Soil amendments enhance soil solarisation efficiency in controlling weeds under the environment of the United Arab Emerites

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Summary The effect of amending soils with manure and plant residues on efficiency of soil solarisation in controlling *Portulaca oleracea* (L.) was assessed under the environment of the United Arab Emirates (UAE). Fresh seeds of *P. oleracea* were buried at 2.5 cm and 15 cm depths in soils amended with manure, plant residues, or not amended (control) for 15, 30 and 45 days. The exhumed seeds were germinated in an incubator adjusted at 15/25°C. The results showed that amending the soil with manure significantly reduced seed germination ability, compared with control plots and plots amended with plant residues. Overall, 69% of the seeds deteriorated after 45 days. The deterioration in seed germination was significantly greater for seeds in the surface soil layer (2.5 cm) than the deeper depth (15 cm).

Keywords Organic amendment, seed viability, soil solarisation, weed control.

INTRODUCTION

Under conducive conditions and with proper use, solarisation can provide excellent control of soilborne pathogens in the field, greenhouse, nursery and home garden. However, under marginal environmental conditions with thermotolerant pest organisms or those distributed deeply in soil, or in order to minimise treatment duration, it is often desirable to combine solarisation with other appropriate pest management techniques to improve treatment efficiency (Stapleton, 1997). Solarisation can be combined with a wide range of organic amendments such as compost, crop residues, green manures and animal manures to increase the pesticidal effect of the combined treatments (Ramirez-Villapudua and Munnecke 1987, Gamliel and Stapleton 1993, Chellemi *et al*. 1997, Haider and Sidahmed 2000, Lira-Saldivar *et al*. 2004). For example, the combination of solarisation and chicken manure for 2–6 weeks was an effective weed management practice to control *Orobanche* sp. and suppress the infestation of other weeds in subsequent planting of cabbage (Haider and Sidahmed 2000). Similarly, in Mexico, goat manure increased soil temperature by 1.5 to 2.5°C, and had an apparent antagonistic effect on weeds tolerant to solarisation alone, such as *Cyperus esculentus* (L.), *Portulaca oleracea* (L.), *Setaria geniculata* (Lam.) Beauv. and *Amaranthus hybridus* (L.) (Lira-Saldivar *et al*. 2004).

It is well documented that long periods of solarisation are required for thermotolerant species, which can be unsatisfactory in intensive agriculture. One way to reduce solarisation period is to augment the killing effect of this technique with soil amendments (Haider and Sidahmed 2000, Stapleton 2000). The aim of the current study was to evaluate the effect of manure and plant residues on the efficiency of soil solarisation in controlling *Portulaca oleracea*. This weed is often used as an indicator species, such that its control with solarisation will often result in control of most weed species. The effect of soil solarisation was evaluated by testing viability of *P. oleracea* seeds buried at different depths for different durations.

MATERIALS AND METHODS

Prior to solarisation, the soil was ploughed, levelled and divided into nine individual raised plots, 20 × 2 m each. Drip irrigation lines were laid in the middle of the plots. The soil was irrigated in early June 2003. Fresh seeds of *Portulaca oleracea* collected from different farms around Al-Ain city, United Arab Emirates (UAE), were divided into 36 mesh bags, each 4 by 6 cm. The factorial experiment was conducted with a completely randomised block design with two replications and three factors, namely, two types of soil amendments in addition to the control (without amendment), two seed burial depths (2.5 cm and 15 cm) and three solarisation durations (15, 30 and 45 days). The amendments were organic cow manure with (0.5 kg m^{-2}) and plant residues (with 2 kg m^{-2}). The plant residues were mainly stalks of Rhodes grass and some other crops. In each plot, two-mesh bags, each contained about 500 *P. oleracea* seeds were buried at each of the two depths (i.e., four bags per plot). The amendments were incorporated into the top 5 cm of soil surface and covered with 75 micrometer transparent polyethylene sheets. The edges of the sheets were buried 15 cm in the soil to prevent heated air and water vapour from escaping.

After 15, 30 and 45 days of solarisation, seeds were exhumed from the mesh bags buried at the different depths. The collected seeds were air dried and the seeds of each replicate were mixed together as a composite sample. Mixed seeds for each treatment were tested for viability by germination in an incubator set at 15/25°C with dark and light. The germination test was conducted in 9 mm plastic Petri-dishes each with one Whatman No. 1 filter paper moistened with distilled water. Four replicate dishes were used for each treatment. Seedlings were counted and removed every alternate day over a 20 day post-seed sowing.

RESULTS

Three-way ANOVA showed significant main effects on final germination percentage of fresh seeds of *P. oleracea* for both depth of seed burial and duration of solarisation, but not for the type of amendment added to the soil during soil solarisation. Although not significant, the germination was lower for plots amended with manure (33%) than plots amended with plant residues (45%) and non-amended plots (38.2%, Table 1).

The interaction between amendments and depth of seed burial on final germination was significant (P<0.001). Seeds buried at 2.5 cm attained significantly lower germination in soil amended with both manure and plant residues (18% for both) than non-amended soil (31.1%). On the other hand, seeds buried at 15 cm attained significantly greater germination in soil amended with the plant residues, compared to non-amended soil (Table 1). This result suggests a deterioration effect of both manure and plant residues for seeds buried at 2.5 cm and the protective effect for plant residues for seeds buried at 15 cm.

Three way ANOVA also showed significant interaction between amendment and duration of solarisation on final germination (P <0.01). While there was no significant difference in the germination after 15 days between the three treatments, the germination after 45 days was significantly lower in soils amended with manure (17%) than in both soils amended with plant residues (27%) or non-amended soils (28.3%). This result indicates that manure had more of a deteriorative effect at 45 days than the other two treatments (Table 1).

DISCUSSION

The results of the present study indicate that soil amendments, especially organic manure, were able to inhibit germination of *P. oleracea* seeds close to the soil surface (2.5 cm) after 45 days of solarisation. Katan (1981) suggested that solarisation might increase the rate of degradation of organic manure to cause accumulation of biotoxic volatile compounds in vapour and liquid, which act as biofumigation of the soil. The toxicity of the generated volatile compounds is expected to be higher at the high soil temperature prevailing during solarisation. In addition, organic manure increases soil temperature with decomposition of these materials (Gamliel and Stapleton 1993, Stapleton 1997).

The results also showed that the amendments did not improve the efficiency of solarisation in controlling seeds buried at the deeper depth (15 cm). In fact, plant residues protect the seeds at 15 cm from deterioration as compared with the other two treatments. The lower

Table 1. Effects of different amendments, depth of seed burial and solarisation duration on final germination percentage (means ± SE) of fresh seeds of *Portulaca oleracea.*

Amendment	Depth (cm)	Duration (days)			Overall
		15	30	45	
Without	2.5	44.0 ± 2.3	34.0 ± 3.8	24-9 ± 2.5	31.1 ± 2.5
	15	62.5 ± 6.4	47.0 ± 2.5	37.0 ± 1.9	48.8 ± 3.8
	Overall	53.2 ± 4.7	40.5 ± 3.2	28.3 ± 2.4	38.2 ± 2.6
Manure	2.5	31.4 ± 2.2	20.5 ± 2.3	0.0 ± 0.0	18.1 ± 3.2
	15	81.6 ± 4.8	45.5 ± 3.2	34.0 ± 1.2	53.7 ± 6.4
	Overall	56.5 ± 9.8	28.8 ± 4.0	17.0 ± 6.4	33.4 ± 4.7
Plant residues	2.5	28.6 ± 1.7	18.3 ± 18.3	9.0 ± 1.9	18.1 ± 2.7
	15	85.1 ± 1.7	45.9 ± 3.6	45.0 ± 1.9	61.4 ± 4.7
	Overall	66.3 ± 8.1	36.7 ± 4.6	27.0 ± 6.9	45.3 ± 4.8
Overall	2.5	34.7 ± 2.3	23.3 ± 2.2	15.8 ± 2.9	23.3 ± 1.8
	15	78.6 ± 3.1	46.1 ± 2.0	38.7 ± 1.6	55.9 ± 3.0
	Overall	59.7 ± 4.6	34.7 ± 2.5	25.0 ± 2.8	41.0 ± 2.5

efficiency of plant residues in reducing germination of seeds buried in soil may be attributed to the nature of these residues and the method of incorporation. The amended plant residues were dry Rhodes grass, which is composed mainly of cellulose and fibres and difficult for soil microflora to decompose. Coelho *et al*. (1999) arrived at a similar result with cabbage amendment in soils and attributed the ineffectiveness of the cabbage to reduce populations of *Phytophthora* spp. to the method of the preparation of cabbage and its incorporation into the soil. In both the present study and that of Coelho *et al*. (1999), the plant residues were amended on the soil surface without grinding it to fine powder, unlike most other similar studies.

Our result suggested a deterioration effect of both manure and plant residues for seeds buried at 2.5 cm and a protective effect for plant residues for seeds buried at 15 cm. Such results recommend grinding plant residues before its incorporation into the soils. In addition, the greater deterioration of the seeds of the surface layer, more than in the deeper layer, suggest that farmers should prepare the soil for cultivation prior to solarisation process and should avoid any ploughing or any kind of soil disturbance that would bring the viable seeds of the deep layer up to the soil surface.

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