Pumpkin Fruit Size and Quality Improve with Leaf Mulch

Christian A. Wyenandt[1,4], Joseph R. Heckman[2], and
Nancy L. Maxwell[3]

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Summary. **A key to profitability in many "u-pick" pumpkin (*Cucurbita pepo*) farm operations is producing attractive, marketable fruit while maintaining suitable field conditions for consumer entry during periods of inclement autumn weather. The use of municipal leaves collected from urban areas may help improve fruit quality and field conditions in u-pick pumpkin operations. In 2005 and 2006, an experiment (randomized complete block design) was conducted to compare four different production systems on pumpkin yield and fruit quality. Treatments consisted of no leaf mulch (bare soil) plus herbicide with 25 lb/acre nitrogen (N) sidedressed (treatment 1), leaf mulch without herbicide with 25 lb/acre N sidedressed (treatment 2), no leaf mulch (bare soil) with herbicide with 75 lb/acre N sidedressed (treatment 3), and leaf mulch without herbicide with 75 lb/acre N sidedressed (treatment 4) during the production season. In 2005, there were no differences in the total number and weight of harvested fruit and weight of orange fruit between production systems. Although the presence of leaf mulch reduced the total number and percentage of orange fruit harvested, there were no significant differences in average weight of orange fruit between production systems. Average weight of orange fruit was significantly higher and similar at both sidedress N rates in both leaf mulch production systems compared with bare soil. In 2006, there were no differences in total number of fruit, number of orange fruit, and percentage of orange fruit at harvest between production systems. Total weight, weight of orange fruit, and average fruit weight of pumpkin fruit was significantly higher and similar at both sidedress N rates in both leaf mulch production systems compared with bare soil. Sidedress N should be applied in accordance to plant growth and environmental factors to overcome any expected N deficiency from N immobilization because of the presence of the leaf mulch and other environmental factors. Applying municipal leaves to the soil surface exhibited a marked advantage over bare soil in producing clean fruit. In both years, the percentage of clean fruit at harvest was higher in both leaf mulch production systems compared with bare soil.**

In the United States, pumpkin crops are produced primarily for wholesale, fresh-market, and ornamental use. Pumpkin production increased 6.4% in the U.S. between 2004 and 2005, totaling 1.1 billion lb in 2005 (U.S. Department Agriculture, 2006). An increase in the demand for pumpkin crops over the past decade has been the result of the growing popularity of events such as fall festivals, grade school farm tours, and u-pick crops. Most farms in New Jersey are surrounded by, or are located near, urban and suburban areas; therefore, many farmers operate roadside markets that sponsor agritourism events featuring the fall harvest of pumpkin crops. In 2007, New Jersey harvested 2500 acres of pumpkin, accounting for 5% of U.S. production (Ingerson-Mahar et al., 2007).

A critical aspect of entertainment agriculture, where agritourism is a main focus of the operation, is maintaining attractive fields that are weed-free and in a condition suitable for consumers to enter. Small farm operators near urban areas could apply autumn leaves collected from municipal shade trees to help 1) maintain an attractive field, 2) maintain suitable soil conditions for customer entry, 3) improve cleanliness of u-pick pumpkin fruit, and 4) improve overall soil health with the addition of organic matter to the soil (Heckman and Kluchinski, 2000a, 2000b). Municipal leaves spread over the soil surface may also help to conserve soil moisture, prevent soil erosion, and build soil fertility (Heckman and Kluchinski, 1996, 2000a, 2000b). Another advantage of leaf mulch is that it may serve as an effective barrier to prevent or reduce annual weeds. Leaf mulch residue that persists season-long for crops such as pumpkin may also provide a natural, physical barrier by preventing fruit from coming into direct contact with the soil, thereby resulting in cleaner fruit for consumers to handle and purchase.

Studies conducted to determine the effects of various production systems and mulches on yield, plant and soil moisture properties, soil erosion, weed control, disease, and fertility with various horticultural crops have shown benefits of mulch (Abdul-Baki and Teasdale, 1997; Acosta-Martinez et al., 1999; Christine et al., 1998; Doring et al., 2005; Hasan et al., 2005; Schonbeck 1998; Wyenandt, 2004), but few studies have been done with pumpkin. A study by Rutledge (1999) determined that vetch residue kept weed competition levels low and resulted in higher quality fruit at harvest with a cleaner, glossier, and brighter appearance compared with pumpkins that were conventionally grown.

Leaf mulching on agricultural land may also benefit local municipalities

[1]Extension Specialist of Vegetable Pathology, Department of Plant Biology and Pathology, Rutgers Agricultural Research and Extension Center, 121 Northville Road, Bridgeton, NJ 08302.

[2]Extension Specialist, Department of Plant Biology and Pathology, 59 Dudley Road, New Brunswick, NJ 08901.

[3]Field Researcher IV, Department of Plant Biology and Pathology, Rutgers Agricultural Research and Extension Center, 121 Northville Road, Bridgeton, NJ 08302

[4]Corresponding author. E-mail: heckman@aesop.rutgers.edu.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
1	ppm	$mg \cdot kg^{-1}$	1
0.9072	ton(s)	t	1.1023
2.2417	ton/acre	$t \cdot ha^{-1}$	0.4461
0.7646	$yard^3$	m^3	1.3080

by providing a cost-effective method to use collected leaves. In New Jersey, 5 million cubic yards of leaves are collected each year by local municipalities for composting or use on farms because state regulations prohibit the disposing of leaves into landfills or with local incineration (Derr and Kluchinski, 1995). In 1994 in New Jersey, a study of municipalities and local farm operators who applied municipal leaves to their land indicated that on-farm mulching had the potential to reduce the cost of municipal leaf management while providing organic matter to the soil and monetary incentives to the farmers through tipping fees paid by municipalities to farmers averaging $3.00/yard^3 (Derr and Kluchinski, 1995). However, a potential concern with the use of municipal leaves as a soil-surface mulch in vegetable production is the high carbon to nitrogen ratio (C:N) of shade tree leaves. Shade tree leaves have a C:N ratio of ≈50:1, and heavy applications of such leaves are likely to cause immobilization of soil N (Heckman and Kluchinski, 1995, 1996). The high C:N ratio of leaves would suggest that higher than normal N fertilizer application rate may be necessary when growing vegetable crops such as pumpkin with municipal leaf mulch.

The objectives of this study were to determine the effects of leaf mulch and sidedress nitrogen rate on pumpkin yield and fruit quality.

Materials and methods

The experiment (randomized complete block, four replications) was conducted in a field at the Rutgers University Snyder Research and Extension Farm in Pittstown, New Jersey, in 2005 and 2006. In each year, new field plots (25 × 25 ft) were established on a Quakertown silt loam soil (fine-loamy, mixed, mesic Typic Hapludult). On 13 June 2005, a calcitic limestone was broadcast and incorporated at a rate of 2 tons/acre to the entire field to achieve a target soil pH of 6.5. The four production systems consisted of no leaf mulch (bare soil) with herbicide with 25 lb/acre N sidedressed (treatment 1), leaf mulch without herbicide with 25 lb/acre N sidedressed (treatment 2), no leaf mulch (bare soil) with herbicide with 75 lb/acre N sidedressed (treatment 3), and leaf mulch without herbicide with 75 lb/acre N sidedressed (treatment 4) during the production season.

On 13 June 2005, 250 lb/acre of 20N–1.7P–6.6K and on 12 June 2006, 166 lb/acre of 30N–0P–0K–7S was broadcast and incorporated to the entire field according to preplant soil tests. Each year after seeding, the herbicide containing ethalfluralin and clomazone (Strategy; Loveland Products, Greeley, CO) was applied at a rate of 1.2 lb/acre a.i. of elthalfluralin and 0.38 lb/acre a.i. of clomazone for weed control in bare soil production systems. In each year, no herbicide was applied to either leaf mulch production system. On 14 June 2005 and 13 June 2006, municipal leaves obtained from a local municipality the prior fall were applied to the soil surface to a depth of ≈6 inches using six passes of a New Holland 520 manure spreader (New Holland, Belleville, PA) per plot, with an annual rate equivalent to 20 tons/acre (dry weight). Municipal leaves were uniformly raked by hand in each plot before seeding. On 14 and 13 June 2005 and 2006, 'Magic Lantern' pumpkin (Harris Moran, Modesto, CA) was seeded by hand in two rows spaced 10 ft apart with 2 ft between hills (three seeds per hill) and then immediately hand-watered with 8 fl oz of water. At pumpkin seeding, leaf mulch from each planting row was moved manually by hand to expose the soil surface before seeding and to prevent leaf mulch from hindering germination. After seeding, carbofuran (Furadan; FMC, Philadelphia, PA) was banded over each row at a rate of 3.8 oz per 1000 linear ft for cucumber beetle (*Diabrotica* spp.) control. On 22 July 2005 and 6 July 2006, at about vine tip in each year, the first ammonium nitrate sidedress application was done to all plots at a rate of 25 lb/acre N. On 2 Aug. 2005 and 24 July 2006, an additional 50 lb/acre N of ammonium nitrate was sidedressed on treatment 3 and treatment 4. Each sidedress N fertilizer application was done by hand by placing a narrow band beside each planting row over the soil or leaf mulch surface. Overhead irrigation was applied at 1/2 inch immediately after each sidedressing.

On 6 July 2006, pre-sidedress soil nitrate test (Heckman, 2002) samples were taken by collecting four cores (2 cm diameter × 30 cm deep) between the planting rows of each pumpkin plot. After collection, soil cores were combined by plot and immediately dried and analyzed for nitrate concentration according to the method of Griffin et al. (1995). SPAD readings were done using a chlorophyll meter (model 502; Minolta, Osaka, Japan) to measure relative chlorophyll levels on the most recent mature leaf on 6, 17, and 24 July 2006. In each year, local extension recommendations for insect and disease control and overhead irrigation were followed during the production season.

On 21 Sept. 2005 and 4 Oct. 2006, all pumpkin fruit were harvested from each plot and weighed. Each harvested fruit was visually rated and scored for the presence of residual soil on the fruit surface to determine

Table 1. Production system, additional sidedress nitrogen (N) and SPAD[z] values for 'Magic Lantern' pumpkin at 23, 34, and 41 DAS in 2006.

Production system	Sidedress N (lb/acre)[x]	SPAD reading date: 23 DAS (6 July)	34 DAS (17 July)	41 DAS (24 July)
No mulch	25	34.9 a[w]	46.9 a	42.1
Mulch	25	30.2 b	43.7 b	43.2
No mulch	75	34.8 a	47.4 a	42.9
Mulch	75	29.9 b	44.8 b	44.3
P		0.0001	0.0012	NS

[z]SPAD readings were taken with a chlorophyll meter (model 502; Minolta, Osaka, Japan).
[y]Production systems seeded on 13 June 2005 and 2006 with additional sidedress N applications made on 22 July and 2 Aug. 2005, and 6 July and 24 2006. The mulch systems received 20 tons/acre (44.8 $t \cdot ha^{-1}$; dry weight) of municipal leaves before seeding. The herbicide containing the a.i., ethalfluralin and clomazome, was applied after seeding to systems without mulch for weed control.
[x]1 lb/acre = 1.1209 $kg \cdot ha^{-1}$.
[w]Values followed by the same letters within a column are not significantly different according to Fisher's protected least significant difference at $P \leq 0.05$.
[NS]Nonsignificant.

the percentage of clean (soil-free) fruit per plot. Pumpkin fruit with adhering soil were scored as zero and fruit with no adhering soil were scored as one (clean). Additionally, at each harvest, the total number and weight of orange and green fruit, average weight of orange fruit, percentage of harvested orange fruit, and percentage of clean fruit (free of soil) per plot were calculated. Data were statistically analyzed using SAS (v9.13; SAS Institute, Cary, NC) with Fisher's protected least significant difference (LSD) to determine any significant differences between treatments.

Results and discussion

In both years, pumpkin seedlings in leaf mulch treatments exhibited the yellowing of leaves within 3 weeks after emergence. The N deficiency was quickly overcome in both years with the first application of sidedress N fertilizer. The first sidedress N was applied 16 d earlier in 2006 because the field plot was scouted sooner and N deficiency symptoms were visually observed at a much sooner date in 2006 (6 July) compared with 2005 (22 July). Relative chlorophyll level measurements in 2006 showed lower values in the leaf mulch production systems at 23 and 34 d after seeding (DAS; Table 1). By 41 DAS, pumpkin plant leaves exhibited no difference in level of greenness among treatments (Table 1). These results show that initial crop N deficiency was temporary and that it was quickly corrected by sidedress N application. A presidedress soil nitrate test performed on 6 July 2006 confirmed higher N immobilization of soil nitrate (NO_3) in leaf mulch production systems; soil NO_3 concentration decreased (P = 0.001) from 14 $mg\cdot kg^{-1}$ on bare soil plots to 5 $mg\cdot kg^{-1}$ on mulch plots (data not shown).

In both years, there were no significant differences in the total number of harvested fruit between production systems. In 2005, there were no differences in the total number and weight of harvested fruit and weight of orange fruit between production systems. Although the presence of leaf mulch reduced the total number and percentage of orange fruit harvested, there were no significant differences in average weight of orange fruit between production systems (Table 2). Average weight of

Table 2. Effects of four different production systems on number and weight of total, orange and green fruit, marketable yield, percentage of orange and percentage of clean fruit of 'Magic Lantern' pumpkin in 2005 and 2006.

Production system[z]	Sidedress N (lb/acre)[y]	Total fruit (no.)	Total fruit wt (kg)[y]	Orange fruit (no.)	Orange fruit wt (kg)	Avg. orange fruit wt (kg)	Green fruit (no.)	Green fruit wt (kg)	Market yield (t·ha-1)[x]	Orange fruit (%)	Clean (%)
					2005						
No mulch	25	57	216	49 ab[w]	200	4.1 b	8.5 ab	17 b	34	85 ab	16 b
Mulch	25	48	242	39 bc	217	5.6 a	9.0 a	25 a	37	81 bc	91 a
No mulch	75	59	222	52 a	205	4.0 b	6.5 b	15 b	35	88 a	19 b
Mulch	75	47	229	36 c	199	5.5 a	10.2 a	30 a	34	78 c	93 a
P		NS	NS	0.0244	NS	0.0002	0.0419	0.0021	NS	0.0036	<0.0001
					2006						
No mulch	25	60	217 b	49	178 b	3.7 c	10 ab	34 a	31 b	81	34 b
Mulch	25	60	290 a	55	275 a	5.0 b	4.0 c	11 c	47 a	92	95 a
No mulch	75	61	211 b	49	175 b	3.6 c	11.0 a	32 ab	30 b	80	32 b
Mulch	75	54	308 a	48	289 a	6.1 a	4.5 bc	14 bc	50 a	89	89 a
P		NS	<0.0001	NS	<0.0001	0.0001	0.0549	0.0502	<0.0001	NS	<0.0001

[z]Production systems seeded on 13 June 2005 and 2006 with additional sidedress nitrogen (N) applications made on 22 July and 2 Aug. 2005 and on 6 July and 24 2006. The mulch systems received 20 tons/acre (44.8 $t\cdot ha^{-1}$; dry weight) of municipal leaves before seeding. The herbicide containing the a.i., ethalfluralin and clomazone, was applied after seeding to systems without mulch for weed control.

[y]1 lb/acre = 1.1209 $kg\cdot ha^{-1}$, 1 kg = 2.2046 lb.

[x]Marketable yield includes mature orange fruit at harvest; $1\cdot ha^{-1}$ = 0.4461 ton/acre.

[w]Values followed by the same letters within a column are not significantly different according to Fisher's protected least significant difference at $P \leq 0.05$.

[NS]Nonsignificant.

orange fruit was significantly higher and similar at both sidedress N rates in both leaf mulch production systems compared with bare soil.

In 2006, there were no differences in total number of fruit, number of orange fruit, and percentage of orange fruit at harvest between production systems. Total weight, weight of orange fruit, and average fruit weight was significantly higher and similar at both sidedress N rates in both leaf mulch production systems compared with bare soil.

In both years, the percentage of clean fruit at harvest was higher when pumpkins were grown on leaf mulch compared with bare soil. In 2005, the percentage of clean fruit at harvest was 91% and 93% in leaf mulch systems compared with 16% and 19% in bare soil production systems (Table 2). In 2006, the percentage of clean fruit at harvest was 89% and 95% in leaf mulch systems compared with 32% and 35% in bare soil production systems (Table 2). In both years, a thin mulch layer persisted until harvest and appeared to be an effective barrier in preventing direct contact of pumpkin fruit with the soil. Total rainfall for the months of June, July, August, and September were 5.8, 10.2, 5.6, and 4.4 inches in 2005 and 2.0, 2.2, 0.5, and 5.5 inches in 2006, respectively.

In both years, field observations suggested that leaf mulch was at least as effective at preventing the growth of annual weeds as the herbicide application to the bare soil plots. Using leaf mulch with herbicide applications may help to further reduce weed pressure in u-pick farm operations. Having clean, weed-free pumpkin fields is especially important in u-pick operations where fields must remain aesthetically inviting and accessible to consumers for extended periods during the fall. Using leaf mulch in addition to herbicide applications may be important in fields where early season herbicide efficacy is lost or reduced toward the end of long production season. In addition to potentially reducing the need to use herbicide for weed control, other benefits of using leaf mulch in pumpkin production include soil erosion reduction, long-term contributions to soil fertility, soil health, and soil moisture retention, especially in fields where supplemental irrigation cannot be done.

Conclusions

In this study, pumpkin yields using leaf mulch without herbicide was equivalent or better than conventional bare soil production systems using herbicide with the same equivalent N sidedress applications. In this study, sidedress N application rate had no effect on the total number of fruit produced in bare soil or leaf mulch production systems, however, the average weight of orange fruit increased when pumpkins were grown on municipal leaf mulch. Results suggest that fields with leaf mulch should be monitored closely and sidedress N should be applied accordingly to overcome an expected, but temporary, N deficiency from N immobilization because of the leaf mulch and its affect on soil conditions. Leaf mulch can help produce cleaner fruit and result in field conditions that may enhance public enjoyment of the agritourism experience. For u-pick operations, having fields accessible during wet conditions in the fall is critical. An advantage of leaf mulch is that it prevents soil from adhering to pumpkin fruit and customer shoes and clothing, resulting in a more enjoyable customer experience. Using leaf mulch may also help reduce costs associated with washing fruit if pumpkins have to be cleaned before sale.

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