

Growth and Yields of Bell Pepper and Winter Squash Grown with Organic and Living Mulches

Nancy E. Roe¹ and Peter J. Stoffella²

Agricultural Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida, 2199 South Rock Road, Fort Pierce, FL 34945

Herbert H. Bryan²

Tropical Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida, 18905 Southwest 280th Street, Homestead, FL 33031

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Abstract. Increasing disposal problems with polyethylene (PL) mulch and greater availability of compost prompted an investigation into the effects of using compost as a mulch on horizontal raised bed surfaces with living mulches (LMs) on vertical surfaces. Wood chips (WC), sewage sludge-yard trimming (SY) compost, and municipal solid waste (MW) compost were applied at 224 t·ha⁻¹ on bed surfaces. Sod strips of 'Jade' (JD) or 'Floritam' (FT) St. Augustinegrass (*Stenotaphrum secundatum* Kuntze) or perennial peanut (*Arachis glabrata* Benth.) (PP) or seeds of a small, seed-propagated forage peanut (*Arachis* sp.) (SP) were established on the vertical sides of the raised beds before transplanting bell pepper (*Capsicum annuum* L.) into the beds. *Phytophthora capsici* reduced pepper plant stand in PL-mulched plots compared with organic mulch (OM) and LM. Despite the stand reduction, total pepper yields were highest in PL plots and, in the OM plots, decreased in the order SY > MW > WC. Early fruit yields and yield per plant were highest from plants in PL plots followed by SY. Among LMs, plants in SP plots produced highest early yields and FT produced the lowest. Plants in PL plots produced the largest fruit. When the same plots were seeded with winter (butternut) squash (*Cucurbita pepo* L.), plant stands were higher in MW than WC and SY. Squash yields were similar between PL and OM plots.

Mulches can reduce water evaporation from the soil's surface, suppress weed growth, restrict fertilizer leaching, and moderate diurnal and seasonal temperature fluctuations.

About 9.5 million kg of polyethylene (PL) mulch is used in Florida annually (Servis, 1992). Although PL mulch has dramatically increased the yields of some vegetable crops, mulch disposal is costly to growers and society. In some areas of Florida, disposal costs increased by as much as 30% in 1 year (Servis, 1992).

Florida's Solid Waste Act of 1988 mandated a 30% reduction in landfilling by Dec. 1994 and prohibited disposal of yard trimmings in landfills after 1 Jan. 1992, resulting in substantial quantities of organic matter available for commercial agricultural uses.

In southern Florida, bell peppers are commonly grown on raised beds due to heavy rainfall during the growing season. When organic mulches (OMs) rather than PL mulches are used, the vertical sides of the beds may deteriorate. Living mulches (LMs) can alleviate soil erosion and maintain soil structure (Grubinger and Minotti, 1990) and may potentially reduce bed degradation.

The objective of these experiments was to determine the influence of several LMs combined with OMs on growth, nutrient status, and yields of bell pepper and winter squash.

Materials and Methods

Two experiments were conducted on a commercial bell pepper field in Boynton Beach, Fla. Soil type was a Myakka sand (sandy,

siliceous, hyperthermic Aeric Haplaquad). Beds were constructed 20 cm high, 92 cm wide, and were spaced 1.7 m, center to center.

Soil electrical conductivity (EC), NO₃-N, and pH were extracted in a 2 water : 1 soil (v/v) suspension. The Walkley-Black dichromate method was used to determine percent organic matter (Nelson and Sommers, 1982). Phosphorus, K, Ca, Mg, Mn, Zn, and Cu were extracted by the Mehlich I method and analyzed by inductively coupled argon plasma (ICP) spectroscopy (Hanlon et al., 1990).

Extractions for municipal solid waste (MW) compost were performed with a Morgan solution (Wolfe, 1982). Nitrogen, P, and S were determined spectrophotometrically. Calcium, K, Mg, Zn, Mn, Cu, and Fe were determined by atomic absorption. EC and pH were measured in a 2 water : 1 soil suspension.

Total N in sewage sludge-yard trimming (SY) compost was analyzed using an N analyzer. Phosphorus, K, Ca, Mg, Mn, Zn, Cu, Fe, and S were analyzed by ICP spectroscopy.

An analysis of variance (ANOVA) was conducted by SAS for each measured variable. Orthogonal contrasts were performed using PL vs. all other treatments. Another ANOVA (with PL treatments removed) was performed with LM and OM as main effects. Since most LM × OM interactions were nonsignificant, means separation of the main effects of LM and OM were performed by Duncan's multiple range test at $P \leq 0.05$.

Bell pepper experiment. On 15 Jan. 1992, a previous bell pepper crop was removed by mowing. Beds, size and shape as previously described, were not replaced. Main plots were 9.1 m long and consisted of three beds and bed sides. A factorial treatment combination of four LMs and three OMs, and a control (PL mulch) was used. Subplots were 9.1 m long and consisted of one bed and bed sides. A split-plot experimental design, with LMs as main plots and OMs as subplots, replicated five times was used.

The white PL mulch (0.0318 mm thick) used for the preceding crop was left on the plots and designated as the control. On 24 Jan. 1992, PL was removed from the plots where the LMs were to be

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¹Postdoctoral research associate. Current address: Texas A & M Univ. Research and Extension Center, Rt. 2, Box 1, Stephenville, TX 76401.

²Professor.

Table 1. Chemical characteristics of municipal solid waste (MW) and sewage sludge–yard trimming (SY) composts.

Mulch	pH	SS ²	Concn (mg·kg ⁻¹)										
			N	P	K	Ca	Mg	Fe	Mn	S	Zn	Cu	B
MW ^y	8.2	2.50	7	47	532	2210	164	8	16	378	17	0.3	7.0
SY ^x	7.2	NA	13,000	9940	2400	2500	37,500	11,400	200	5900	300	500.0	20.0

²SS = soluble salts (mmhos·cm⁻¹).

^yAnalysis obtained from Reuter Recycling.

^xAnalysis obtained from Palm Beach County Solid Waste Authority.

established. The St. Augustine grasses 'Floritam' (FT) and 'Jade' (JD), in 40 × 60-cm sod pieces, were creased in the center and laid on bed sides with about half of the strip lying vertically along the bed and half lying horizontally in the alley.

Sodium *N*-methylthiocarbamate (Vapam) at 74 liter·ha⁻¹ was injected into all beds on 29 Jan. using an injection wheel with openings at 30 cm.

Perennial peanut (PP) rhizome mats were laid on 7 Feb. in the same manner as the grass sod. There was minimal soil around the peanut roots; therefore, they were covered slightly by removing soil from the bed surfaces and alleys.

To protect bed surfaces during the LM growth period, aged wood chips (WC), principally from *Melaleuca quinquenervia* (Cav.) Blake, were spread 5 cm deep on bed surfaces on 21 Feb.

A small-seeded forage peanut (*Arachis* sp.) (SP) was seeded into bed sides on 28 Feb. Each hill, consisting of two to three seeds, was planted 2.5 cm deep and 20 cm apart. Percent germination was 62% by a 5-day germination test in moist paper towels at room temperature. Hills lacking an emerged seedling were reseeded with three to four seeds on 13 Mar.

LMs were weeded as needed and watered by subsurface seepage irrigation during spring and summer. Growth of one-half of each FT plot was mowed on 27 Mar., 17 Apr., 22 June, and 29 July 1992 and 22 Jan. 1993. The other half was sprayed with butyl 2-[4-(5-trifluoromethyl-2-pyridinyloxy) phenoxy] propanoate (fluazifop) at 0.16 kg·ha⁻¹ (Hinton and Minotti, 1983) on 4 May and 25 Aug. 1992 and 8 Jan. 1993 using a manually operated backpack pump sprayer. JD plots were treated similarly, but slower growth necessitated mowing only on 22 June 1992 and 22 Jan. 1993 and applying herbicide only on 25 Aug. 1992

WC compost was removed from surfaces of two of the three beds in each (main) LM plot on 6 June. On 17 June, MW compost (Reuter Recycling of Florida, Pembroke Pines, Fla.) (Table 1) was spread manually on one of these uncovered beds in each LM plot. On 8 July, the remaining bed in each main plot was covered with SY compost made in a covered-bin facility operated by Palm Beach County, Fla. Both mulches were used at a rate of 224 t·ha⁻¹, resulting in a depth of ≈5 cm.

Drip irrigation was installed on 31 Aug. One drip line (Netafim, Orlando, Fla.) was laid 2 to 5 cm deep in the center of each bed. Emitters spaced at 45 cm each delivered ≈18 ml·min⁻¹. Two daily irrigations were used, with each supplying ≈9340 liter·ha⁻¹. Nutrients at 1.1N–0.9K (kg·ha⁻¹) were added through the irrigation system with each application to all plots. White PL mulch (0.0318 mm thick) was replaced in PL plots, but no additional mulch was added to OM plots. On 17 Sept., isopropylamine salt of *N*-(phosphonomethyl) glycine (glyphosate) spray was applied to the bed surfaces at a rate of 3 liter·ha⁻¹ to control weeds and LMs that had grown onto the surface.

Soil samples were taken 0.0 to 7.5 and 7.5 to 15.0 cm deep on 23 Sept. using a 5-cm-diameter sampling tube. Samples were air-dried for 60 days before testing for NH₄-N, NO₃-N, P, K, Ca, Mg, Zn, Cu, Mn, and organic matter. Data from these soil tests were

analyzed as a split-split plot experimental design using LM as the main plot, OM as the subplot, and soil depth as the sub-subplot.

Bell pepper seedlings ('PR-3002'), ≈5 weeks-old, were transplanted into the beds on 6 Oct. Plants were spaced 30 cm apart in two rows spaced 45 cm apart. Plant population was 39,120 plants/ha.

The most recently matured leaf from 15 plants in each plot was collected for tissue analysis on 4 Dec. 1992. Leaves were dried for 5 days at 68C, ground, extracted, and analyzed according to Hanlon and DeVore (1989).

One plant from each plot was severed at the soil's surface on 4 Dec. 1992. Two root core samples were taken from each of these plants, 5 cm from the plant toward the outside edge of the bed, and 5 cm from the plant toward the center of the bed. Samples were taken from the mulch and from soil depths of 0.0 to 7.5 and 7.5 to 15 cm using the same sampling tube used to extract soil samples. Roots were washed and screened to separate them from the mulch or soil (Jackson and Bloom, 1990). Shoots (including attached fruit) and roots were dried at 70C for 11 days and weighed. Percentages of roots at each soil depth were transformed using a square-root arcsin before conducting an ANOVA.

Fruit were harvested on 29 Dec. 1992 and 18 Jan. 1993 from a 6.1-m length of each plot. Due to plant losses to *Phytophthora*, mowed and herbicide-treated subplots of the grass LM plots were combined for harvest data collection. In the first harvest, fruit were graded into large (U.S. Fancy, diameter at least 7.5 cm and length at least 8.75 cm) and medium (U.S. no. 1, diameter and length at least 6.75 cm) (Hochmuth, 1988). In the second harvest, all marketable graded fruit were U.S. medium.

Winter squash experiment. The pepper plants were removed by mowing on 22 Jan. 1993. This process also resulted in mowing much of the 'Floritam' St. Augustinegrass, since it reached 0.5 m above the bed surface in some plots. Bed surfaces were sprayed with glyphosate (3 liter·ha⁻¹) to kill weeds and remaining pepper plants. The MW and SY mulches were about half their original depth.

'Waltham' butternut squash was manually seeded on 4 Feb. into machine-made holes spaced 23 cm apart and slightly offset from the center of each bed, with one seed per hole. Plots were manually weeded on 19 Feb., 9 Mar., and 24 Mar. Plants in each plot were counted on 1 Mar. and reported as the percentage of the potential plants per plot.

Soil temperatures were recorded three times daily using a temperature probe inserted 15 cm deep in one random location per plot on 10, 11, 12, 14, 15, 16, 28, and 30 Mar. Temperatures were designated as morning (between 7:00 and 8:00 AM), midday (between 1:00 and 2:00 PM), or evening (between 5:00 and 6:00 PM).

Fruit longer than 15 cm were harvested, weighed, and counted on 11 May, and data were analyzed as previously described.

Results and Discussion

Bell pepper experiment

Soil tests. LM × OM × soil depth (D) and LM × OM interactions were not significant for any measured variable (Table 2).

The OM × D interaction was significant for soil P, K, and Mg concentrations. Soil P concentration was higher in deeper soil under WC compost and lower under SY and MW composts than at the shallow depth. Potassium and Mg concentrations were higher in deeper soil under MW and lower under WC and SY than at the shallow depth. Additional K and Mg provided by the SY mulch (Table 1) and the susceptibility of K and Mg to leaching may have resulted in higher concentrations of these elements at the shallow depth.

The LM × D interaction was significant for soil Ca concentration. Calcium concentration was higher at the deeper depth in PP plots and lower at deeper depth in the other LMs. This may be related to the differential in Ca uptake and use between the PP and the other LMs.

Soil NO₃ concentration was higher in PL plots compared with OM plots and in SY plots compared with the other two OMs (Table 2). Paul and Clark (1989) reported that lack of tillage tends to increase microbial activity at or near the soil's surface. Nitrate produced by nitrification of the organic N in the compost may have leached equally into both soil depths, with most lost through deeper soil leaching. Fertilizer was not applied to PL plots for 1 year before soil sampling. However, despite adding compost to OM plots, soil N and a large portion of K and Mg remained higher in PL plots, apparently due to the prevention of leaching by PL mulch. The other plots were unmulched for 1 month, mulched with wood chips for 3 to 4 months, and mulched with OM compost for 3 additional months before the soil samples were taken. Soil pH was 7.2, and, with the high pH of the composts (Table 1) and the high moisture level maintained by seepage irrigation, additional N may have been lost through volatilization.

Soil P concentration under PL mulch was similar to that of OM plots (Table 2). Tukey and Schoff (1963) measured higher soil P concentration under legume hay and straw mulches but not under

peanut hulls, corn cobs, sawdust, or foam rubber compared with grass sod or cultivated plots.

PL-mulched plots were higher in soil K compared with other treatments (Table 2). Tukey and Schoff (1963) reported greater availability of weakly and readily available K in soils under legume hay than under synthetic mulches. They also reported no consistent or significant differences in Ca or Mg concentration between soils incubated under one of five different OMs or four synthetic mulches. Soil Ca concentration in our plots was higher in SY and MW compost plots than in WC compost plots. PL-mulched plots had higher soil Mg concentration compared with other treatments (Table 2). Higher soil Mg concentration in PP and SP suggests that the more vigorous FT may have used more of the available Mg.

Soil organic matter content was higher in plots with JD, PP, and SPLMs than in those with FT. The FT was the most vigorous LM, a result suggesting higher organic matter production. However, the organic matter content in FT plots at this sampling date may have been in large portions that were screened out before testing.

Oms did not seem to reduce nutrient leaching as much as PL mulch. A mature compost incorporated into the soil may have retained more nutrients than the mulches. Duxbury et al. (1989) alluded to insufficient information on which pools of organic matter (old, stable or newer, labile) most influence cation exchange capacity (CEC). However, CEC of humic acid increases with increasing pH (Harada et al., 1975), and humic acid increases with compost maturity (Jimenez and Garcia, 1992). Soil testing methods used here may not have extracted all nutrients from the organic fraction of the soil, as testing methods that may be accurate on unamended soils may not be appropriate for the same soils with organic matter amendments (O'Keefe et al., 1986).

Leaf tissue samples. Nutrients in all leaf tissue samples tested were in the adequate or high range for early fruit setting of peppers (Hochmuth et al., 1991).

Table 2. Soil characteristics of experimental plots before transplanting peppers.

Mulch ^z	Concn (mg·kg ⁻¹)								Organic matter (%)
	NO ₃	P	K	Ca	Mg	Zn	Cu	Mn	
PL	15.6	279	74.0	1797	105.1	14.0	12.9	23.6	1.4
Living mulch (LM)									
FT	1.5	264	42.1	1478	75.8 b ^y	14.6	10.7	17.3	1.3 b
JD	2.1	281	44.6	1885	80.5 ab	14.9	10.0	18.0	1.5 a
PP	0.3	277	46.3	1778	91.9 a	15.1	11.0	18.4	1.6 a
SP	1.3	274	45.7	1572	91.9 a	18.6	10.6	17.5	1.5 a
Organic mulch (OM)									
MW	0.6 b	263 b	23.7 b	1791 a	82.2	15.6	9.9 b	17.8	1.5
WC	0.1 b	271 b	17.3 c	1556 b	86.8	14.2	11.6 a	17.3	1.5
SY	3.1 a	288 a	93.1 a	1688 a	86.1	17.6	10.2 b	18.2	1.5
Soil depth (D) (cm)									
0.0–7.5	1.0	275	15.7	1696	86.2	15.7	10.7	17.5	1.5
7.5–15.0	1.6	273	41.7	1661	83.8	15.9	10.5	18.0	1.5
F test (D)	NS	NS	**	NS	NS	NS	NS	NS	NS
Interactions									
LM × OM	NS	NS	NS	NS	NS	NS	NS	NS	NS
OM × D	NS	**	**	NS	**	NS	NS	NS	NS
LM × D	NS	NS	NS	**	NS	NS	NS	NS	NS
LM × OM × D	NS	NS	NS	NS	NS	NS	NS	NS	NS
Contrasts									
PL vs. others	**	NS	**	**	**	NS	**	**	NS

^zPL = polyethylene, FT = 'Floritam', JD = 'Jade', PP = perennial peanut, SP = seed-propagated forage peanut, MW = municipal solid waste compost, WC = wood chips, SY = sewage sludge-yard trimming compost.

^yMean separation in columns within mulch types by Duncan's multiple range test, *P* = 0.05.

^{ns,**}Nonsignificant or significant at *P* = 0.01.

The OM × LM interaction was significant for leaf K concentrations (Table 3), which was highest in plants grown in SY with all LMs except FT, in which K was highest in plants from WC plots. Higher leaf K concentration in SY plots may be a result of higher soil K concentration in SY plots (Table 2). Leaf K concentration was lowest in MW with all LMs. Miller (1960) reported highest K in plants that received high K or low P or Mg fertilizer solutions, indicating that interactions of these ions affect their availability.

The OM × LM interaction was also significant for leaf Mg concentration (Table 3), which was highest in SY OM with all LMs except SP, in which Mg was highest with WC. Leaf Mg was lowest in MW OM with FT LM, in WC OM with JD and PP LMs, and in SY OM with SP LM.

Thomas and Heilman (1964) reported that pepper yields were positively correlated to leaf N content and fertilizer N added. Leaf N content from plants grown with grassy LMs was generally higher than in plants from plots with peanut mulches (Table 3), but yields were not higher than in peanut LMs (Table 4). Immobilization of N by MW compost as reported by Hornick (1988) was not evident in the leaf N concentration of peppers (Table 3), probably because the MW was not soil incorporated.

Leaf P, K, and Zn concentrations were higher and Mg was lower in OM and LM than in PL plots. The lower leaf P concentration in plants from PL plots may be a result of P use by fruit, which were earlier and larger on plants in PL plots (Table 4). Thomas and Heilman (1964) reported that leaf P concentrations in peppers decreased as fruit developed if adequate N was present but increased if N was deficient.

Plants from SY plots were generally larger and higher-yielding than plants from the other OMs (Table 4). This suggests that there may be some dilution of nutrients in foliage and earlier and/or greater translocation of nutrients into fruit of SY plots than on MW or WC. Thomas and Heilman (1964) reported declining leaf N concentration of bell peppers as fruit neared the green-mature stage, suggesting that N was translocated from leaves to fruit.

Leaf Mn and Cu concentrations were very high in all samples (Table 3), probably because fungicides containing Mn and Cu were applied to the plants.

Plant stands. No significant interactions occurred for plant

stand (Table 4). At 101 and 107 days after transplanting, stands were lower in PL plots compared with other plots. *Phytophthora capsici* was detected in root and stem samples taken from several plots. The disease is associated with excess water and is spread by splashing water (Black et al., 1991). Rainfall during January 1993 was >300 mm, so conditions were ideal for disease development. Madden and Ellis (1990) reported increased splashing of simulated rainfall on PL-mulched strawberries (*Fragaria xananassa* Duch.) compared with those mulched with straw. Elmer and Ferrandino (1991) reported earlier onset of *Verticillium dahliae* in eggplant (*Solanum melongena* L.) grown with PL mulch compared with unmulched plants.

Shoot and root growth. Shoots of pepper plants from PL plots were larger than those of plants from other plots (Table 4). Shoot weights were similar among plants from OM or LM plots.

Percentages of root mass in the mulches and at the two soil depths were similar, which may be due to the inherent variability of root systems, the root sampling method (Asghar et al., 1987), or the placement of drip emitters (Bar-Yosef et al., 1980). Coefficients of variation for roots in the mulches and at 0.0 to 7.5 and 7.5 to 15.0 cm deep were 89, 34, and 48, respectively.

Transplanting crews, accustomed to working with PL mulch, tended to place the root systems of the plants in the mulches rather than deeper into the soil. This encouraged the growth of roots in the mulches and may have accounted for some of the decreased yields from plants in the WC plots. Inbar et al. (1993) reported that using wood products in potting mixes often results in N deficiency in plants. The chips we used were large, with pieces as long as 7 cm, making adequate contact between roots and soil difficult.

Fruit yields. The OM × LM interactions were not significant for fruit yields (Table 4). Total yields from PL plots were higher than from LM and OM plots. Yields of bell peppers on PL mulch increased 25% in a wet year and 3% in a dry year compared with yields of pepper plants grown with no mulch (Locascio and Fiskell, 1977). Maynard et al. (1962) reported increases in early and total yields of peppers with increasing N due to higher fruit set. Total fruit yields, yields per plant, and fruit size (Table 4) were generally higher from plants grown in plots with high soil N and K concentrations (Table 2). In a tropical environment, pepper plants mulched

Table 3. Nutrient concentration of pepper leaves from plots mulched with polyethylene or organic and living mulches.

Mulch ^y	N ^z	P	K	Ca	Mg	Zn	Mn	Cu	Fe
	(%)			(mg·kg ⁻¹)					
PL	5.1	0.34	3.8	2.16	0.86	85.0	392	304	100
Living mulch (LM)									
FT	5.3 a ^x	0.58 a	4.4	2.06	0.54	100.1	383 b	313 b	116
JD	5.2 a	0.52 b	4.4	2.15	0.55	95.7	396 ab	327 ab	122
PP	5.1 ab	0.52 b	4.6	2.14	0.52	98.5	420 a	348 a	114
SP	4.9 b	0.53 b	4.3	2.18	0.57	96.0	409 ab	334 ab	130
Organic mulch (OM)									
MW	5.2	0.50	4.2 c	2.27 a	0.54	100.8 a	394	324	118
WC	5.1	0.57	4.5 b	1.99 c	0.55	98.9 a	423	340	132
SY	5.1	0.54	4.6 a	2.13 b	0.54	93.1 b	389	328	111
Interaction									
OM × LM	NS	NS	*	NS	*	NS	NS	NS	NS
Contrasts									
PL vs. others	NS	**	**	NS	**	**	NS	NS	NS

^zTotal Kjeldahl N.

^yPL = polyethylene, FT = 'Floritam', JD = 'Jade', PP = perennial peanut, SP = seed-propagated forage peanut, MW = municipal solid waste compost, WC = wood chips, SY = sewage sludge-yard trimming compost.

^xMean separation in columns within mulch types by Duncan's multiple range test, *P* = 0.05.

NS,*,**Nonsignificant or significant at *P* = 0.05 or 0.01, respectively.

Table 4. Bell pepper plant stands, shoot weight, root weights from soil cores, and yields from plots mulched with white polyethylene or organic materials.

Mulch ^x	Stand (%)		Shoot wt (g)	Mulch	Root (%)		Fruit yield			
	DAT ^z				Soil depth (cm)		(t·ha ^{-1w})	(g/plant ^w)	Early ^y (%)	Size (g/fruit)
	101	107			0–7.5	7.5–15				
PL	18	2	28.1	0	52.0	48.0	6.99	329	98	206
Living mulch (LM)										
FT	73	54	10.2	12.5	57.8	29.7	2.86	116	62 b ^v	174
JD	72	50	11.0	18.9	49.1	32.0	3.23	136	67 ab	179
PP	63	45	11.2	24.1	51.7	24.2	2.51	114	69 ab	182
SP	62	40	12.1	6.0	56.3	37.7	3.18	142	78 a	189
Organic mulch (OM)										
MW	71	51	11.3	10.9	57.6	31.5	2.95 b	122 b	70 ab	174
WC	62	43	8.8	13.4	46.9	39.7	1.86 c	86 b	59 b	192
SY	70	49	13.4	21.9	56.7	21.4	4.03 a	174 a	77 a	176
Interaction										
OM × LM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Contrasts										
PL vs. others	**	**	**	---	NS	NS	**	**	**	**

^zDAT = days after transplanting.

^yPercentage of fruit in first harvest.

^xPL = polyethylene, FT = 'Floritam', JD = 'Jade', PP = perennial peanut, SP = seed-propagated forage peanut, MW = municipal solid waste compost, WC = wood chips, SY = sewage sludge-yard trimming compost.

^wTotal of two harvests: 28 Dec. 1992 and 15 Jan. 1993.

^vMean separation in columns within mulch types by Duncan's multiple range test, $P = 0.05$.

^{ns,**}Nonsignificant or significant at $P = 0.01$.

with organic materials produced lower yields than plants mulched with white, silver, or black PL or unmulched plants in summer or winter (Goyal et al., 1984).

Smaller plants and decreased yields in OM, especially in WC plots (Table 4), suggest a lack of N. Plants in WC plots were also lighter in color than others (data not shown). Soil tests indicated lower NO₃ in OM plots (Table 2), so a dilution effect may have accounted for the similar leaf tissue results. This apparent decrease in available N in OM plots may be due to a combination of leaching, immobilization, and volatilization. Locascio and Fiskell (1977) suggested that higher soil N content measured under PL mulch plots compared with unmulched soil was due to decreased leaching under PL. The immobilization of N by compost has been reported (Jimenez and Garcia, 1989). Although some composts contain large amounts of N, mineralization often proceeds slowly and the N may not be available at the critical time for plant uptake. In several trials with mushroom (*Agaricus* spp.) compost, tomato yields increased only when the compost was supplemented with N, P, and K (Stephens et al., 1989).

Early yields from PL plants accounted for 98% of the harvest, as only 2% of the plants were still living by the second harvest date (Table 4). Percentage of early yields from plants in WC plots was lower than from plants in SY plots. This reflected the inhibited growth of plants in WC plots.

Winter squash experiment

Soil temperatures. Although morning temperatures were similar, midday and evening temperatures under PL were higher than in OM and LM plots (Table 5). Midday temperatures in OM plots were highest under MW and lowest under WC, probably due to differences in color and insulating properties of the mulches.

Plots with peanut LMs had higher evening temperatures than grass-mulched plots. The grass covered bed sides more uniformly and heavily than the peanuts (data not shown), thereby protecting the soil from direct radiation.

Plant stands. Although final stands were similar (Table 5), earlier emergence of squash seedlings was noted in OM plots, probably because nighttime temperatures under these mulches remained warmer than under PL during the germination period (data not shown). More favorable growing conditions resulted in fewer disease losses of the squash crop during the season than of the pepper crop.

Plant stands of MW plots were the highest of any of the OMs (Table 5). Direct seeding in OM usually resulted in placing seed directly in the mulch. Germination percentages of radish (*Raphanus sativus* L.), dill (*Anethum graveolens* L.), and alfalfa (*Medicago sativa* L.) have been lower in SY than MW compost (Roe and Kostewicz, 1992). Placing seed directly in the WC mulch may have inhibited germination in that mulch. Plant stand in PP plots was lower than that in the other LMs, probably because vigorous growth of PP through the beds resulted in a competitive effect.

Fruit yield. Total fruit yields were similar among treatments (Table 5). Number of fruit per plant (34) from PL-mulched plots was higher compared with fruit per plant (24) from OM plots, resulting in smaller fruit from plants in PL plots. Schales and Sheldrake (1966) reported no significant differences in muskmelon yields from plants mulched with clear or white PL compared with plants mulched with peatmoss. When straw mulch was compared with clear, white, or black PL mulch another year, muskmelon yields were higher in all PL mulches (Schales and Sheldrake, 1966).

Improved crop growth with OMs or composts has been attributed to reduced weed growth (Carter and Johnson, 1988), temperature moderation (Palada et al. 1992), retained soil moisture (Asghar et al., 1987), changes in soil physical condition (Batista y Cuba, 1943), and suppression of plant pathogens (Bryan and Lance, 1991). Despite reduced plant stands in PL-mulched plots, pepper plants were larger and produced higher yields than those grown with OMs. However, in the subsequent squash crop, these yield differences were not evident. The economics of PL vs. compost

Table 5. Soil temperatures, squash plant stands, and yields from plots mulched with white polyethylene or organic and living mulches.

Mulch ^y	Soil temp (°C) ^z			Stand (%) 28 DAS ^x	Fruit yield		Fruit size (g/fruit)
	Morning	Midday	Evening		(t·ha ⁻¹)	(g/plant)	
PL	17.0	23.1	23.6	62	9.51	973	436
Living mulch (LM)							
FT	17.6	21.5	22.2 b ^w	56 a	8.95	871 a	556
JD	17.4	21.6	22.5 ab	56 a	9.56	943 a	535
PP	17.5	21.5	22.6 a	47 b	7.79	869 a	574
SP	16.9	21.5	22.7 a	59 a	7.19	698 b	537
Organic mulch (OM)							
MW	17.4	21.7 a	22.5	60 a	8.18	768 b	541
WC	17.5	21.4 b	22.4	50 b	7.87	819 ab	554
SY	17.2	21.6 ab	22.6	54 b	9.07	948 a	557
Interaction							
OM × LM	NS	NS	NS	NS	NS	NS	NS
Contrasts							
PL vs. others	NS	**	**	NS	NS	NS	**

^zTemperatures recorded at 15 cm soil depth for 8 days in March 1993.

^yPL = polyethylene, FT = 'Floritam', JD = 'Jade', PP = perennial peanut, SP = seed-propagated forage peanut, MW = municipal solid waste compost, WC = wood chips, SY = sewage sludge-yard trimming compost.

^xDays after seeding.

^wMean separation in columns within mulch types by Duncan's multiple range test, $P = 0.01$.

^{ns,**}Nonsignificant or significant at $P = 0.01$.

mulches, practical application methods, and long-term effects of compost use in vegetable crop production systems also warrant evaluation.

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