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Interactions of Poultry Litter, Polyethylene Mulch, and Floating Row Covers on Triploid Watermelon

J.T. Baker and D.R. Earhart
Department of Horticultural Sciences, Texas Agricultural Experiment Station, Texas A&M University Agricultural Research and Extension Center, P.O. Box E, Overton, TX 75684

M.L. Baker
Department of Horticultural Sciences, Texas Agricultural Extension Service, Texas A&M University, Texas A&M University Agricultural Research and Extension Center, P.O. Box 38, Overton, TX 75684

F.J. Dainello
Department of Horticultural Sciences, Texas Agricultural Extension Service, Texas A&M University, College Station, TX 77843

V.A. Haby
Department of Soil and Crop Sciences, Texas Agricultural Experiment Station, Texas A&M University Agricultural Research & Extension Center, P.O. Box E, Overton, TX 75684

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Abstract. **Triploid watermelon (*Citrullus lanatus* Thunb.) was grown on the same plots in 1990 and 1991 and fertilized with either poultry litter or commercial fertilizer. Additional treatments included bare soil or plots mulched with black polyethylene, and plots with or without spunbonded fabric row covers over both bare soil and mulch. Watermelon yields were unaffected by fertilizer source in 1990 but were significantly higher for poultry litter than for commercial fertilizer treatment in 1991. Polyethylene mulch significantly increased postharvest soil NO_3 and leaf N concentrations in 1990 and increased yield and yield components in both years. There were no beneficial effects of row covers on yield in either year, presumably because no early-season freezes occurred.**

Prior to the widespread use of commercial fertilizers, vegetable producers relied heavily on livestock manures and crop rotations involving legumes to maintain soil fertility (Kelly, 1990). The poultry industry in the United States contributed >$12 billion to the national economy in 1992 and is projected to grow by 5% per year into the foreseeable future. Several southern states are experiencing rapid growth in poultry production and are significant contributors to the ≈20 million tons of poultry litter (a combination of bedding material and manure) produced annually. In order to economize on transportation costs, poultry is produced in concentrated areas. The litter from these operations is often eliminated by applying it as a fertilizer to nearby pastures and crops, as it contains most mineral elements essential for plant growth (Hileman, 1967; Shipp et al., 1980) and is a valuable alternative to mineral fertilizer N and P in maintaining or restoring soil fertility (Hileman, 1967). Additionally, poultry litter increases soil organic matter, which can benefit crop production by increasing soil water holding capacity, cation exchange capacity, and structural stability. However, the litter can degrade water quality through the leaching of nitrates into ground water and surface runoff of N and P into rivers and lakes (Liebhardt et al., 1979; Westerman et al., 1988). These concerns have helped spur interest in environmentally safe management of poultry litter in cropping systems while maintaining production goals.

Over the past 25 years, plasticulture, or the use of polyethylene mulch to cover the soil, and use of drip or trickle irrigation have increased substantially in commercial vegetable production systems (Ashworth and Harrison, 1983; Loy and Wells, 1975). The benefits of plasticulture include: more favorable soil water and temperature regimes; improved water and fertilizer-use efficiencies; reduced nutrient leaching; increased CO_2 concentration in the air around the plant; reduced soil and wind erosion; higher crop yields; increased plant growth and development leading to earlier crop production; cleaner and higher quality produce; weed suppression; and disease control (Clarkson, 1960; Jones et al., 1977; Perry and Sanders, 1986; Wien and Minotti; 1987). However, no information is available on the use of poultry litter in intensive crop management systems utilizing polyethylene mulch and row covers for the production of triploid watermelon.

Due mainly to their ability to trap heat, polyethylene row covers are often used for the production of early vegetables in several regions of the world (Dalrymple, 1973). Slitted or perforated polyethylene row covers eliminate the need for manual ventilation required with solid plastic row covers (Guttormsen, 1972), have increased day and night soil and air temperatures in several studies (Loy and Wells, 1982; Taber, 1983; Wien and Bell, 1981), and have usually increased early crop yields, although effects on total yields have been variable (Loy and Wells, 1982; Taber, 1983; Wien and Bell, 1981).

Triploid watermelons have become increasingly popular among consumers in recent years and projections indicate that this trend will continue (Karst, 1990). Because of the high cost of seed and poor germination under suboptimal conditions, intensive production systems with seedling transplants appear to be justified (Marr et al., 1991). The objectives of this study were to compare yields, yield components, and leaf and soil nutrient contents of triploid watermelons fertilized with either poultry litter or commercial fertilizer and grown with or without polyethylene mulch or spunbonded floating row covers.

Materials and Methods

Experiments were conducted in 1990 and 1991 on the same plots at the George Millard Farm near Nacogdoches, Tex. The soil is a Darco sandy loam (loamy, siliceous, thermic, Grossarenic Paleudalts). In 1990, treatments included fertilization with poultry litter vs. commercial fertilizer, bare soil vs. black polyethylene mulch, and no cover vs. spunbonded fabric row covers in a 2 × 2 × 2 factorial. The 1990 experiment was arranged as a split-split-plot design with three replications. Fertilizer source was the main plot, mulching the subplot, and row covers the sub-sub-plot. The experiment was conducted on 0.9-m-wide, shaped beds spaced 2.0 m apart, center to center. Each sub-sub-plot consisted of three beds, 6.1 m long, planted to triploid watermelon ('Tiffany'). The seedlings were transplanted by hand and spaced 0.9 m apart within each bed. One pollinizer plant was transplanted at both ends of each bed at the same plant spacing as the triploid plants. Additional pollinizer plants were transplanted in the two outer or border beds on each side of the experimental area. Pollinizer cultivars were 'Royal Jubilee' and 'Mirage' in 1990 and 1991, respectively.

Agricultural grade lime (892 $kg \cdot ha^{-1}$) was applied on 22 Mar. 1990. No additional lime was added in 1991. In 1990, no preplant herbicides were applied while bensulide (*O,O*-diisopropyl S-2-benzenesulfonaminoethyl phosphorodithioate) was preplant incorporated on 26 Mar. 1991 at 5.4 $kg \cdot ha^{-1}$. In both experiments, average commercial analysis ($g \cdot kg^{-1}$)

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of the composted poultry litter was 32N–26P–39K–25Ca–8Mg with a pH of 6.8 and 40 g of water per kilogram. Moist poultry litter (2.7 t·ha^{-1}) was broadcast applied and then incorporated on 3 Apr. 1990; in 1991, it was banded by hand over row centers at a depth of ≈15 to 20 cm on 3 Apr. Commercial fertilizer was applied at 45, 31, and 59 kg·ha^{-1} for N, P, and K, respectively. In both experiments, preplant poultry litter and commercial fertilizer were applied prior to bed formation. All plots received additional N at 17 kg·ha^{-1} by fertigation with KNO_3 through the trickle irrigation system at the beginning of vining. Total nutrients applied were: 52, 28, and 90 kg·ha^{-1} of N, P, and K, respectively, for the poultry litter and 52, 48, and 107 kg·ha^{-1} of N, P, and K, respectively, for the commercial fertilizer source. To test whether these fertilizer rates were in fact adequate for maximum yield, a preplant fertilizer rate was established as a sub-sub-sub-plot in 1991 by halving each 6.1-m length of plot bed into two 3-m sections for both the poultry litter and commercial fertilizer treatments. One of these 3-m sections received the above noted amounts of poultry litter or commercial fertilizer (1X rate) while the other received twice this amount (2X rate).

Both triploid and pollinizer seeds were planted in the greenhouse in flats (cell size 5.1 × 6.4 × 7.6 cm) filled with a commercial peat-vermiculite mix (Fison's No. 2; Sun Gro Horticulture, Bellevue, Wash.) on 6 Mar. 1990 and 15 Mar. 1991. The seedlings were transplanted in the field on 9 Apr. 1990 and 3 Apr. 1991 and fruit were harvested from the center bed of the three beds in each plot on 28 and 25 June in 1990 and 1991, respectively. Fruit were counted and weighed from six plants in the 6.1-m-long sub-subplots in 1990 and three plants from the 3-m-long sub-sub-subplots in 1991. In both experiments, soluble solids concentration of two fruit per plot was determined with a portable, hand-held refractometer. In the interval between the two watermelon experiments, rye (*Secale cereale* L., cv. Elbon), planted 19 Sept. 1990 and harvested 4 Mar. 1991, served as a cover crop.

In both experiments, photodegradable black polyethylene mulch, 1.5 mil thick and 1.2 m wide, was used, while row covers consisted of spunbonded fabric 2.1 m wide. All plots were irrigated through drip tape for equal time intervals both years to avoid drought stress. The row covers weighed 118.4 g·m^{-2} in 1990, while a much lighter fabric weighing 13.5 g·m^{-2} was used in 1991. Both the mulch and row covers were applied on the day of transplanting in both experiments. Row covers were removed on 4 and 2 May in 1990 and 1991, respectively.

Leaf tissues were analyzed in 1990 but not in 1991. Fifteen individual leaves were detached from the sixth node proximal to the growing point at final harvest of each plot for the 1990 experiment. The watermelon leaves were dried and ground to pass a 1-mm sieve. Leaf subsamples were digested at 350 °C using a $LiSO_4$–H_2SO_4–Se–$CuSO_4$ catalyst mixture (Nelson and Sommers, 1980) and analyzed for leaf N content with an ammonium ion electrode (Eastin, 1976).

The soil was analyzed following harvest in both growing seasons and prior to transplanting in 1991 on 6 Mar. Following final harvest in 1990, soil samples were collected from the 0- to 0.15- and 0- to 0.3-m soil depths in each plot on 11 July and prior to transplanting in 1991 for the 0- to 0.3-m soil depths. The samples were air dried and ground to pass through a 2-mm screen prior to analysis. Soil pH and electrical conductivity (EC) were determined in a 1 soil : 2 water mixture. Phosphorus and exchangeable K, Ca, and Mg were extracted from 1.5 g of soil with 30 mL of 1.4 M ammonium acetate–0.025 M H_4EDTA solution adjusted to pH 4.2 with 1.0 M HCl (Hons et al., 1990). This solution was reacted for 1 h on a reciprocating shaker set to 250 cycles/min. Soil nitrate concentration was determined using the copperized cadmium reduction method (Keeney and Nelson, 1982). Phosphorus concentrations in soil extracts were measured by the ammonium molybdate, ascorbic acid procedure (Murphy and Riley, 1962) and in leaf tissue digests by the vanadomolybic acid method (Jackson, 1958). Calcium, Mg, and K in soil extracts and Ca, Mg, and K in tissue digests were determined by atomic absorption spectrophotometry and soil Na by flame emission.

Results and Discussion

Fertilizer source did not significantly affect yield, yield components (Table 1), or leaf tissue nutrient concentrations (Table 2) in 1990. Poultry litter application produced significantly higher levels of postharvest NO_3, P, Ca, and Mg in the upper 0- to 0.3-m soil layer than did application of commercial fertilizer (Table 3). In 1991, both yield and melon numbers were significantly higher for plants fertilized with poultry litter (Table 4). Maynard (1990) also found that fertilization with composted poultry manure resulted in equal or higher yields of several horticulturally important food crop species relative to use of commercial fertilizers.

Doubling both the poultry litter and commercial fertilizer rates in 1991 did not significantly affect yield but did increase average melon mass (Table 4). In 1991, pretransplant soil nutrient levels (data not shown) in the 0- to 0.3-m layer of poultry litter-treated soil were significantly higher only for *P* (40.2 vs. 17.4 mg·kg^{-1}), indicating little differential nutrient carryover among fertilization treatments from the 1990 growing season. Other possible explanations for this effect of fertilizer source on yield include changes in soil physical properties resulting from the additional organic matter in poultry litter, such as increased available soil water capacity (Warren and Fonteno, 1993). Soluble solids of the harvested watermelon fruit averaged 10.3 ± 1.8 and 10.0 ± 1.0 in 1990 and 1991, respectively, but were not significantly affected by any of the treatments.

Yield increases from using mulch were large and highly significant in both growing seasons (Tables 1 and 4). Mulching also increased average individual melon mass in 1990, and both the size and numbers of melons in

Table 1. Interaction of mulch (M) and row cover (RC) treatments on yield and yield components of triploid watermelon grown in 1990. Pretransplant fertilizer source (FS) treatments were poultry litter and chemical fertilizer. Main effect means for FS omitted (NS).

Mulch	Row cover	Yield (Mt·ha^{-1})	Melon no. (1000/ha)	Melon fresh mass (kg/melon)
Yes	Yes	81.7	28.0	3.0
	No	81.3	23.9	3.4
	Mean	---	---	3.2
No	Yes	28.2	34.5	1.9
	No	58.8	23.4	2.6
	Mean	---	---	2.3
Significance of F				
FS		NS	NS	NS
M		0.004	NS	0.010
FS × M		NS	NS	NS
RC		0.016	NS	NS
FS × RC		NS	NS	NS
M × RC		0.015	NS	NS
FS × M × RC		NS	NS	NS

^{NS}Nonsignificant at $P \le 0.05$.

Table 2. Effects of fertilizer source (FS), mulch (M) and row covers (RC) on leaf tissue nutrient concentrations for triploid watermelon grown in 1990. Main effect means for FS and RC omitted (NS).

	N	P	K	Ca	Mg
Mulch			% dry mass		
Yes	4.5	0.6	6.2	2.3	0.6
No	3.7	0.5	5.9	1.8	0.5
Significance of F					
FS	NS	NS	NS	NS	NS
M	0.020	NS	NS	0.021	NS
FS × M	NS	NS	NS	NS	NS
RC	NS	NS	NS	NS	NS
FS × RC	NS	NS	NS	NS	NS
M × RC	NS	NS	NS	NS	NS
FS × M × RC	NS	NS	NS	NS	NS

^{NS}Nonsignificant at $P \le 0.05$.

1991. The benefits of using polyethylene mulch include reductions of nutrient leaching, conservation of soil moisture (Ashworth and Harrison, 1983) and increases in near-surface air and soil temperature (Ham et al., 1993; Wien and Minotti, 1987). Wien et al. (1993) attributed increased aboveground growth of tomatoes grown with polyethylene mulch to enhanced root growth and nutrient uptake. Warming plant roots increases nutrient uptake (Clarkson and Warner, 1979; Kabu and Toop, 1970). For example, nitrogen uptake was stimulated when root temperatures were raised from 13 to 28 °C (Moorby and Graves, 1980). In 1990, postharvest soil nitrate concentration in the upper 0- to 0.3-m soil layer was significantly higher in mulched treatments (Table 3), probably because of reduced nutrient leaching and a warmer, more moist soil environment favorable to promoting greater N mineralization. This higher soil nitrate concentration was associated with significantly greater leaf N concentration (Table 2). Thus, at least part of the yield increase for plants grown with plastic mulch in these experiments can be attributed to improved N nutrition.

Row cover, mulch, and the associated interaction significantly affected yield in 1990 (Table 1). The yield reduction caused by row covers for the nonmulched treatment (Table 1) may have been associated with the physical damage and abrasion of the plants observed when the row covers were removed. This problem was alleviated in 1991 when much lighter weight material was used for the covers. In 1991, row covers did not significantly affect either yield or yield components (Table 4). The reason why the covers did not reduce yield when mulch was used in 1990 (Table 1) is unclear, but may have been associated with the overall improvements in yield and yield components in both experiments, and leaf and soil nutrient concentrations in 1990, when mulch was used. The lack of beneficial effects of row cover on yield in 1991 can be attributed to the absence of frost or low temperatures during this experiment.

Conclusions

We conclude that composted poultry litter is a viable alternative to commercial fertilizers for production of triploid watermelon. Inclusion of an unfertilized overwintering cover crop appears to be one way of reducing the accumulation of soil P for cropping systems utilizing poultry litter as a fertilizer source. Our results indicate that polyethylene mulch increases triploid watermelon production in part by improving N availability and uptake.

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Table 3. Effects of fertilizer source (FS), mulch (M) and row covers (RC) on postharvest soil chemical properties and nutrient concentrations in 1990. Main effect means for RC omitted (NS).

	Soil chemical properties							
		EC	NO_3	P	K	Ca	Mg	Na
Treatment	pH	($dS\cdot m^{-1}$)	($mg\cdot kg^{-1}$)					
			0- to 0.15-m soil layer					
FS								
Poultry	6.1	90.0	9.5	100.9	52.3	871	62.9	35.3
Commercial	6.4	61.9	2.1	37.8	40.1	730	40.7	39.8
M								
With	6.3	85.2	8.0	64.4	54.5	776	54.3	38.7
Without	6.2	66.7	3.7	74.3	37.9	825	49.2	37.6
Significance of F								
FS	NS	0.027	NS	NS	NS	NS	0.034	NS
M	NS	0.019	NS	NS	NS	NS	NS	NS
FS × M	NS	NS	NS	NS	NS	NS	NS	NS
RC	NS	NS	NS	NS	NS	NS	NS	NS
FS × RC	0.050	NS	NS	NS	NS	NS	NS	NS
M × RC	NS	NS	NS	NS	NS	NS	NS	NS
FS × M × RC	NS	NS	NS	NS	NS	NS	NS	NS
			0- to 0.3-m soil layer					
FS								
Poultry	6.0	54.1	2.5	68.0	39.0	481	37.0	36.6
Commercial	6.0	35.2	0.8	31.7	30.5	382	24.6	33.5
M								
With	6.1	50.8	2.4	55.1	36.5	460	35.3	37.6
Without	5.9	38.4	0.9	44.6	33.0	403	26.2	32.6
Significance of F								
FS	NS	NS	0.044	0.012	NS	0.048	0.043	NS
M	NS	NS	0.035	NS	NS	NS	NS	NS
FS × M	NS	NS	NS	NS	NS	NS	NS	NS
RC	NS	NS	NS	NS	NS	NS	NS	NS
FS × RC	0.005	NS	NS	NS	NS	NS	0.004	0.023
M × RC	NS	NS	NS	NS	NS	NS	NS	NS
FS × M × RC	NS	NS	NS	NS	NS	NS	NS	NS

[NS] Nonsignificant at $P \le 0.05$.

Table 4. Main effect of fertilizer source (FS), mulch (M), row cover (RC), and preplant fertilizer rate (R) on yield and yield components of triploid watermelon grown in 1991. Main effect for RC omitted (NS).

Treatment	Yield ($Mt\cdot ha^{-1}$)	Melons (1000/ha)	Melon fresh mass (kg/melon)
FS			
Poultry	92.4	22.5	4.1
Commercial	68.6	18.8	3.4
M			
With	106.0	25.0	4.2
Without	55.0	16.0	3.3
R			
1X[z]	72.4	19.2	3.5
2X	88.6	21.8	4.0
Significance of F			
FS	0.029	0.002	NS
M	0.003	0.011	0.007
FS × M	NS	NS	NS
RC	NS	NS	NS
FS × RC	NS	0.032	NS
M × RC	NS	0.047	NS
FS × M × RC	NS	NS	NS
R	NS	NS	0.019
FS × R	NS	NS	NS
M × SR	NS	NS	NS
RC × R	NS	NS	NS
FS × M × R	NS	NS	NS
FS × RC × R	NS	NS	NS
M × RC × R	NS	NS	NS
FS × M × RC × R	NS	NS	NS

[z] 1X and 2X refer to single and double preplant fertilizer application rates, respectively.

[NS] Nonsignificant at $P \le 0.05$.

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