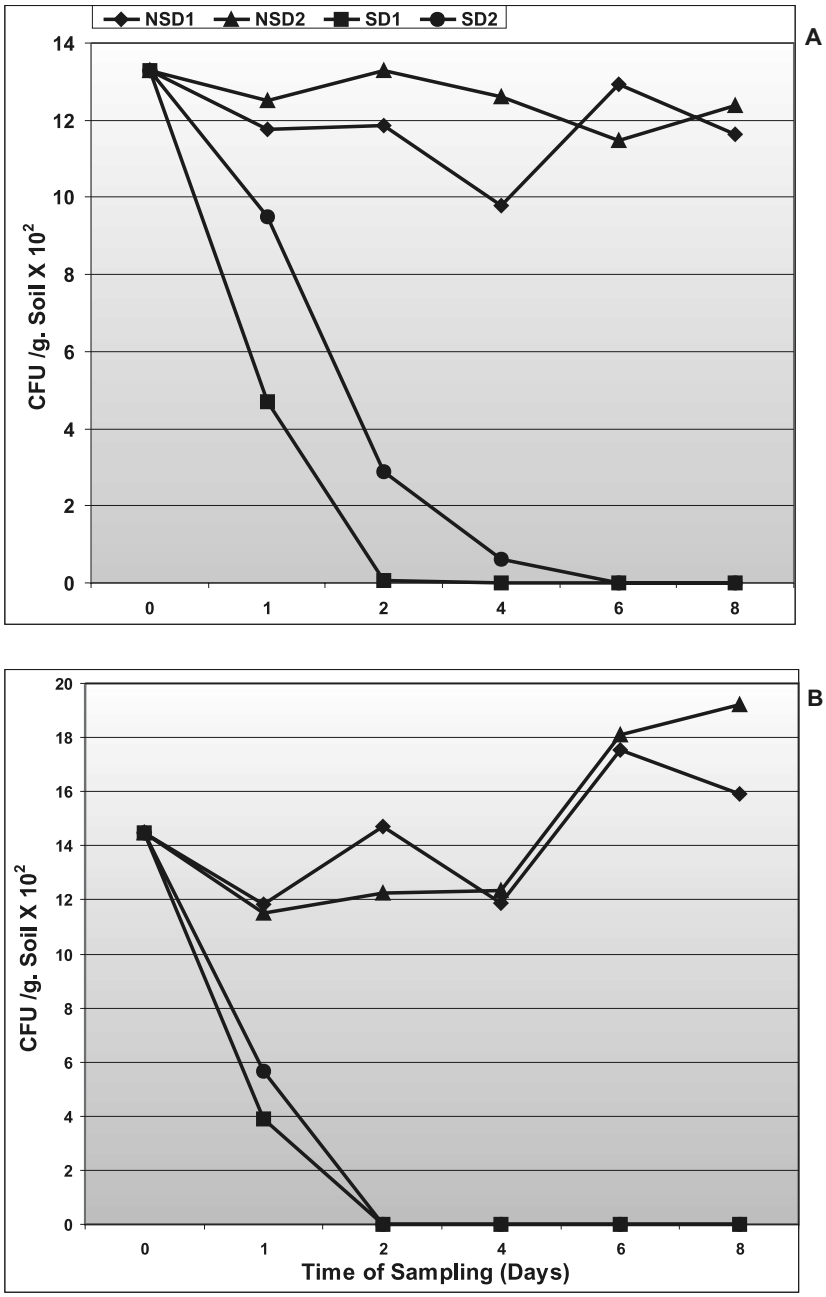

Fig. 2. Effect of solarization of peat moss on population density of *Pythium aphanidermatum* (colony forming units/gram dry soil) from 14-22 April (A) and from 15-23 August (B). Samples were taken from 0-7.5 cm (D1) and 7.5-15 cm (D2). Plastic bags containing peat moss were left under the sun (S) or in the shade (NS) as control.

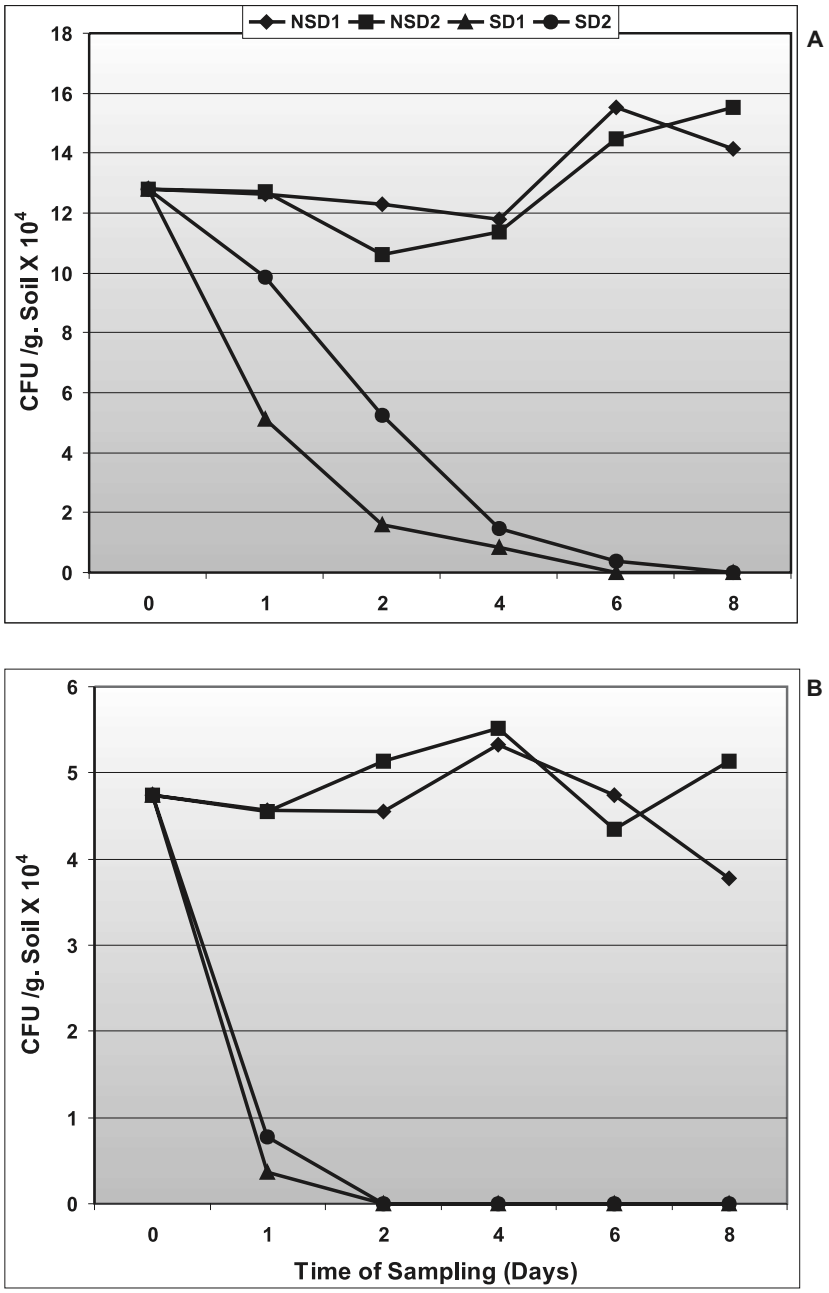

Fig. 3. Effect of solarization of peat moss on population density of *Fusarium oxysporum* (Colony Forming Units/Gram Dry Soil) from 14-22 April (A) and from 15-23 August 2004 (B). Samples were taken from 0-7.5 cm (D1) and 7.5-15 cm (D2). Plastic bags containing peat moss were left under the sun (S) or in the shade (NS) as control.

Discussion

Solarization of commercial peat moss in transparent polyethylene bags in the spring and the summer was efficient in eradicating tested *P. aphanidermatum* and *F. oxysporum* fungi. Many reports have indicated that solarization was effective in reducing or completely eliminating *Pythium*[22, 26-29] or *Fusarium* spp.[23, 29-32] and controlling their diseases. It was reported also that *F. oxysporum* was less sensitive to the high temperatures generated by solar heating than the other tested pathogenic fungi[19, 20]. These results explain the delay in eradication of *F. oxysporum* compared to *P. aphanidermatum* especially in the spring experiment.

Solarization of potting mixes in clear plastic bags seems to be more effective in killing fungal plant pathogens and in a shorter time as was evident in this research and the work done by other researchers[22, 23] as compared to the conventional soil solarization method. This is due mainly to the fact that solarization, causing decomposition of organic matter, will induce the release of volatile compounds, which are toxic to fungi, such as sulfur containing substances, alcohols and aldehydes[33-35]. These volatile compounds will be trapped in the closed plastic bags and hence will be more efficient in affecting fungi than in field soils[23].

The second factor that contributes to the increase of the efficiency of solarization in plastic bags as compared to field soil is the daily turn over of the bags. This way will insure more exposure to the solar radiation[23]. In soil solarization, however, lower temperatures are expected at lower profiles that are further from the surface of the soil[17, 29, 36].

This method represents an easy, economical and safe technique in disinfestations of plant soil media. Leaving potting mixes or commercial plant media in clear plastic bags for few days under solar radiation is effective to eradicate the two commonly distributed pathogens in commercial peat moss, *Pythium aphanidermatum* and *Fusarium oxysporum.* This technique was even efficient at cooler seasons where temperatures were not as high as the summer days.

References

[1] **Cartwright, D.K.,** Commercial potting medium as the source of *Pythium* causing a disease on tobacco transplants, *Plant Disease*, **79:** 583 (1995).

[2] **Coyier, D.L.,** Pathogens associated with peat moss used for propagation, *International Plant Propagator's Society Combined Proceeding*, **28:** 70-72 (1978).

[3] **El-Meleigi, M.A., Al-Rokiba, A.A., Hassan, Z.M., Ibrahim, G.H., El-Shair, S.M.** and **Al-Omair, M.,** Effect of seed treatment with *Trichoderma*, nonpathogenic *Fusarium* or antagonistic rhizobacteria on the control of cucumber and tomato damping off in greenhouse

in Saudi Arabia, *Proc. 1st Scientific Symp. on Controlled Environment Agriculture*, pp: 179-187 (1992).

[4] **Favrin, R.J., Rahe, J.E.** and **Mauza, B.,** *Pythium* spp. associated with crown rot of cucumbers in British Columbia greenhouses, *Plant Disease*, **72:** 683-687 (1988).

[5] **Kim, S.H., Forer, L.B.** and **Longenecker, J.L.,** Recovery of plant pathogens from commercial peat-products, *Proc. Phytopathological Soc.*, **2:** 124 (1975).

[6] **Robertson, G.R.,** Occurrence of *Pythium* spp. in New Zealand soils, sands, pumices and peat, and on roots of container-grown plants, New Zealand, *J. Agric. Res.*, **16:** 357-365 (1973).

[7] **Jarvis, W.R.,** *Managing Diseases in Greenhouse Crops*, APS Press, St. Paul, Minnesota, USA, p: 288 (1992).

[8] **Powell, C.C., Jr.,** The safety and efficacy of fungicides for use in *Rhizoctonia* rot control of directly potted unrooted poinsettia cutting, *Plant Disease*, **72:** 693-695 (1988).

[9] **Bartok, J.W.,** Steam sterilization of growing media, In: Landis, T.D. Dumroese (tech. Coord.), *Proceedings, Forest and Conservation Nursery Association* (1994).

[10] **Brazelton, R.W.,** Sterilizing soil mixes with aerated steam, *Agric. Eng.*, **49:** 400-401(1968).

[11] **Chase, A.R.** and **Poole, R.T.,** Root rot: Is steam treatment the answer? *Greenhouse Manager* (June), pp: 142-149 (1985).

[12] **Campiglia, E., Temperini, O., Mancinelli, R., Marucci, A.** and **Saccardo, F.,** Soil solarization in the Mediterranean environment: Effect on weed control and yield of cos lettuce (*Lactuca sativa* L., var longifolia lam), *Italus-Hortus*, **5:** 36-42 (1998).

[13] **Lopez-Herrera, C.J., Perez-Jimenezrm, R.M., Basalotte-Ureba, N.J., Zea-Bonilla, T.** and **Melero-Vera, J.M.,** Effect of soil solarization on the control of Phytophthora root in avocado, *Plant Pathology*, **46** (3): 329-340 (1997).

[14] **Cascone, G., D'Emilio, A., Polizzi, G.** and **Grillo, R.,** Effectiveness of greenhouse soil solarization with different plastic mulches in controlling corky root and root knot on tomato plants, *Acta Hort.*, **523:** 145-150 (2000).

[15] **Streck, N.A., Schneider, F.M.** and **Buriol, G.A.,** Soil heating by solarization inside plastic greenhouse in Santa Maria, Rio Grande do Sul, Brazil, *Agricultural and Forest Meteorology*, **82:** 73-82 (1996).

[16] **Ghini, R., Bettiol, W., Spadotto, C.A., Morare, G.J., Paraiba, L.C.** and **Mineiro, J.L.,** Soil solarization for the control of tomato and eggplant Verticillium wilt and its effect on weed and micro-arthropod communities, *Summa Phytopathologica*, **19:** 183-189 (1993).

[17] **Katan, J.,** Solar heating (Solarization) of soil for control of soilborne pests, *Ann. Rev. Phytopathol.*, **19:** 211-236 (1981).

[18] **Katan, J.,** Soil solarization, In: *Innovative Approaches to Plant Disease Control*, I. Chet, (ed.), John Wiley & Sons, N.Y. (1987).

[19] **Chellimi, D.O., Olson, S.M.** and **Mitchell, D.J.,** Effects of soil solarization and fumigation on survival of soilborne pathogens of tomato in northern Florida, *Plant Disease*, **78:** 1167-1172 (1994).

[20] **Porter, I.J.** and **Merriman, P.R.,** Effects of solarization of soil on nematode and fungal pathogens at two sites in Victoria, *Soil Biol. Biochem.*, **15:** 39-44 (1983).

[21] **Pullman, G.S., DeVay, J.E.** and **Garber, R.H.,** Soil solarization and thermal death: A logarithmic relationship between time and temperature for four soilborne plant pathogens, *Phytopathology*, **71:** 959-964 (1981).

[22] **Duff, J.D.** and **Barnaart, A.,** Solarization controls soilborne fungal pathogens in nursery potting mixes, *Australasian Plant Pathology*, **21:** 20-23 (1992).

[23] **Kaewruang, Sivasithamparam, K.** and **Hardy, G.E.,** Effect of solarization of soil within plastic bags on root rot of gerbera (*Gerbera jamesonii* L.), *Plant and Soil*, **120:** 303-306 (1989).

[24] **Sunboul, Y.H.,** Basal stem rot of vegetables in controlled environment greenhouses in western Saudi Arabia: (B) disease characterization, *Journal of King Abdulaziz University, Meteorology, Environment and Arid Land Agriculture Sciences,* **12:** 25-35 (2001).

[25] **Tuite, J.,** *Plant Pathological Methods, Fungi and Bacteria*, Burgess Publishing Company, Minneapolis, Minn., USA, p: 239 (1968).

[26] **Gamliel, A.** and **Stapleton, J.J.,** Effect of chicken compost or phosphate and solarization on pathogen control, rhizosphere microorganisms and lettuce growth, *Plant Disease*, **77:** 886-891 (1993a).

[27] **Kassaby, F.Y.,** Solar-heating soil for control of damping-off diseases, *Soil Biology and Biochemistry*, **17:** 429-434 (1985).

[28] **Kulkarni, R.N., Kalra, A.** and **Ravindra, N.S.,** Integration of soil solarization with host resistance in the control of dieback and collar and root rot diseases of periwinkle, *Tropical Agriculture (Trinidad)*, **69:** 217-222 (1992).

[29] **Sunbol, Y.H.,** Effect of soil solarization on population densities of *Pythium aphanidermatum, Fusarium oxysporum* and total soil fungi in the western region of Saudi Arabia, *Egyptian Journal of Applied Sciences*, **19:** 24-35 (2004).

[30] **Dwivedi, S.K.,** Soil solarization adversely affects some fungal pathogens causing wilt disease of guava (*Psidium guajava* L.), *Soil Biology and Biochemistry*, **25:** 1635-1636 (1993).

[31] **Katan, J., Fishler, G.** and **Grinstein, A.,** Short- and long-term effects of soil solarization and crop sequence on *Fusarium* wilt and yield of cotton in Israel, *Phytopathology*, **73:** 1215-1219 (1983).

[32] **Martyn, R.D.** and **Hartz, T.K.,** Use of soil solarization to control *Fusarium* wilt of watermelon, *Plant Disease*, **70:** 762-766 (1986).

[33] **Gamliel, A.** and **Stapleton, J.J.,** Characterization of antifungal volatile compounds evolved from solarized soil amended with cabbage residues, *Phytopathology*, **83:** 899-905 (1993b).

[34] **Lewis, J.A.** and **Papavizas, G.C.,** Effect of volatiles from decomposing plant tissues on pigmentation, growth and survival of *Rhizoctonia solani, Soil Science*, **118:** 156-163 (1974).

[35] **Ramirez-Villapudua, J.** and **Munneccke, D.E.,** Effect of solar heating and soil amendments of cruciferous residues on *Fusarium oxysporum* f.sp. *conglutinans* and other organisms, *Phytopathology*, **78:** 289-295 (1988).

[36] **Sunboul, Y.H.** and **Al-Sulaimani, S.J.,** Soil Chemical Composition and Fungal Populations as Affected by a Combination of Soil Solarization and Chicken Manure Amendment, *Ann. Agric., Sc., Mushtuhur*, **37:** 2655-2666 (1999).

تشميس البيتموس التجاري في أكياس البولي إيثيلين الشفافة وتأثيره على حيوية بعض الفطريات الممرضة للنباتات

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المستخلص. أجريت تجربتان لاختبار تأثير التشميس كوسيلة غير كيميائية لتعقيم البيتموس والمعروف كمصدر رئيس للقاح الكثير من مسببات الأمراض الفطرية. وقد تمت عملية التشميس في فصلي الربيع والصيف من عام ٢٠٠٤، وذلك بتعريض أكياس البولي إيثيلين الشفاف – والتي ملئت بالبيتموس والملقح صناعيا بالفطرين: *Fusarium oxy-sporum* و *Pythium aphanidermatum* – للشمس. وقد بلغت متوسطات درجات الحرارة العظمى اليومية ٥١ و ٢ , ٥٤ درجة مئوية لفصلي الربيع والصيف، وبزيادة قدرها ١٦ , ٨ و ١٦ , ٩ درجة مئوية، مقارنة بالأكياس غير المشمسة (المغطاة)، على التوالي. وقد دلت النتائج لتجربة الصيف أن كلا الفطرين قد تم التخلص منهما خلال يومين من بداية التجربة من عينات البيتموس السطحية (٠ – ٥ , ٧) والعميقة (٥ , ٧ – ١٥ سم) التي أخذت أثناء التجربة. أما بالنسبة لتجربة الربيع، فقد أظهر الفطر *F. oxy-sporum* قدرة أكبر على البقاء مقارنة بالفطر *P. aphanidermatum* . حيث تم التخلص من الأول للعمقين السطحي والعميق خلال ستة وثمانية أيام ، بينما تم التخلص من الثاني خلال يومين وستة أيام ، على التوالي. كما لم يوجد تأثر معنوي في أعداد الفطريات في الأكياس المظللة مع وجود تذبذب في الأعداد مع الوقت. وبذلك تعتبر طريقة التشميس للبيتموس داخل أكياس البلاستيك الشفافة من الوسائل الفعالة والاقتصادية والآمنة والبسيطة للتخلص من مسببات الأمراض الفطرية ، حتى في الفصول الأقل حرارة عن حرارة الصيف.