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LONG-TERM EFFECTS OF SOIL SOLARIZATION ON DENSITY LEVELS OF SOIL-BORNE FUNGI AND STALK-ROT INCIDENCE IN SORGHUM

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Abstract

The effect of soil solarization on the control of soil-borne pathogens of grain sorghum, in Upper Egypt, was studied. Solar heating gradually reduced most of the isolated fungi to very low levels, comparable to the non-tarped treatments. Populations of *Aspergillus* spp., *Penicillium* spp. and *Macrophomina phaseolina* were found to increase at the end of the solarization treatment i.e. 6 months. Sorghum plant stand increased in solarized plots indicating the positive effect of soil heating on reducing numbers of propagules of soil-borne pathogens. Also, stalk-rot disease of grain sorghum could be controlled by planting the crop in solarized plots. These promising results indicate the possibility of using this method to control soil-borne diseases in Upper Egypt.

INTRODUCTION

Soil solarization, the hydrothermal process for disinfestation of soil (Stapleton & De Vay 1986) is widley used nowadays to eliminate soil-borne disease incidence. Soil solarization is not chemical, but targets mesophylic organisms, which include most plant pathogens and pests, without destroying the beneficial bacteria and mycorrhizal fungi (Stapelton & De Vay, 1986; Pullman *et al.* 1981 and Stapelton & De Vay, 1984). Promising results for controlling soil-borne pests in regions having high temperature and intense solar radiation could be obtained by applying soil solarization. Egypt possesses factors needed for successful application of this method. Satour (1997) reported that soil solarization was introduced into the country in 1981 as a new technology to minimize the harmful effects of soil-borne diseases in the traditional agriculture of Egypt. Satour *et al.* (1991) stated that soil solarization is a very effective treatment against several soil-borne diseases in Egypt, including the onion white rot, tomato crown rot. Besides, several nematodes and most of the common weed species could also be completely controlled.

The present investigation was carried out to judge the importance of using soil solarization to combat soil-borne fungi responsible for damping off and stalk-rot diseases of grain sorghum in Egypt.

MATERIALS AND METHODS

The experiments were carried out in fields naturally infested with non specialized soil-borne pathogens, such as Fusarium spp., *Macrophomina phaseolina, Rhizoctonia* solani ... etc. The fields are located at Gerga, Sohag governorate (Upper Egypt).

Experimental layout and design:

Prior to solarization, plots (3x6m) were ploughed, leveled and surface irrigated. They were covered with black or transparent plastic sheets (200 u thickness) for different intervals (2,4&6 months) between mid January and mid July, 1996 and 1997. Treatments were quadruplicated according to the split plot design. Non-tarped soil acted as control. Soil temperatures were measured monthly by using a subsoil thermograph.

Soil sampling and count of fungal colony forming units (cfu):

Soil samples were taken from the experimental plots of each treatment (at about 15 cm depth) at the end of each solarization period i.e. 2, 4 & 6 months. Composite samples, three subsamples from each plot, were used for determining the fungal populations following the method of Grossman (1967). Fungal frequency was recorded in 6 replicate plates after incubation for 7 days at 30^{O}C and the most frequent fungi in the non-covered soil were studied for their tolerance to solariation.

Assesment of plant stand and stalk-rot disease:

Effect of soil solarization on sorghum plant stand and stalk-rot incidence was studied. Grain sorghum *(sorghum bicolor)* local variety; susceptible to stalk-rot was planted in four replicate plots of the solarized soil at the end of the whole experiment i.e. mid July, 1997 and 1998. Sorghum sown in non-solarized plots served as control. Plant stand was recorded as percentage of survived seedlings after 21 days of planting. Stalk-rot disease incidence was estimated and tabulated as infection percent after 100 days of planting.

RESULTS AND DISCUSSION

Soil temperature was weekly recorded and the average temperature for each month was calculated for the non-covered soil as well as the mulched plots at 20 cm depth. It was found that soil temperature gradually increased from January to July with an obvious difference between that of the non-covered and covered soil (Table 1). No effect of plastic colour on soil temperature was observed.

It is worth mentioning that high atmospheric as well as soil temperatures are prevailing in Upper Egypt, even at winter time. Results presented in Table (1) indicate that soil solarization, in general, caused an obvious increase in soil temperature throughout the present investigation. Many investigators reported the positive effect of soil solarization on increasing soil temperature (Hill *et al.*, 1982; Sarhan, 1991 & Satour *et al.*, 1991).

Table 1. Effect of soil solarization on maximum soil temperature at 20cm depth when mulched with transparent or black sheets:

Month	Temperature C	
	Non-tarped	Tarped plots
January	33	41
February	38	44
March	40	49
April	42	50
May	43	55
June	43	57

Effect on density levels of soil-borne fungi:

An obvious decrease in the number of propagules of isolated fungi was found, in gener, al at the end of 2 months of soil solarization with either black or transparent plastic tarps (Tables 2 & 3). Effect of transparent tarp on the microorganisms was, generally slightly higher than of the black one. Abu-Gharbieh *et al.* (1991) stated that the black and transparent tarps significantly reduced populations of *Fusarium oxysporum & F.solani,* but the latter was slightly more effective. The reason is the effectiveness of the clear polyethylene in raising soil temperature compared with the black one (Standifer *et al.,* 1984). Gradual reduction in the number of propagules of most fungi occurred by prolonging the period of soil solarization from 2 to 6 months. The number of propagules decreased greatl/ (after 6 months of application) indicating their sensitivity to solar heating. These results confirm those obtained by Katan & De Vay (1991) and Pullman & De Vay (1984) who stated that the efficiency of solarization would be improved by increasing the treatment time. But, an increase in the populations of *Aspergillus* spp., *Penicillium* spp. and *Macrophomina phaseolina* was found at the end of each solarization period. This is in conformity with the findings of Abu-Gharbieh *et al.* (1991). It was reported by Stapleton & De Vay (1982) and De Vay (1991) that *Aspergillus spp. & Penicillium* spp. are the most frequent fungi that could

Table 2. Effect of soil solanzation on population density of some soil-borne fungi (x 103 CFU/g oven dry soil) when black and transparent sheets were used (1994).

Fungi	Treatments (from mid Jan. to mid July)	Fungal frequency		
		Non Tarped	Tarped	
			Black	Black
Fusarium spp.	After 2 mon.	56.60	40.50	38.30
	After 4 mon.	49.70	6.05	7.05
	After 6 mon.	48.10	2.70	0.50
Penicillium spp.	After 2 mon.	4.20	4.90	3.70
	After 4 mon.	3.80	4.05	4.05
	After 6 mon.	4.90	5.01	4.00
Colletotrichum spp.	After 2 mon.	2.40	1.10	0.80
	After 4 mon.	2.20	0.80	0.50
	After 6 mon.	1.90	0.01	0.07
Trichoderma spp.	After 2 mon.	7.50	5.40	4.60
	After 4 mon.	6.00	5.11	3.80
	After 6 mon.	3.00	2.70	2.80
Rhizoctonia spp.	After 2 mon.	5.60	2.90	1.50
	After 4 mon.	5.60	2.10	1.01
	After 6 mon.	7.10	1.00	0.00
Alternaria spp.	After 2 mon.	3.50	2.68	2.50
	After 4 mon.	2.80	1.55	1.01
	After 6 mon.	1.01	0.01	0.01
Aspergillus spp.	After 2 mon.	29.70	30.50	29.91
	After 4 mon.	29.00	29.05	27.80
	After 6 mon.	21.00	27.05	20.05
Helminthosporiu ms pp.	After 2 mon.	8.80	5.90	3.50
	After 4 mon.	7.90	20.00	2.01
	After 6 mon.	8.10	0.50	0.00
Curvularia spp.	After 2 mon.	5.80	3.75	2.05
	After 4 mon.	6.20	3.01	2.01
	After 6 mon.	4.50	1.01	1.01
Macrophomina Phaseolina	After 2 mon.	50.00	51.00	49.20
	After 4 mon.	48.40	50.56	47.00
	After 6 mon.	46.88	49.30	50.80
Rhizopus spp.	After 2 mon.	4.50	1.50	2.01
	After 4 mon.	5.00	0.12	0.00
	After 6 mon.	2.80	0.01	0.00

Table 3. Effect of soil solarization on population density of some soil-borne fungi (x 10^3 CFU/g oven dry soil) when black and transparent sheets were used (1994).

Fungi	Treatments (from mid Jan. to mid July)	Fungal frequency		
		Non Tarped	Tarped	
			Black	Black
Fusarium spp.	After 2 mon.	70.80	33.20	29.50
	After 4 mon.	61.40	13.70	11.20
	After 6 mon.	45.00	0.95	1.25
Penicillium spp.	After 2 mon.	2.30	2.50	1.90
	After 4 mon.	1.10	1.01	1.25
	After 6 mon.	1.00	1.01	1.00
Colletotrichum spp.	After 2 mon.	1.50	1.50	0.05
	After 4 mon.	1.10	1.01	0.03
	After 6 mon.	0.02	0.01	0.00
Trichoderma spp.	After 2 mon.	5.40	4.55	4.48
	After 4 mon.	5.44	3.08	4.05
	After 6 mon.	3.12	2.00	2.00
Rhizoctonia spp.	After 2 mon.	7.70	3.42	4.40
	After 4 mon.	5.05	2.70	1.10
	After 6 mon.	3.00	1.16	1.00
Alternaria spp.	After 2 mon.	4.90	2.80	2.50
	After 4 mon.	4.00	2.55	1.01
	After 6 mon.	2.40	0.01	0.01
Aspergillus spp.	After 2 mon.	36.00	33.20	28.20
	After 4 mon.	36.50	36.50	31.50
	After 6 mon.	29.01	29.50	28.50
Helminthosporiu ms pp.	After 2 mon.	13.50	16.70	15.10
	After 4 mon.	12.70	8.80	6.50
	After 6 mon.	12.70	7.50	1.02
Curvularia spp.	After 2 mon.	3.00	0.60	0.80
	After 4 mon.	3.10	0.01	0.01
	After 6 mon.	1.80	0.00	0.01
Macrophomina Phaseolina	After 2 mon.	50.00	51.00	49.20
	After 4 mon.	48.40	50.56	47.00
	After 6 mon.	46.88	49.30	50.80
Rhizopus spp.	After 2 mon.	4.00	1.50	2.01
	After 4 mon.	4.80	0.12	0.00
	After 6 mon.	1.95	0.01	0.00

be recovered from the solarized soils. These fungi are thermotolerant, therefore, their population densities remain relatively high following solarization. Moreover, they may increase to levels higher than those present in non-solarized soil. Population density of *Trichoderma* species, on the other hand, was slightly affected by soil solarization. This fungus repesents the antagonistic fungi which inhibit the development of pathogenic ones (Tjamos and Paplomatas, 1988 and Kaewruang *et al.,* 1989). The numbers of propagules in the non-tarped soil, were always higher than those found in tarped treatments and showed no big difference throughout the time of experiment. This was found to be true in the two years of experiment i.e.1996 & 1997.

These results indicate the possibility of using this method to reduce the number of pathogen propagules in the soil to avoid infection with soil-borne plant pathogent in such hot soils in Upper Egypt.

Effect on plant stand and stalk-rot incidence:

Results presented in Table (4) show that soil solarization was effective in improving seedling emergence and survived plants. Mean percent of plant stand obviously increased from 60.40 & 64.10% in non-tarped to 91.53&94..40% in tarped plots in 1997 & 1998, respectively. Increased sorghum plant stand in solarized plots reflects the effect of solar heating on soil-borne pathogens and decreasing competition with weeds (Abdallah *et al.,* 1998). A complex mode of action has been suggested for soil disinfestation by solarization, including direct and indirect thermal effect, induced biological control, and changes in soil volatile components (Stapleton and De Vay, 1986). This mode of action may explain the increase of plant stand in sorghum plants. No obvious difference between black and transparent tarps on plant stand was found.

Table 4. Effect of soil solarization, after 6 months of mulching with transparent & black sheets on sorghum plant stand.

Year	% Plant stand			
	Non-tarped	Tarped		
		Black	Transparent	Mean
1997	60.40	92.20	90.85	91.53
1998	64.10	94.80	94.00	94.40

At 100 days after planting, infection of sorghum plants with stalk-rot disease was asessed. It was found (Table 5) that soil solarization clearly reduced the mean of disease incidence from 45.50 & 41.40% in the non-tarped to 4.05 & 6.85% in the tarped soil in 1997 & 1998, respectively. Tarp color did not affect the efficacy of solar heating in this respect. These findings agree with those reported by many other investigators dealing with soil-borne fungi (Sarhan, 1991; Stapleton, 1991, Besri, 1982. and Besri, 1985). Pullman *et al.* (1981) reported that soil-borne propagules of fungi subjected to subethal heat effects during solarization appear to be delayed in germination and have reduced virulence to host plants, that vary with temperature and the duration of exposure. In addition, these fungi appear to have an increased sensitivity to antagonistic fungi and to bacteria which are less affected by soil solarization (Freeman & Katan, 1988; Greenberger *et al.* 1984; Katan, 1988; Greenberger *et al.*, 1984; Katan, 1985). Lifshitz *et al.* (1983) stated that weakened slerotia are intensely colonized by *Trichoderma harziamum* and other microorganisms. It was found from the present investigation that numbers of propagules of *Trichoderma* spp. were not affected by soil solarization. Decrease of fungal population densities in solarized plots (Table 1 & 2) may also explain the reduction of infection with stalk-rot of sorghum plants. Therefore, controlling such soil-borne pathogens responsible for stalk-rot diseases biologically is anticipated by soil solarization.

Table 5. Effect of soil solarization, after 6 months of mulching with transparent & black sheets on sorghum stalk-rot.

Year	%infection			
	Non-tarped	Tarped		
		Black	Transparent	Mean
1997	45.50	5.00	3.10	4.05
1998	41.40	7.70	6.00	6.85

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التأثيرات طويلة الاجل نتيجة تشميس التربة بالتغطية بشرائح البلاستيك علي مستويات أعداد الفطريات الكامنة في التربة وعلي مرض عفن الساق وعدد النباتات القائمة في الحقل من الذرة الرفيعة

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أجري هذا البحث بأرض موبوءة ببعض مسببات الامراض الكامنة في التربة الغير متخصصة والتي تسبب ضعف الإنبات وشدة الاصابة للذرة الرفيعة للحبوب باعفان الساق بمركز جرجا بمحافظة سوهاج بمصر العليا. حيث تمت تغطية الارض بشرائح البولي إثيلين الأسود أو الشفاف (سمك ٢٠٠ ميكرون) ابتداء من منتصف شهر يناير وحتي منتصف شهر يوليو ١٩٩٦ و ١٩٩٧. وقد تم عمل عزل لفطريات السائدة في التربة كل شهرين من بدء عملية التشميس. كما تمت زراعة القطع التي تم تشميسها لمدة ستة شهور متواصلة (عند نهاية التجربة) بصنف بلدي قابل للإصابة بعفن الساق من الذرة الرفيعة للحبوب حيث تم تقدير عدد النباتات القائمة بالحقل بعد ٢١ يوم من الزراعة وكذا نسبة الاصابة بعفن الساق بعد ١٠٠ يوم من الزراعة وذلك في القطع التي تم تغطيتها والمقارنة.

واتضح من الدراسة انه حدث خفض شديد في أعداد الفطريات السائدة في التربة المغطاه بصفة عامة نتيجة التشميس لمدة شهرين من بداية التجربة مع خفض تدريجي بزيادة فترة التغطية من ٢ إلي ٦ شهور. إلا أنه لوحظت زيادة في أعداد كل من الفطر ماكروفومينا فاسيولينا وكذا الفطريات التي تتبع جنس أسبرجلس وبنيسيليم بعد انتهاء فترات التغطية، كما لم تتأثر أعداد العزلات الفطريات التابعة لجنس ترايكودرما.

ومن جهة أخري فقد أدت زراعة محصول الذرة الرفيعة للحبوب في التربة التي سبق تشمسيها لمدة ستة شهور إلي تحسن نسبة النباتات القائمة في الحقل وكذا خفض واضح في نسبة الاصابة بأعفان الساق بدرجة واضحة مما يثبت تأثير تغطية التربة علي التخلص من مسببات الامراض الكامنة في التربة والتي تصيب الذرة الرفيعة للحبوب.