In-row Preplant Manure Composting Reduces Weed Populations

Barakat Abu-Irmaileh¹

Department of Plant Protection, University of Jordan

Azmi Abu-Rayyan

Department of Horticulture and Crop Science, University of Jordan

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Abstract. Fresh manure is normally broadcasted on the soil surface in vegetable growing areas of Jordan as a source of nutrients and organic matter. However, it can be an environmental pollutant and may lead to the outbreak of many health-related pests, especially houseflies. Field experiments were conducted in two locations to study the effect of in-row composting of four different fresh manures and olive pomace on preplant weed control in vegetables. In the first experiment, main treatments were as follows. 1) Organic materials were applied preplant and then the soil was covered with black polyethylene (BPE) sheets for 6 weeks (M). 2) Treatments were the same as in (M) but the soil surface was covered by BPE mulch for the whole growing season (MP). 3) There was soil incorporation of organic materials preplant, but the soil surface was unmulched during the 6-week period and weeds were controlled chemically later in the season (MC). 4) For the control (C), fresh organic materials were soil incorporated manually at time of planting. Each main treatment included four sub-treatments. Each sub-treatment received a different source of organic material: cow, poultry, or sheep manure or olive pomace. In the second experiment, the rates of poultry manure (0, 5, and 10 kg·m⁻²) comprised the main treatments. Each treatment included four sub-treatments in which the manure was soil-incorporated then subplots were covered by BPE sheets for either 0, 2, 4, or 6 weeks. The composting process in the main treatments M and MP raised soil temperatures significantly at a 15-cm depth above soils without manure amendments. Soil temperatures were higher, especially with poultry manure, although not significantly different in all cases. Composting poultry manure was more effective in reducing weed dry weights compared with other organic materials.

Improved use of animal manures has a central role in efforts to decrease the undesirable environmental impacts of farming (Brown, 1995; University of California, 2001). Efficient use of nutrients in organic amendments can reduce the need for applied mineral fertilizers. Composting of manure can also reduce weed seed viability (Bahman and Lesoing, 1999) and reduce other pests, such as plant diseases and flies (Brown, 1995). Many attempts have been made to adapt organic waste treatment technologies for managing animal manures. The treatments are normally designed to solve odor problems, recover nutrients and energy from manure, increase the fertilizer value, reduce the volume, or decrease the pollution potential to allow safe discharge of the manure in the environment (Hammill and Murphy, 1999). Manure management practices are strictly regulated and enforced in the developed countries to minimize pollution problems (Hammill and Murphy, 1999). But management of surplus manure in the animal production sector is far from satisfactory in developing

countries. Manure is normally sold at low prices to farmers who spread raw manure on the soil surface at rates ranging from 50 to 100 t·ha⁻¹. Manure is considered a source of nutrients and organic matter for improving soil fertility and soil texture. However, this practice creates an environmental hazard, as manure is a favorable medium for the multiplication and propagation of various microorganisms and insects, including houseflies (*Musca domestica* L.) (Crosskey and Lane, 1993). In addition, manure can intensify weed problems. Collected raw manure from grazing animal barnyards (goat and sheep) is normally contaminated with seeds of various plant species; as these animals, and to a lesser extent cattle, are normally allowed to graze crop remains and weeds after harvest (personal observation). Therefore, raw manure could increase the weed seed bank on receiving fields. Thus, disposal of manures, without any further composting treatment, is a major environmental pollutant in agro-ecosystems.

Weed infestations are one of the most limiting factors in irrigated vegetable production. Weed infestations can result in serious yield losses compared to other constraints in crop production (Abu-Irmaileh and El Kady, 1997; Azrag, 1985). Weeds can drastically reduce yields (Abu-Irmaileh, 1991b) and may lead to crop failure in noncompetitive vegetable crops such as onions, *Allium cepa* L., and carrots, *Daucus carota* L. ssp. *sativus* (Hoffm.) Thell. Chemical weed control is a difficult task in

small farming systems, especially where intercropping is practiced, or when two or three different crops are sequentially rotated per year. Residual herbicides limit crop rotation and herbicide drift could be risky in small farms where many crops are grown in close proximity, if not inter-cropped (Ross and Lembi, 1999). Farmers in most developing countries remove weeds by manual hoeing (Parker and Abu-Irmaileh, 1987). In these countries chemical weed control is typically unaffordable, especially if more than one herbicide is required and if market economics limit profits. Nonchemical weed control practices are favored by many small farmers in warm regions if the systems are cost effective. An example is soil solarization with black plastic mulch that has been widely adopted by Jordanian farmers in the Jordan Valley for the control of weeds and other pests (Abu-Irmaileh and Saghir, 1994). However, such practice is limited to the hottest months of the year.

Aerobic manure composting converts manure into compost at a rate that depends on many factors including the availability of moisture and oxygen. Heat generation can elevate temperatures to ≈65 °C under a controlled aerobic composting process (Hammill and Murphy, 1999). Such high temperatures could be effective in controlling pest propagules and weed seeds under moist conditions (Al-Raddad, 1979; Brown, 1995; Grooshevoy, 1939; Linke et al., 1991; Silva et al., 1996; Stapleton and De Vay, 1982; University of California, 2001). Temperatures from composting are normally highest in moist manure. In watered beef lot manure, temperatures can reach 62.8 °C and effectively kill weed seeds within 1 week of composting (Bahman and Lesoing, 1999). It is also known that with increasing soil temperatures less time is required to inhibit soilborne pests. For example, it has been found that a temperature of 37 °C is lethal for many mesophilic fungi if it is maintained in the soil for four weeks (Pullman et al., 1981), whereas at 47 °C, a 1- to 6-h exposure will inhibit egg hatching of many nematodes (Lamberti and Greco, 1991).

Fly larvae do not survive composting at such high temperatures (Brown, 1995). Heat generated during decomposition is sufficiently high enough to warm propagating media when manure is placed underneath the propagating frames (Maynard et al., 1999; McGroarty, 1998).

The objective of this study was to determine the effect of composting manure applied in planting rows, on weed populations in onions and eggplant.

Materials and Methods

Effect of in-row composting on weed control. Field experiments were conducted during the 2000–01 growing season at two locations in the Jordan valley; the Agricultural Research Station–University Farm (longitude 35° 35.7'E, latitude 32° 05'N), and at a private farm in Kreimeh, 20 km north of the university farm. Soil in both locations is ostocheptic calciorthid. In-row composting was conducted by thor-

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¹Faculty of Agriculture, University of Jordan; email barakat@ju.edu.jo.

oroughly mixing organic materials with the soil to a depth of 30 cm in the planting rows. Mixing was done manually. The soil surface was either covered by black polyethylene (BPE) sheets or left uncovered during the 6-week period prior to planting. Composting was conducted for 6 weeks, starting on 14 Sept. 2000, until 30 Oct. 2000, at the university farm; and from 4 Nov. 2000 until 17 Dec. 2000, at Kreimeh. Short day onion seedlings, *Allium cepa* L. 'Texas Early Grano 502', were planted in rows 30 cm apart and at 20-cm distances in each row, immediately after the end of the composting period. All plots were drip irrigated to field capacity once per week during the composting period and stopped during periods of rainfall. Drip lines were 50 cm apart, with emitters 40 cm apart in-line. Fertilizers were not added. Onion brown rot caused by the fungus *Botrytis* spp. was controlled as needed by the application of a combination of cymoxanil and mancozeb (Remaltin, cymoxanil 4% and mancozeb 46%,) at an a.i. rate of 2.5 g·L⁻¹ followed by procimidonate at an a.i. rate of 1.0 g·L⁻¹ 2 weeks later. The experiment included four main treatments, 10 × 2 m in size: 1) composting under BPE cover, 60 µ thick for 6 weeks before planting (M); 2) composting as in M, then BPE mulch was used for the whole growing season (MP); 3) composting for 6 weeks without BPE but controlling emerging weeds with a postemergent application of cycloxydim applied at 0.2 kg·ha⁻¹ a.i. to emerging weeds, followed 1 week later by oxadiazon applied at 1.25 kg·ha⁻¹ a.i. as a preemergent to obtain broad spectrum weed control (MC); and, 4) a control treatment in which fresh organic materials were soil-incorporated at the time of planting (C). Weeds were allowed to grow in C for almost the whole growing season. Subplots in the main treatments received either cow, sheep, poultry manure or olive pomace and were thoroughly mixed in the soil at rate of 10 kg·m⁻². The subplot size was 2 × 1.5 m with 0.5 m alleys on all sides. The experiment was arranged in a split plot design with four replications.

To monitor the effect of fresh manure and olive pomace composting on soil temperature, soil thermometers (bench checked for accuracy to ± 0.1 °C) were placed at a 15 cm depth in each subplot of the main treatments M and MP and in an untreated, mulched soil as a check. Temperatures were recorded twice daily at 8:00 AM and at 3:00 PM. The average of these two soil temperatures were used to calculate a daily mean. From these, weekly means were calculated during the composting period. Beginning in February 2001, weed species and weed dry weights were recorded from the middle 1 m² of each subplot during their flowering stages. Green bunch onions were harvested at Kreimeh during the middle of March to determine crop yield. Onions were harvested at the University Farm in early June 2001, to determine the crop yield as dry bulb onions. Soil analysis performed at the University of Jordan determined the soil to be a sandy loam with 80% sand, 12.5% silt and 7.5 % clay, with <1% organic matter. Soil pH ranged from 7.5 to 7.9.

Effect of rate and periodicity of poultry manure composting on weed control efficacy.

Since composting with poultry manure gave the best weed control in the first experiment, a split-plot field experiment with four replications was conducted at the university farm to study the efficacy of weed control and vegetable yields using different rates of applied poultry manure, composted for varying lengths of time. The main treatment was the duration of composting, and subplots were the rates of application. Fresh poultry manure was thoroughly mixed with the soil in the planting rows at rates of 0, 5, or 10 kg·m⁻² to a depth of 30 cm, then covered with BPE for 0, 2, 4, or 6 weeks followed by planting. The 6-week treatment was initiated on 17 Mar. 2001; the four week treatment on 1 Apr. 2001; the two week treatment on Apr. 15, 2001, and the zero week treatment were mixed in-row at planting time. The subplot size was 1.5 × 3 m. At the end of the composting period, the BPE cover was removed and eggplant, *Solanum melongena* L. 'Classic', was planted in early May 2001. The plots were drip-irrigated the same as in the previous treatment with the exception that irrigations were scheduled every 5 d, which is a normal irrigation cycle for farmers at this time of year. Fertilizers were not added and no other pest control was required. Data on weed dry weights and weed species present were recorded in late June. Five eggplants were taken at flowering stage from the middle of each subplot to obtain their fresh weight.

Four plots were established outside the experimental area as untreated and unamended checks to determine soil temperatures during each composting period. The soil of each subplot was thoroughly mixed with cow, olive pomace, poultry or sheep manure at 10 kg·m⁻², irrigated, then covered with BPE. Soil thermometers were inserted in the plots at 15-cm depths, and temperatures were recorded as previously described.

Analysis of variance was conducted with the SAS program, version 7, for split-plot arrangement, and the interactive means were

separated by least squared means according to GLM procedure (Statistical Analysis System, 1998). LSD_{0.05} values are shown on tables where appropriate.

Results and Discussion

Effect of in-row composting on weed control. All treatments with preplant in-row composting of organic materials (M, MP, or MC) had significantly lower weed dry weights than the control treatment, C, at both locations (Table 1). Plots with composted manure in the planting row under BPE cover for 6 weeks before planting (M and MP) resulted in the best weed control at the university farm. When the organic materials were composted without BPE cover during the 6-week period (MC), weeds emerged and they were controlled with herbicides. The applied post emergent herbicides reduced weed growth, but did not achieve complete control of weeds, resulting in higher weed dry weights than in the M or MP plots. Weed species appearing in MC plots after herbicide applications were mainly *Cyperus esculentus* L. and *Cynodon dactylon* (L.) Pers. Weed dry weights in the MC treatment, at Kreimah, also tended to be higher than in M or MP, but was not significant (Table 1). The dominant weed species in MC plots at Kreimah were *Melilotus indica* (L.) All., *Polygonum aviculare* L., *Lolium perenne* L., and *Sorghum halepense* (L.) Pers. These weeds seemed to tolerate the applied herbicides, grew vigorously in the absence of competition from other vegetation, overtopped onion plants and caused significant reductions in the green bunch onion yields compared to those in treatments M or MP (Table 1). In addition to the previous species, *Portulaca oleraceae* L., *Sisymbrium irio* L., and *Malva nicaeensis* All. appeared in the control treatment plots. The dominant weed species in the control plots at the university farm included *Chenopodium album* L., *C. murale* L., *Amaranthus retroflexus*

Table 1. Separate effects of the various treatments on total weed dry weights and onion yield at Kreimeh and University farm (10 km south of Dayr Alla).

Treatment	Total weed dry wt (g·m ⁻²)		Onion yield (t·ha ⁻¹)	
	University farm	Kreimah	University farm (mature bulbs)	University farm (green bunch)
Main plot treatment ^a				
M	8.4 c ^y	5.17 bc	55.3 a	52.62 b
MP	16.4 c	1.0 c	47.7 b	67.04 a
MC	45.2 b	51.67 b	42.4 b	25.58 c
C	185.9 a	154.64 a	4.8 c	8.39 d
LSD _{0.05}	19.01	50.36	7.57	6.65
Subplot treatment				
Cow	75.9 ab	82.6 a	35.5 b	41.66 b
Olive pomace	57.3 b	34.6 ab	42.8 ab	22.50 c
Poultry	34.7 c	17.1 b	44.3 a	50.28 a
Sheep	88.1 a	78.1 a	27.6 c	39.18 b
LSD _{0.05}	19.01	50.36	7.57	6.65
Significance				
Main treatment	***	***	***	***
Subplot treatment	***	**	***	***
Main × subplot	***	NS	**	NS

^aM = in-row manure composting under BPE cover, MP = in-row manure composting under BPE cover + BPE mulch for the whole growing season, MC = in-row manure composting without BPE cover + chemical weed control treatment, C = manure and olive pomace was mixed with the soil at time of planting.

^yMeans within columns with the same letters are not significantly different at $P \leq 0.05$, according to least square means by GLM procedures (SAS institute, 1998).

L., *Sonchus oleraceus* L., *Malva nicaeensis*, and *Cynodon dactylon*.

Composting under BPE cover during the 6-week period before planting, in the main treatments M and MP, effectively reduced weed growth throughout the growing season. This may be because the BPE cover during the composting process retained more volatile compounds evolving from the soil, such as ammonia and ammonium, which enhanced detrimental effects on weed growth. Ammonia is known to be a product of manure composting and could reduce plant growth at high enough concentrations. It has been reported to have a scorching effect on plant foliage (Simpson, 1986), and it is used as a defoliant in many crops (Foster et al., 1995). There were no statistical differences in weed dry weights between the main treatments M and MP. Mulching with BPE after composting, (MP) enhanced onion growth early in the season and resulted in higher green bunch yields at Kreimah (Table 1).

Manure types varied in their effects on weed dry weights. Poultry manure was the most effective in reducing weed dry weights at the university farm, but was comparable to olive pomace at Kreimah (Table 1). Manures in the control treatment C resulted in the highest weed dry weights at the university farm, but the subplots which received cow or sheep manure resulted in higher weed dry weights than poultry manure or olive pomace (Table 2). This result was expected as sheep, and to a lesser extent cows, are normally allowed to graze either in rangeland or in farms after crop harvest, while poultry are normally fed in confinement (personal observation). Onion yields were significantly improved by the in-row composting of organic materials in any of the main treatments; M, MP, or MC. But onion yields in subplots receiving sheep manure was the lowest in the MC treatment probably because the herbicides used did not control all weeds present.

Overall, preplant composting of organic materials improved crop dry weights and enhanced weed control. Even though not always statistically different from other sources of organic material, there seemed to be a trend for in-row composted poultry manure to give lower weed dry weights and a general improvement of onion yields. (Table 1). This could be that poultry manure is higher in nitrogen and phosphorous content (Ensminger, 1970; Maynard et al., 1999; Simpson, 1986), in addition to its greater efficacy in controlling weeds (Tables 1, 2, and 5).

The yield of green bunch onions in the olive pomace treatment was significantly lower than the poultry manure treatment at Kreimah, except in control plots (Table 1). Even though both treatments were normally less contaminated with weed seeds, the olive pomace treatment had a higher weed infestation, especially *Melilotus indica*, which overtopped onion plants and was probably responsible for the lower yields. Onion bulb yields obtained from olive pomace at the university farm were similar to that of poultry manure (Table 1). Onion bulb yields from poultry plots were higher than that from olive pomace in the MC treatment, probably

due to a lower weed infestation (Table 2). Weed infestations in the subplots of olive pomace and poultry manure in treatments M, MP, and C were the lowest.

It is well established that mulching with BPE can raise soil temperatures (Hopen, 1965; Lai, 1974), but in-row composting of organic materials resulted in higher soil temperature than BPE in this experiment during the summer months (Table 3). Comparing soil temperatures at 15 cm depths, daily means were always higher in plots where manures or olive pomace were applied than those in mulched soils without manure or olive pomace (Table 3). The highest weekly mean soil temperatures

were in plots which received poultry and sheep manure, followed by olive pomace or cow manure (Table 4). Composting of poultry manure raised the weekly mean from 3.2 to 10.1 °C over that in soil without manure (Table 4). The highest weekly mean soil temperature was 47.7 °C in plots, which received poultry manure during the last week of the composting period 17 Mar. to 30 Apr. (Table 4). Such a rise in temperature could also be obtained by soil solarization using BPE during the hottest months of the year (Abu-Irmaileh, 1991b). This rise in soil temperature at the 15-cm depth was associated with effective weed control. But these temperatures were only obtained

Table 2. Interactive effects of the various treatments on total weed dry weight and onion bulb yield at the university farm.

Treatment ^a	Cow manure	Olive pomace	Poultry manure	Sheep manure
Total weed dry wt (g-m ⁻²)				
M	7.0 f ^b	10.3 ef	0.1 f	16.5 ef
MP	19.5 ef	12.8 ef	8.4 f	25.0 ef
MC	39.4 def	46.9 de	2.7 ef	67.6 cd
C	238.0 a	159.1 b	103.3 c	243.0 a
Onion bulb yield (t-ha ⁻¹)				
M	52.8 ab	62.2 ab	52.3 ab	54.0 ab
MP	40.8 b	60.1 ab	48.8 ab	41.0 b
MC	47.2 b	44.3 b	62.8 a	15.3 c
C	1.0 cd	4.7 cd	13.6 cd	0.1 d

^aM = in-row manure composting under BPE cover, MP = in-row manure composting under BPE cover + BPE mulch for the whole growing season, MC = in-row manure composting without BPE cover + chemical weed control treatment, C = manure and olive pomace was mixed with the soil at time of planting.

^bMeans with the same letters, within either parameters (total weed dry weight or onion bulb yield), are not significantly different at $P \leq 0.05$, according to least square means by GLM procedures (SAS institute, 1998).

Table 3. Temperature means $\pm$ SE at 15 cm depth taken daily at 8:00 AM and 3:00 PM under black plastic during the 6-week composting period in Kreimah and the university farm locations. Check is composed of mulched plots without organic material.

Treatment	Soil temp (°C)		
	University farm		Kreimah
	Onion (15 Sept. to 30 Oct.)	Eggplant (17 Mar. to 30 Apr.)	Onion (1 Nov. to 30 Dec.)
Cow	32.3 $\pm$ 0.7 b ^a	33.8 $\pm$ 0.5 b	23.6 $\pm$ 0.6 b
Olive pomace	32.3 $\pm$ 0.7 b	33.1 $\pm$ 0.5 b	24.5 $\pm$ 0.6 b
Poultry	33.8 $\pm$ 0.8 b	36.3 $\pm$ 0.6 c	25.9 $\pm$ 0.6 c
Sheep	33.1 $\pm$ 0.7 b	34.5 $\pm$ 0.5 b	24.2 $\pm$ 0.6 b
Check	28.0 $\pm$ 0.5 a	31.5 $\pm$ 0.4 a	20.7 $\pm$ 0.5 a

^aMeans within columns with the same letters are not significantly different.

Table 4. Weekly means of soil temperature ($\pm$ SE) at 15 cm depth taken at 3:00 PM during the 6-week period of manure composting. Organic material was not mixed into soil in the check plots.

Treatment	Weekly means of soil temp (°C) ^a					
	1 st	2 nd	3 rd	4 th	5 th	6 th
Kreimah (1 Nov. to 30 Dec)						
Cow	34.1 $\pm$ 0.6 b	32.7 $\pm$ 0.4 b	27.1 $\pm$ 0.6 b	25.0 $\pm$ 0.2 b	23.7 $\pm$ 0.4 b	22.6 $\pm$ 0.2 b
Olive pomace	34.6 $\pm$ 0.2 b	33.4 $\pm$ 0.3 b	30.0 $\pm$ 0.4 c	27.9 $\pm$ 0.5 cd	25.3 $\pm$ 0.6 b	22.6 $\pm$ 0.4 b
Poultry	35.7 $\pm$ 0.4 c	35.0 $\pm$ 0.4 c	32.0 $\pm$ 0.5 d	28.4 $\pm$ 0.4 d	26.7 $\pm$ 0.4 c	25.7 $\pm$ 0.3 c
Sheep	34.7 $\pm$ 0.4 b	33.3 $\pm$ 0.5 b	27.9 $\pm$ 0.7 b	26.9 $\pm$ 0.5 c	24.3 $\pm$ 0.5 b	22.4 $\pm$ 0.2 b
Check*	26.9 $\pm$ 0.4 a	27.0 $\pm$ 0.3 a	24.7 $\pm$ 0.4 a	22.4 $\pm$ 0.3 a	19.9 $\pm$ 0.3 a	19.0 $\pm$ 0.4 a
University farm-onion (15 Sept. to 30 Oct.)						
Cow	40.9 $\pm$ 0.7 b	39.4 $\pm$ 0.7 b	39.8 $\pm$ 0.3 b	37.4 $\pm$ 0.4 b	33.5 $\pm$ 0.5 b	27.9 $\pm$ 0.6 b
Olive pomace	41.5 $\pm$ 0.6 b	40.2 $\pm$ 0.7 b	39.2 $\pm$ 0.3 b	36.1 $\pm$ 0.5 b	33.9 $\pm$ 0.5 b	26.5 $\pm$ 0.8 b
Poultry	44.3 $\pm$ 0.7 c	41.7 $\pm$ 0.9 b	41.6 $\pm$ 0.4 c	37.6 $\pm$ 0.9 b	35.7 $\pm$ 0.3 c	28.4 $\pm$ 0.7 b
Sheep	41.6 $\pm$ 0.5 b	40.1 $\pm$ 0.8 b	40.3 $\pm$ 0.4 b	36.7 $\pm$ 0.5 b	34.4 $\pm$ 0.4 b	28.6 $\pm$ 0.4 b
Check	36.7 $\pm$ 0.2 a	34.0 $\pm$ 0.7 a	34.9 $\pm$ 0.5 a	31.2 $\pm$ 0.5 a	29.2 $\pm$ 0.7 a	24.6 $\pm$ 0.7 a
University farm-eggplant (17 Mar. to 30 Apr.)						
Cow	33.9 $\pm$ 0.2 a	36.1 $\pm$ 0.8 b	36.9 $\pm$ 0.9 b	37.2 $\pm$ 0.9 b	40.9 $\pm$ 0.5 c	42.3 $\pm$ 1.0 b
Olive Pomace	34.8 $\pm$ 0.3 b	35.3 $\pm$ 0.6 ab	36.3 $\pm$ 0.9 ab	36.9 $\pm$ 0.4 b	39.4 $\pm$ 0.5 b	42.8 $\pm$ 0.6 b
Poultry	36.4 $\pm$ 0.7 c	38.9 $\pm$ 0.8 c	39.0 $\pm$ 1.0 c	41.1 $\pm$ 1.1 d	44.1 $\pm$ 0.7 d	47.7 $\pm$ 0.6 c
Sheep	34.9 $\pm$ 0.6 b	36.5 $\pm$ 1.0 b	37.4 $\pm$ 1.0 bc	38.6 $\pm$ 0.9 c	40.8 $\pm$ 0.4 c	43.5 $\pm$ 0.4 b
Check	33.2 $\pm$ 0.8 a	34.3 $\pm$ 0.8 a	34.8 $\pm$ 1.1 a	32.5 $\pm$ 1.0 a	35.6 $\pm$ 0.4 a	37.6 $\pm$ 0.4 a

^aMeans within columns with the same letters in each location are not significantly different.

Table 5. Separate effects of composting period and rate of application of poultry manure on dry weight means of eggplants and weeds.

Treatment	Dry wt ²	
	Eggplant (g/plant)	Weeds (g-m ⁻²)
Composting period (weeks)		
0	13.56 b	468.0 a
2	15.23 ab	424.6 ab
4	18.67 ab	397.6 bc
6	23.16 a	342.0 c
LSD _{0.05}	9.32	64.72
Rate of application(kg-m ⁻²)		
0	12.85 b	594.0 a
5	16.87 ab	308.3 b
10	23.24 a	321.9 b
LSD _{0.05}	8.07	56.05
Significant levels		
Rate of application	*	***
Composting period	NS	**
Period × rate	NS	NS

²Means within columns with the same letters are not significantly different at $P \leq 0.05$, according to least square means by GLM procedures (SAS institute, 1998).

ns, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

for 1 week during the in-row composting period. In-row composting treatments were effective in controlling weeds even when soil temperatures were less than that obtained by soil solarization. The enhanced efficacy in weed control during the composting process could be partly due to the rise in temperature. However, weed seeds can be killed during composting even though lethal temperatures are not reached (Bahman and Lesoing, 1999). The efficacy of the composting process for controlling soilborne living propagules is not necessarily dependent on simply raising soil temperatures. For instance, imbibed weed seeds have been reported to be killed faster than nonimbibed weed seeds at typically sublethal soil temperatures when under mulch (Standifer et al., 1984). The rise in soil temperature obtained as a result of in-row composting in the soil may be less than the rise obtained during soil solarization with clear polyethylene sheets during summer months (Abu-Irmaileh, 1991a). Some weed species and other soilborne pest propagules may not be controlled effectively if plastic mulch is applied during the winter months when solar energy levels are lower. When fresh manures are mixed in-row during the cooler time of the year (15 Sept. to 30 Oct.) at rates used in this research the heat generated from decomposition does not bring about soil temperatures high enough for effective weed control (Tables 3 and 4). Apparently, some weed species present required soil temperatures higher than this to be killed (Egley, 1983). However, weed dry weights were apparently much less than that of the control treatment, C (Tables 1, 2, and 5). Soil temperatures taken at 3:00 PM in plots where poultry manure was composted was raised to 44.3 °C at a 15 cm depth during the period of 15 Sept. to 30 Oct. (Table 4). Soil temperatures in the upper soil layer, near the surface could be 5 to 6 °C higher toward afternoon hours (Arcidiacono et al., 1997) possibly reaching 50 °C. These temperatures could provide effective control of heat sensitive winter weed species. Seeds of many weed species lose their viability within 1 week of soil solarization with transparent PE sheets in midsummer (Egley, 1983).

Weed species observed in plots where organic material was composted under PE for 6 weeks without any further mulching included *Cyperus esculentus*, *Cynodon dactylon*, *Prosopis farcta* (Banks et Sol) Macbride, *Sorghum halepense*, *Melilotus indica*, and *Vicia narbo-nense* L. Weed species effectively controlled included *Chenopodium murale*, *C. album*, *Amaranthus retroflexus*, *Sonchus oleraceus*, *Polygonum aviculare*, and *Sisymbrium irio*. Fewer weeds were observed in plots where poultry manure or olive pomace was composted. In addition to a loss in the viability of weed seeds (Bahman and Lesoing, 1999), this result could be due to lower contamination from poultry manure or olive pomace which normally contains fewer weed seeds, and to the higher heat generated during composting, especially in plots receiving poultry manure. It is also probable that ammonia and other nitrogenous compounds released during the decomposition of organic materials (Simpson, 1986) participated in reducing weed seed viability and suppressing subsequent weed growth.

Effect of rate and periodicity of poultry manure composting on weed control efficacy. In-row composting of poultry manure at 10 kg-m⁻² for 6 weeks effectively reduced weed dry weights and improved eggplant dry weights (Table 5). Weed growth was significantly reduced when poultry manure was mixed in the planting row and composted for 4 and 6 weeks. However, the in-row composting process is a preplant treatment and requires that the field be crop free for the whole period of composting. Even though not statistically different, composting poultry manure at either 5 or 10 kg-m⁻² for 4 weeks showed a trend toward higher crop dry weights and brought about significantly lower weed dry weights than 0 kg-m⁻² rate of manure application during this growing season (Table 5). Thus in cases where a crop-free, 6-week period is not feasible, composting for 4 weeks may provide some measure of weed control and increase yields.

Even though data on weed control and on improvement of crop plant growth suggest that higher rates of poultry manure is more effective, this may pose undesirable environmental side

effects. Higher application rates combined with heavy irrigation may lead to the emission of nitrogen and carbon into the air, and the leaching of nitrogen to ground and surface water, while the accumulation of heavy metals in the soil may induce levels in crops that exceed human health standards (de Wit et al., 1999).

Covering the soil with BPE mulch during the cooler months, without poultry manure before planting, did not reduce weed dry weights (Table 5). Unlike mulching with BPE during the summer months for the purpose of weed control by soil solarization, (Abu-Irmaileh, 1991a, 1991b), mulching during the composting period between March and April, did not raise soil temperatures high enough to control weeds (Tables 3 and 4).

Temperatures in manure composting lagoons can reach 65 °C (Silva et al., 1996; University of California, 2001). However our soil temperatures during in-row composting never reached 65 °C. The highest weekly mean of soil temperatures taken at 3:00 PM for cow manure was 42.3 °C, olive pomace 42.8 °C, poultry manure 47.7 °C, and sheep manure 43.5 °C (Table 4). Although not statistically significant, soil temperatures in poultry manure treatments were consistently higher than in other organic material sources (Table 3). This effect might have contributed to greater control of the dominant weed species, especially during the warmer period (Table 5). The summer weed species that flourish under moist warm conditions include *Amaranthus retroflexus*, *Polypogon monspeliensis* (L.) Desf., *Portulaca oleraceae*, *Prosopis farcta*, and *Tribulus terrestris* L.

In conclusion, composting organic material within the planting row was effective in reducing weed populations under certain circumstances. This effect was not due to elevated soil temperatures in all cases, as the warming effect did not raise soil temperatures enough to control weed seeds and other propagules in the soil during the whole composting period. High temperatures were only achieved when composting was done during the warmest part of the seasons which lasted for only 1 week. The composting process could have reduced seed viability of sensitive weeds by the releasing volatile decomposition products. In-row manure composting under some conditions might be an alternative to soil solarization since it does not have to be performed during the hottest month of the year. The farmer can apply this method provided there is a crop-free period from 4 to 6 weeks long. Manure or olive pomace composting not only provided good weed control but it improved the growing conditions and increased crop yield. This process could provide better management of organically cultivated crops and reduce environmental pollution. However, further verification of its environmental impact should be performed in order to make better management decisions regarding the use of these techniques.

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