Kader, A.A. 1985. Modified atmospheres and low-pressure systems during transport and storage, p. 58-64. In: Postharvest technology of horticultural crops. Coop. Ext., Univ. of California. Div. of Agr. and Natural Sci. Special Publ. 3311.

Kader, A.A., D. Zagory, and E.L. Kerbel. 1989. Modified atmosphere packaging of fruits and vegetables. Crit. Rev. Food Sci. Nutr. 28:1–30.

Kawada, K. 1981. Use of polymeric films to extend postharvest life and improve marketability of fruits and vegetables, p. 87–99. In: D.G. Richardson and M. Meheriuk (eds.). Controlled atmospheres for storage and transport of perishable agricultural commodities. Symposium Seriea rapid California procedure in commercial controlled atmosphere facilities.

Rizvi, S.S. 1988. Controlled and modified atmosphere packaging of fruits and vegetables. New York's Food and Life Sci. Quarterly 18:19–23.

Salunkhe, D.K. and M.T. Wu. 1973. Effects of low oxygen atmosphere storage on ripening and associated changes of tomato fruits. J. Amer. Soc. Hort. Sci. 98:12–14.

Smith, S., J. Geeson, and J. Stow. 1987. Production of modified atmospheres in deciduous fruits by the use of films and coatings. HortScience 22:772–777.

Comparisons of Shredded Newspaper and Wheat Straw as Crop Mulches

David A. Munn[1]

Additional index words. **recycled paper, corn, tomatoes, soybeans**

Summary. **This study compared shredded newspaper, wheat straw (*Triticum aestivum* L.) mulch, and bare soil as surface treatments under sweet corn [*Zea mays* L., var. Saccharata (Surt.)], field corn (*Z. mays* L.), soybean [*Glycine max* (L.) Merr.], and processing tomatoes (*Lycopersicon esculentum* Mill.). In a replicated study with limited mechanical weed control and no chemical weed control in 1990, and no weed control except for the mulch in 1991, the mulches provided a cooler, moister soil environment and effective suppression of most annual and some perennial weeds. The rank order of yields was the same for all three crops in 1990: newspaper mulch > wheat straw mulch > bare soil cover. In 1991 the rank order for yield was: soybeans/newspaper mulch > wheat straw > bare soil ($P < 0.01$); field corn/newspaper mulch > bare soil > wheat straw ($P > 0.10$). The straw and newspaper mulches had similar effects on yield, weed control, soil moisture, and soil temperature. They were significantly different from bare soil in many crop and mulch combinations studied. A brief evaluation of high rates of newspaper mulch showed no apparent growth problems for corn and soybeans and no heavy metal accumulation in the soil. Since shredded newspaper from community recycling programs is available at low cost ($40–50/ton vs. $90–100/ton for straw), this material is an attractive soil-management alternative in horticultural and agronomic production systems.**

[1]Associate Professor.

The Ohio State University Agricultural Technical Institute, Wooster, OH 44691.

Mulches are widely used in the production of horticultural crops (Ashworth and Harrison, 1983; Barland, 1990; Robinson, 1988), and crop residue is an important component of conservation tillage systems (Wilhelm et al., 1986). Many communities are under pressure to recycle metal, glass, and paper products to reduce landfill volume and conserve resources (Glen, 1990). Large supplies of newspaper are created in many areas without facilities for repulping this product. The question arises as to whether agriculture could use recycled newspaper in creative and economically feasible ways. Shredded newspaper has been used satisfactorily as bedding for dairy cows (Temple, 1989, 1990). Carter and Johnson (1988) found flat sheets (four thicknesses) of newspaper to be useful in mulching eggplant (*Solanum melongena* L.) but less effective than pine straw (*Pinus* sp. L.) or black plastic mulch at conserving soil moisture and suppressing weeds.

This study was designed to compare the crop mulch value of shredded newspaper with wheat straw at similar application rates and to determine if high rates of newspaper mulch are detrimental to plants or soils.

In 1990 an experiment was conducted to compare bare soil, wheat straw mulch, and shredded newspaper mulch on the yields of sweet corn, soybean, and processing tomatoes. In 1991 the study was repeated with field corn and soybeans. Mulch cover was expected to affect soil moisture, temperature, and weed control and, therefore, plant yields (Barland, 1990).

Materials and Methods

1990 Experiment. In 1990 the experimental site was prepared by four passes with a rear-tine tiller to create a level and loose seedbed free of weeds and trash. The soil used was Glenford silt loam (Aeric Ochraqualfs), a deep, moderately well-drained soil formed on Wisconsin-age glacial lake beds and on terraces along streams. The land in sweet corn and soybeans had been in sweet corn the year before. Because soil test P and K levels were very high (Table 1), starter fertilizer was not used with the sweet corn and soybeans. 'White-N-Gold' sweet corn was planted in 30-inch (0.76 m) rows 24 feet (7.3 m) long on 1 June 1990. Fourteen rows were planted to provide

Table 1. *Soil test results from mulch experiments*[z].

Soil cover	pH 1:1	Buffer pH SMP test	Bray P[y] (lb/acre)	Exch K[x] (lb/acre)	Exch Ca (lb/acre)	Exch Mg (lb/acre)	CEC (meq/100 g)	OM (%)
			Composite samples (10 July 1990)					
Bare	7.0	7.0	374	570	3840	520	12	2.8
Straw	6.9	7.0	418	653	3650	467	12	3.3
Newspaper	7.2	7.0	374	483	4230	449	13	2.9
			Composite samples before planting the two crop areas (May 1991)					
Corn area	6.9	7.0	374	594	3150	562	11	---
Soybean area	7.1	7.0	330	540	3540	492	12	---

[z]*Samples were a composite of 15 cores collected from 0- to 8-inch (0- to 20-cm) depths from each soil cover. The tests were done by The Ohio State Univ. Research Extension Analytical Laboratory according to Standard Soil Test Methods for the North Central Region. Results in lbs/acre ÷ 2 = mg·kg*$^{-1}$.

[y]*Soil levels >100 lb/acre are adequate for corn, soybeans, and tomatoes.*

[x]*Soil levels >300 lbs/acre are adequate for corn, soybeans, and tomatoes.*

12 rows for mulch treatments and one outside row on each side as border rows. Final harvest population averaged 34,000 plants/acre (85,000 plants/ha) by stand counts, which was very high, even with adequate N fertilizer and rainfall. There were some barren stalks and small ears at harvest.

'Redman' soybeans treated with a fresh soybean *Rhizobium japonicum* inoculum were seeded in rows 30 inches wide and 24 feet long on 24 May 1990. Stand establishment was very uniform.

Mulch as shredded newspaper and wheat straw was added in paired rows assigned in a completely randomized design for each crop. Each crop block consisted of two pairs of rows of bare soil, two pairs mulched with straw, and two with newspaper, plus the single border rows on each side, which were not included in the yield measurements. The shredded newspaper was obtained from the Wayne County Salvation Army in strips ≈3/8 inch (1 cm) wide and 24 to 36 inches (61 to 91.5 cm) long at $30–$50/ton (909 kg). Application rates were 3.4 tons/acre (7.6 Mg·ha^{-1}) [depth of mulch, 6 to 8 inches (15 to 20 cm)] for the shredded newspaper and 5.0 tons/acre (11.2 Mg·ha^{-1}) [depth of mulch, 4 to 6 inches (10 to 15 cm)] for the wheat straw. The weights per area are fresh weights of paper and straw.

Six- to 10-inch (15- to 25-cm) 'Ontario 7921' tomato seedlings were transplanted into the field on 25 May 1990. Tomato plants were fertilized individually with ≈3 g dry 32N–3P–10K on 12 June. There were 11 plants per row at a plant spacing of 24 inches (0.61 m) in rows 30 inches (0.76 m) apart.

The tomato experiment was initiated with four single rows of each treatment in a completely randomized design plus single outside border rows. This area had grown cowpeas [*Vigna unguiculata* (L.) Walp.] in 1989. Soil temperatures at the 4-inch (10-cm) depth were obtained on several dates via a metal-stemmed thermometer (Weston Model 2261) with three to four repeated soil temperature measurements in each treatment. Soil cores were collected on 10 July under each soil cover, and the percent moisture by weight was measured. Soil cores were composited from all crops under the same surface cover. The percent moisture was determined by weighing duplicate samples before and after oven drying for ≥48 h at 104C. Soil chemical tests for pH, buffer pH, organic matter, and four key nutrients (P, K, Ca, Mg) were measured in single composite samples from each soil-cover treatment (Table 1).

1991 Experiment. The 1991 study was repeated in the same location as the 1990 work, using corn and soybeans as the crops. Corn followed tomatoes, and soybeans followed sweet corn the year before. The experimental layout consisted of one block each of 16 rows of corn and 16 rows of soybeans each 38 feet (11.6 m). The outer two rows on each side were considered to be border rows leaving 12 rows of each crop for the assignment of mulch treatments. The seedbed was prepared by three passes with a rear-tine tiller. 'Gutwein 2595' hybrid corn was planted on 2 May 1991 in 30-inch (0.76-m) rows at 25,000 plants/acre (10,000 plants/ha). 'Century 84' soybeans were planted on 3 May 1991 to a stand of three plants per foot (30 cm). Because the soil test levels for P and K were very high (Table 1), no fertilizer was used. On 15 May, after emergence, urea was broadcast at 200 lbs N/acre (227 kg·ha^{-1}) and incorporated by rototilling between the rows to a depth of 2 inches (5 cm) between corn rows. This was the only tillage or weed control after seedbed preparation before planting. No tillage or hand weeding was done in the soybeans after seedbed preparation and planting.

The mulch treatments were applied over the rows of established plants on 22 May. Rows were treated in pairs chosen in a completely random design within the 12 available rows. There were two pairs (replications) of rows of bare soil, two of wheat straw mulch at 2 tons/acre (4.48 Mg·ha^{-1}), and two of shredded newspaper mulch at 2 tons/acre (4.48 Mg·ha^{-1}). The source and nature of the paper were the same as in 1990. Yields were measured on individual rows.

The pairs of outside border rows were used in 1991 to evaluate whether high rates of newspaper mulch would be detrimental to the plants or adversely affect soil properties. Six-foot segments (1.83 m) of the two pairs of border rows of both corn and soybeans were used to create plots that received 0, 2, 4, 8, 12, and 16 tons of shredded newspaper mulch per acre (1 ton/acre = 2.24 Mg·ha^{-1}). Leaf tissue was collected from selected treatments to evaluate nutrient status and the possibility of micronutrient excesses. The corn received urea at 200 lbs N/acre (227 kg·ha^{-1}). Soybeans were neither fertilized with N nor inoculated with *Rhizobia* because soybeans were grown successfully (with root nodules) on the same land the previous year. The corn ear leaves at initial silking (11 July) and the upper, fully formed soybean trifoliolate leaves at early flower (30 July)

Table 2. ***Soil temperature measurements at 4-inch depths as influenced by mulch treatment and crop cover in 1990.***

Crop	Date	n	Mean soil temp (°C ± SD)[z]			LSD	
			Bare soil	Newspaper mulch	Straw mulch	0.01	0.05
Tomatoes	26 June	4	21.9 ± 0.55	17.7 ± 0.72	19.4 ± 0.44	1.33	0.94
All crops	3 July	9	20.9 ± 0.66	19.0 ± 0.44	19.4 ± 0.61	1.11	0.83

[z]*Values are averages ± SD of n determinations at the 4-inch (10-cm) depth. Temperature differences were significant among soil covers at* P *= 0.01 at both dates. The impact of crop on soil temperature on 3 July 1990 was not significant at* P *= 0.10.*

were collected by compositing 10 to 12 leaves from each plot of selected treatments. The foliar analyses were done by The Ohio State Univ. Research Extension Analytical Laboratory using the Kjeldahl procedure for N and ICP spectroscopy for the other nutrients.

Eight to 10 soil cores collected on 28 Nov. from 0 to 4 inches (0 to 10 cm) deep on selected plots were composited for analysis for soil organic matter and selected heavy metals: Pb, Cd, Ni, Cr, Cu, and Zn. The paper mulch was scraped away from the soil surface before collecting each sample. Organic matter in the soil was determined by the Walkley–Black procedure, and the metals on samples that were wet-digested with 1:1 HNO_3:$HClO_4$ were taken to volume with deionized water and analyzed by ICP spectroscopy. The metal analyses were done on soil samples from the two replicates of corn border plots and one of the soybean border plots for a total of three replicates. Organic matter was determined on the two replicates from corn and two from soybeans. The combined data were analyzed by one-way analysis of variance (ANOVA).

Table 3. ***Soil moisture content as affected by mulch treatment in 1990 and 1991.***[z]

Mulch treatment	Percent moisture (wt/wt basis)		
	10 July 1990	26 June 1991	17 Sept. 1991
Bare	12.9	10.1	15.7
Straw	20.8	9.5	15.9
Newspaper	21.0	10.2	14.4
LSD (0.05)	1.4	0.2	0.9

[z]*Mulch application rates differed across years. Cores were taken 0 to 8 inches deep in both years. All crop areas were composited together in 1990, whereas only the soybean plots were included in 1991.*

Results and Discussion

1990 Experiment. The 1990 growing season was much wetter (Table 5) and slightly warmer than average (2907 accumulated heat units vs. a 30-year mean of 2677; heat units accumulated per day were calculated as $[(T_{max}°F + T_{min}°F)/2] - 50F$). Both newspaper and straw reduced (P = 0.01) soil temperatures (Table 2) and increased soil moisture content early in the summer (Table 3). Soil temperature beneath newspaper on 26 June was lower (P = 0.01) than beneath straw, which temperature was lower than beneath bare soil. The two mulch materials, while cooler than bare soil (P= 0.01), were not different from each other on 3 July. Soil moisture content was similar between the two mulch materials (Table 2), but it was higher (P= 0.01) than the bare soil in soil cores collected from the 0- to 8-inch (0- to 20-cm) depth on 10 July.

No statistical comparisons of soil chemical test results were made, but the data appeared similar across bare soil, straw, and newspaper mulch treatments (Table 1). While the mulch covers were very heavy at the time of application, they broke down over the growing season until very little surface residue was left by 24 Oct., when soybean harvest was complete.

Yields of sweet corn and processing tomatoes (Table 4) were affected by mulch cover at P< 0.10 and P< 0.05, respectively. Soybean yields (Table 4) followed the same trends, but the results did not differ (P > 0.10) among treatments for soybeans. Corn and soybean yield increases associated with plant-residue mulches have been attributed to greater soil water supply (Skekour et al., 1987) and to soil water and soil temperature differences associated with the mulch treatments (Wilhelm et al., 1986), and with improved weed suppression (Crutchfield et al., 1985). The mulched tomato plants were larger, with more vines and fruit, than those grown on bare soil. This is consistent with the report of Olansantan (1985). The biggest plants were noted on the newspaper mulch treatment. The highest yields for all three crops came in the rows mulched with shredded newspaper, and the lowest yields were under bare soil conditions. The two mulches had similar impacts on soil temperatures,

Table 4. ***Yields as affected by soil mulch treatments in both years.***

Soil cover[z]	1990			1991	
	Sweet corn[y] (dozen/acre)	Soybeans[x] (bushels/acre)	Tomatoes[w] (tons/acre)	Corn (bushels/acre)	Soybeans (bushels/acre)
Bare	530	41	15.5	62	11.7
Straw	923	45	20.5	59	15.4
Newspaper	1074	47	24.6	74	17.6
LSD	263 (0.10)	NS (0.10)	5.8 (0.05)	NS (0.10)	2.5 (0.05)

[z]*The rates of mulch applied were different in the two seasons.*
[y]*Dozens/acre × 2.5 = dozens/ha..*
[x]*Bushels/acre × 60 lb/bushel = lb/acre × 1.12 = kg•ha^{-1}.*
[w]*Tons/acre × 2.24 = Mg•ha^{-1}.*

Table 5. ***Precipitation data for 1990 and 1991 on the OARDC campus, 3 miles (4.8 km) from the experimental site.***

Month	Precipitation (monthly/season totals in inches) 1990	1991	Long-term avg
May	4.94	2.64	3.96
June	2.45	1.67	3.99
July	6.80	0.86	4.19
August	4.49	3.07	3.70
September	4.53	2.63	3.16
October	4.57	1.08	2.35
Totals	27.78	11.95	21.35

soil water content, and weed suppression.

Weed control benefits from the mulch deserve separate mention. All rows of plants were rototilled lightly [2 to 3 inches (5 to 7.5 cm) deep] before mulch application. No further mechanical weed control or chemical weed control was conducted. There was heavy weed pressure in the area used for the experiment.

1991 Experiment. The 1991 growing season was different from 1990. The precipitation was much lower than the 30-year mean (Table 5). For the same period (1 Apr.–30 Oct.) in 1991 there were 3590 heat units, 854 more than the 30-year average at Wooster, Ohio. Yields of both crops were rather low across all treatments because of drought (Table 4). The soybean yields from the straw and newspaper mulch treatments were not significantly different at $P = 0.05$, although both mulches gave significantly higher yields than the bare soil treatment. The corn yields were more variable; and while newspaper mulch had the highest yields, straw and bare soil were very similar, and no treatment effects were significant at $P = 0.10$.

In 1990 weed problems seemed to be a key factor in crop yield, but no detailed weed control ratings were made. Both mulches suppressed small annual weeds effectively. Neither mulch suppressed rough pigweed (*Amaranthus retroflexus* L.), nor were they effective in suppressing perennials such as Canada thistle [*Cirsium arvense* (L.), Scop.] or yellow nutsedge (*Cyperus esculentus* L.). Low-growing annuals such as common ragweed (*Ambrosia artemisiifolia* L.) and several annual grasses were heavy in the bare soil rows. These weeds both reduced yield and interfered with hand harvest of the tomatoes. Weed problems were greatest in tomatoes, which were, as expected, the least competitive crop in suppressing weeds. The wheat straw used was clean and relatively weed and weed-seed free. However, weedy hay or straw used as mulch can actually introduce more or different weed seeds. Shredded newspaper, in addition to its lower cost and superior smothering of weeds, is free of weed seed.

In the 1991 experiment, no herbicides were used nor mechanical or hand-weeding done. In every case, shredded newspaper provided the best weed control (Table 6). Straw was significantly less effective than shredded paper ($P < 0.05$) in suppressing weeds but was superior to bare soil at the same level of significance. Weed control was a likely key in these studies to yield differences among mulch treatments. Mulch treatment affected weed control scores more than yield or soil properties in the 2nd year of this work.

Soil temperatures on virtually every date observed were not significantly different ($P = 0.05$) between newspaper and straw, but the two mulches were always significantly cooler ($P = 0.05$) than the bare soil treatment (Table 7). These temperature differences were most apparent in June, as cool soil was still warming up. In the hot, dry weather of 28 Aug. and 17 Sept., the temperatures were not significantly different across treatments.

Soil moisture contents in cores at the 0- to 8-inch (0- to 20-cm) depth collected on 26 June and 17 Sept. were very similar (≈10%), even though there were significant differences in some cases (Table 3). Although higher in September, soil moisture contents were again similar across the treatments (≈15%). The results of 1990 (the wet year) and of the published literature where mulches resulted in more stored soil moisture were not seen in 1991.

The border rows of both corn and soybeans had been used to create duplicate small plots mulched with rates of 0, 2, 4, 8, 12, and 16 tons/acre. Plant leaf samples were collected at the appropriate growth stage for corn and soybeans. The means of duplicate results for several levels of mulch were calculated and compared with sufficiency ranges of most soil-supplied essential elements as reported in the *Ohio Agronomy Guide* (1988)(Table

Table 6. ***Weed control scores for several mulch conditions in corn and soybeans in 1991.***

Crop and surface mulch cover	Date and weed control score[z] 14 June	26 June	11 July	18 July	24 July	8 Aug.	28 Aug.	12 Sept.	Season mean
Corn									
Bare	8.5	9.3	8.5	7.5	6.5	5.5	5.0	6.5	7.4
Straw	5.0	5.8	5.5	5.0	4.5	3.0	3.5	3.5	4.2
Newspaper	1.5	5.3	4.0	3.0	3.5	2.5	2.5	3.0	3.5
LSD 0.05	1.6	1.6	1.6	1.1	1.6	1.6	1.6	1.6	0.5
Soybeans									
Bare	7.5	7.8	7.0	6.5	7.0	6.0	6.0	7.5	6.9
Straw	5.0	4.5	5.0	5.5	4.0	4.5	4.5	6.0	4.9
Newspaper	2.5	3.3	3.5	2.5	3.5	4.0	3.5	5.5	3.5
LSD 0.05	1.7	1.7	1.7	1.2	1.7	1.7	1.7	1.7	0.6

[z] *1 = No weeds; 10 = severe infestation*

Table 7. *Average soil temperature at 4-inch (10-cm) depth for several mulch conditions in 1991.*

Crop and surface mulch cover	Date of measurement and soil temp (°C) at 4-inch (10-cm) depth: 3 June	14 June	26 June	18 July	28 Aug.	17 Sept.	Season mean
Corn							
Bare	23.5	19.6	21.6	*	25.0	22.2	22.3
Straw	21.7	18.5	20.3	*	24.6	22.2	21.6
Newspaper	21.8	18.3	20.7	*	24.2	21.8	21.4
LSD 0.05	0.77	0.67	0.67	---	0.67	NS	0.28
Soybeans							
Bare	23.9	20.6	23.3	27.4	25.7	23.8	24.1
Straw	22.1	18.6	21.3	23.8	25.4	22.8	22.3
Newspaper	21.7	18.1	21.0	24.1	25.6	23.5	22.9
LSD 0.05	1.56	1.39	1.39	1.39	NS	NS	0.56

**Thermometer broken in dry compact soil.*

8). The levels of duplicates were similar and within levels considered sufficient for most nutrients by Ohio research guidelines. Some N deficiency was noted across all corn plots (Table 8). Dry weather may have limited N mobility and uptake. Soybean N levels were sufficient at all levels of mulch. The fact that the newspaper mulch was applied on the soil surface and not incorporated by tillage may have minimized any N-immobilization effect in the first year. Corn was marginal in P and soybeans were marginal in K, but these levels were not related to rates of newspaper mulch (Table 8). Again, this may have resulted from drought, since soil P and K levels were quite high (Table 1).

Soil samples were collected from selected plots to evaluate organic matter and several heavy metals. Analysis of variance showed no treatment-related differences in organic matter or the metals Pb, Ni, Cr, Cu, and Zn (Table 9). The metal Cd was not reported in Table 9, but it was <0.33 $mg \cdot kg^{-1}$ in every sample analyzed. These findings are heartening in the case of the metals and somewhat surprising in that no organic matter buildup was noted. Yields are not reported because these plots were border rows, but the corn yields were measured and were not significantly affected by rate of mulch applied when evaluated by one-way ANOVA or linear regression techniques. McGrath (1991), in highlighting several projects evaluating newspaper as compost and mulch, reported no marked increase in polychloroaromatic hydrocarbons in wheat crops grown with shredded newspaper compared with that grown in peat. Heavy metals were not reported.

Wheat straw was an effective crop mulch cover for the reduction of high soil temperatures, conservation of moisture, and suppression of weeds. This agrees with previous results (Crutchfield et al., 1985). An unexpected result was that shredded newspaper, available at low cost from cities with recycling programs, was apparently just as effective as or even superior to wheat straw at keeping the soil moist and cool and in suppressing competing weeds at 2.0 or 3.4 tons/acre. There was no apparent short-term (6 months after application) impact of high rates of newspaper on soil chemical properties such as organic matter or selected heavy metals. Very little troublesome residue was left on the soil surface at season's end to interfere with fall or spring tillage and preparation for a winter cover crop or next season's crops except in plots receiving ≥8 tons of newspaper mulch/acre. Using this low-cost product in agronomic and horticultural mulches, like using it in animal bedding, helps in community recycling efforts and saves landfill space.

Literature Cited

Ashworth, S. and H. Harrison. 1983. Evaluation of mulches for use in the home garden. HortScience 18(2):180–182.

Barland, J. 1990. Mulch—Examining the facts and fallacies behind the uses and

Table 8. *Plant analysis from corn and soybeans mulched with incremental amounts of shredded newspaper.*

Mulch rate (tons/acre)	Elemental concn in plant tissue[z]: N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	B (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)	Mo (ppm)
Corn													
0	2.11	0.27	2.37	0.54	0.22	36	77	14.0	6.5	22	30	8.2	1.01
4	2.58	0.29	2.32	0.59	0.22	34	81	12.0	8.1	23	25	5.6	1.31
8	2.30	0.31	2.53	0.55	0.22	32	83	9.9	7.8	23	38	4.7	1.17
16	2.12	0.27	2.36	0.58	0.21	30	75	8.4	6.8	21	23	5.7	1.27
Sufficiency[y] Range	2.90- 3.50	0.30- 0.50	1.91- 2.50	0.21- 1.00	0.16- 0.60	20- 150	21- 250	4- 25	6- 20	20- 70	20- 300	100- 300	---
Soybeans													
0	4.48	0.27	1.71	1.36	0.20	71	125	74	8.1	62	14	<5.0	---
4	4.67	0.30	1.93	1.33	0.25	75	126	73	8.3	68	13.3	<5.0	---
8	4.95	0.32	1.94	1.32	0.22	100	131	77	8.1	68	26	<5.0	---
16	4.83	0.30	1.86	1.24	0.21	76	126	67	8.3	62	---	<5.0	---
Sufficiency[y] Range	4.25- 5.50	0.30- 0.50	2.01- 2.50	0.36- 2.00	0.26- 1.00	21- 100	21- 55	4- 25	10- 30	21- 50	20- 300	100- 300	1.0- 5.0

[z]*Mean of duplicate samples.*

[y]*Ohio Cooperative Extension Service Agronomy Guide (1988), p. 20. A level considered normal or adequate for satisfactory plant growth.*

Table 9. *Soil test from plots receiving graded levels of newspaper mulch*[z].

Rate of mulch[y] (tons/acre)	Organic matter (%)	Pb	Ni	Cr	Cu	Zn
				($mg\cdot kg^{-1}$)		
0	3.2 ± 0.13	93 ± 6	22 ± 2	26 ± 3	25 ± 4	134 ± 30
4	3.2 ± 0.18	---	---	---	---	---
8	3.2 ± 0.27	72 ± 11	21 ± 2	29 ± 5	23 ± 6	122 ± 17
16	3.1 ± 0.30	91 ± 39	22 ± 2	28 ± 3	23 ± 6	157 ± 62

[z]*Values in the table are means±SD. No results were significantly different at $P = 0.10$ by one-way ANOVA. There were four replications for organic matter and three for metal analyses.*
[y]*Tons/acre × 2.24 = $Mg\cdot ha^{-1}$*

benefits of mulch. Amer. Nurseryman 172(4):132–141.

Carter, J. and C. Johnson. 1988. Influence of different types of mulches on eggplant production. HortScience 23(1):143–145.

Crutchfield, D.A., G.A. Wicks, and O.C. Burnside. 1985. Effect of winter wheat (*Triticum aestivum*) straw mulch level on weed control. Weed Sci. 34:110–114.

Glen, J. 1990. Curbside recycling reaches 40 million. Biocycle 31(7):30–37.

McGrath, M. 1991. Newspaper in the garden, round two (newspapers as compost). Organic Gardening 38 (Sept./Oct.):16.

Ohio Agronomy Guide. 1988. 12th ed., Ohio Coop. Ext. Serv. Bul. 472. p. 20–29.

Olansantan, F.O. 1985. Effects of intercropping, mulching, and staking on growth and yield of tomatoes. Expt. Agr. 21:135–144.

Robinson, D.W. 1988. Mulches and herbicides in ornamental plantings. HortScience 23(3):547–552.

Skekour, G.M., R.A.I. Brathwaite, and C.R. McDavid. 1987. Dry season sweet corn response to mulching and antitranspirants. Agron. J. 79:629–631.

Temple, G. 1989. Potential uses and problems of using shredded paper for animal bedding. Penn. Ext. News (May) no. 08801720, Coop. Ext. Service, Penn State Univ., State College.

Temple, G. 1990. Newsprint gets farmer and livestock okay. Biocycle 37(9):60–63.

Wilhelm, W.W., J.W. Doran, and J.F. Power. 1986. Corn and soybean yield response to crop residue management under no-tillage production systems. Agron J. 78:184–189.

Acknowledgements

Research conducted at the Agricultural Technical Institute Apple Creek Farm, Apple Creek, Ohio. Appreciation is expressed to two of my undergraduate students, Cheri Nemes and Craig Kramer, who helped plan, plant, and mulch the corn and soybeans in 1991 as part of a special problem in a plant research practices course. Also, I gratefully acknowledge support for this work in the amount of $500 provided as a scholarly activity seed grant by my institution.

Postharvest Performance of Southern Highbush Blueberry Fruit

Gregory A. Lang and Jiaxun Tao

POSTHARVEST HORTICULTURE

Additional index words. **_Vaccinium_ spp. hybrids, early market, fruit quality, storage life, shelf life**

Summary. **The postharvest performance of early ripening southern highbush blueberries 'Sharpblue' and 'Gulfcoast' was evaluated under storage and simulated retail conditions. In general, 'Gulfcoast' fruit were 28% heavier than those of 'Sharpblue', which had a higher percent soluble solids concentration (SSC) and lower titratable acidity (TA). Quality loss, as indexed by fresh weight, percent decayed fruit, or changes in SSC, pH, or TA, was insignificant in first-harvest fruit of either cultivar when kept in storage (2C) for up to 7 days. Transfer of fruit stored at 2C for 3 days to simulated retail conditions at 21C for 4 days significantly increased fresh weight loss and decay, but not beyond levels deemed unmarketable. Second-harvest fruit were smaller than first-harvest fruit, and those of 'Sharpblue' fruit were more prone to decay. However, storage quality of both cultivars was acceptable through 11 days at 2C. Retail quality, as influenced by decay incidence, was acceptable after 3 days at 2C plus 4 days at 21C, but not after 3 days at 2C plus 8 days at 21C. Overall, fruits of these early ripening southern highbush blueberry cultivars performed well under postharvest conditions and are suitable for expanding production of premium fresh blueberries by growers in the Gulf coastal plains.**

Department of Horticulture, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA 70803.

Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript no. 91-28-5397. We thank A.M. Saxton for statistical advice and N.S. Lang, D.H. Picha, and E.E. Puls for their critical reviews of the manuscript.