11. Gould, A.R. 1986. Factors controlling generation of variability *in vitro*. Cell Culture and Somatic Cell Genetics of Plants. Vol. 3. I.K. Vasil Ed. Academic Press, Inc. Boston. p.549–565.

12. Groose, R.W., and E.T. Bingham. 1984. Variation in plants regenerated from tissue cultures of tetraploid alfalfa heterozygous for several traits. Crop Sci. 24:655–658.

13. Karp, A. 1989. Can genetic instability be controlled in plant tissue culture. Inter. Assoc. Plant Tissue Culture Newsletter. 58:2–11.

14. Kavanagh, J.A., S.A. Hunter, and P.J. Crossan. 1987. Micropropagation of catawba hybrid rhododendrons, 'Nova Zembla', 'Cynthia', and 'Pink Pearl'. Proc. Intern. Plant Prop. Soc. 36:264–272.

15. Knuttel, A.J. 1989. Tissue culture troubles. Amer. Nurseryman. 170(11):43–48.

16. Lloyd, G. and B. McCown, 1980. Commercially-feasible micropropgation of mountain laurel, Kalmia latifolia, by use of shoot-tip culture. Proc. Intern. Plant Prop. Soc. 30:421–437.

17. McCown, B.H., and G.B. Lloyd. 1983. A survey of the response of *Rhododendron* to *in vitro* culture. Plant Cell Tissue Organ Cult. 2:77–85.

18. Rosati, P., D. Goggioli, and L. Giuchi. 1986. Genetic stability of micropropagated loganberry plants. J. Hort. Sci. 61:33–41.

19. Sinden, S.L., and J.F. Shepard. 1983. Variation at the cellular level. HortScience. 18:837–840.

20. Sutter E., and R.W. Langhans. 1981. Abnormalities in chrysanthemum regenerated from long term cultures. Ann. Bot. 48:559–568.

21. Tamura, M., R.Tao, and A. Sugiura. 1992. Highly stable regeneration from long-term cultures of Japanese persimmon callus. HortScience. 27:1048.

22. Torrey, J. 1967. Morphogenesis in relation to chromosomal constitution in long term plant tissue cultures. Physiol. Plant. 20:265–275.

23. Votruba, R., and K. Kodytek. 1988. Investigation of genetic stability in *Chrysanthemum morifolium* 'Blanche Poitevine Supreme' after meristem culture. Acta Hort. (226):311–319.

24. Westerhof, J., F.A. Hakkaart, and J.M.A. Versluijs. 1984. Variation in two *Begonia x Hiemalis* clones after *in vitro* propagation. Scientia Hort. 24:67–74.

25. Zimmerman, R.H. 1990. Variation in tissue culture propagated plants. Proc. Intern. Plant Prop. Soc. 40:455–462.

Chopped Newspaper for Weed Control in Nursery Crops[1]

Norman E. Pellett and David A. Heleba[2]
Department of Plant and Soil Science
University of Vermont, Burlington, VT 05405

Abstract

Chopped newspaper was evaluated as a weed control mulch for nursery row crops. Newspaper mulch at 2.3 and 3.6 kg/m^2 [4.2 lb/yd^2 (≈ 10 cm or 4 in depth) and 6.3 lb/yd^2 (≈ 15 cm or 6 in depth), resp.] suppressed weed germination for two seasons without a negative effect on *Daphne burkwoodii* 'Carol Mackie', *Physostegia virginiana*, and *Salix caprea*. *Gaillardia grandiflora* had less growth when mulched with newspaper during one experiment, but not in another. The authors observed that wetting the newspaper mulch after application followed by compression with a lawn roller pressed the paper into a mat which resisted blowing and weathering. Further reduction in blowing of paper mulch was achieved by applying a tackifier after rolling. Bark mulch at 19.4 dm^3/m^2 (988 in^3/yd^2 ≈ 10 cm or 4 in depth) resulted in weed suppression comparable to either of the two rates of newspaper mulch and better than bark at 9.7 dm^3/m^2 (494 in^3/yd^2 ≈ 5 cm or 2 in depth). All mulch treatments moderated maximum soil temperatures on July 5, 1993 at 7.5 cm (3 in) depth by more than 10C (18F) when non-mulched soil increased to 36C (96.8F). The rate or type of mulch applied resulted in similar summer soil temperatures at 2.5 and 7.5 cm (1 and 3 in) soil depth.

Index words: paper, mulch, weed suppression.

Species used in this study: Carol Mackie daphne (*Daphne burkwoodii* Burkwood. 'Carol Mackie'); Goblin gaillardia (*Gaillardia* x *grandiflora* Hort. 'Goblin'); crown of snow physostegia (*Physostegia virginiana* Benth. 'Crown of Snow'); and goat willow (*Salix caprea L.)*.

Significance to the Nursery Industry

Weeds are a continual problem in nursery production and in landscape maintenance. Many growers use herbicides for weed control, but the environmental hazards, real and perceived, are creating a need for alternatives. Organic or plastic mulches are sometimes useful alternatives. Grain straws, peanut hulls, sawdust, bark and many other locally available organic materials are used by nurseries and landscapers for mulch; however, they are not all readily available or reasonably priced in some regions. This study demonstrated that chopped newspaper mulch provided acceptable weed control in nursery row crops. The higher mulch rate resulted in weed suppression for two seasons and showed little decomposition by May of the third season. Rolling the wetted paper after application provided a dense uniform mat which appeared to resist weathering and blowing by wind.

Introduction

Newspaper is an organic material which contributes high volumes to landfilling, but is finding new uses. Chopped newspaper is currently used for livestock bedding, and subsequently, distributed on crop fields mixed with animal wastes as fertilizer (4, 6). Chopped newspaper has proven

[1]Received for publication July 15, 1994; in revised form January 23, 1995.

[2]Professor and Research Technician, respectively. Project supported in part by the Vermont Association of Professional Horticulturists.

effective as an insulating cover for container grown nursery plants (8). There has been some concern about heavy metal content in the ink. Color newsprint mulch slightly increased levels of lead in vegetables, millet and apples in a 1979 report (5). However, lead and other heavy metals have been greatly reduced in newspaper print in recent years with increased use of soybean oil as a base for the ink (3). When used on non-food nursery crops, low heavy metal concentrations may not pose a problem. Munn (7) showed no increase in heavy metals in soils mulched with shredded newspaper at 7.6 Mg/ha (3.4 tons/A) in 1991.

The 1990 cost of baled chopped newspaper for livestock bedding in Wisconsin was $60 per ton (4) and $40 to $50 per ton in a 1990 Ohio study (7). Sheets of newspaper have been used successfully for weed control among rows of eggplant (2) and conifer seedlings (10). Newspaper mulch provided acceptable control of annual weeds and no reduction in growth of sweet corn, field corn, soybeans and tomatoes (7) and strawberries (1). Shredded newspaper and wheat straw mulches provided cooler, moister soil conditions than non-mulched soil (7).

Our study evaluated the weed suppression potential of chopped newspaper over two seasons and determined its effect on selected perennial nursery crops and soil temperature. We also compared the effect of chopped newspaper with bark mulch on weed control on perennial nursery crops and on summer soil temperatures.

Materials and Methods

General procedures. Experiment one began in 1992 and continued during 1993 when additional paper mulch was applied to selected treatments to determine if additional mulch was necessary for successful weed control. Plants were field planted from #100 [12 cm (4.8 in) diameter and depth] containers at the University of Vermont Horticultural Research Center in South Burlington and irrigated twice weekly (≈ 2 cm of water). The soil was Windsor loamy sand (Entic Haplorthods). A green manure crop of buckwheat (*Fagopyrum esculentum*) was rototilled into the soil during the autumn before planting each experiment. Soil was prepared for spring planting by rototilling one day prior to planting. All weeds growing during the experiments started from seed; there were no residual crowns or rhizomes in the soil. Baled chopped newspaper was purchased from a supplier who acquired the newspaper at Vermont landfills where citizens brought their paper for recycling.

Experiment 1. Five mulch treatments were applied on May 21, 1992 to three plant taxa that had been planted 0.4 m (1 ft) apart in rows 0.9 m (3 ft) apart one week earlier from containers. The taxa were *Daphne burkwoodii* 'Carol Mackie', *Gaillardia grandiflora* 'Goblin', and *Physostegia virginiana* 'Crown of Snow'. *Daphne* cuttings were taken June 1991 and *Gaillardia* and *Physostegia* were started from seed in March, 1992. After field planting from containers, each plant was top dressed with approximately 9 g (one tbsp) of 10N-5.1P-8.3K (10-10-10) granular fertilizer.

The five mulch treatments were randomized in each of four blocks. In each treatment within each block there were eight *Daphne* and six each of *Gaillardia* and *Physostegia*. The treatments applied to 7 m^2 plots (5 × 15 ft) were: 1) no mulch, 2) 2.3 kg/m^2 newspaper (low paper, 4.2 lb/yd^2 ≈ 10 cm or 4 in depth) , 3) 2.3 kg/m^2 newspaper with a tackifier (Hydro-stik™ used in hydroseeding, Finn Corporation, Fairfield, OH) applied as coarse spray at 4.3 g/m^2 in 9.5 liters of water to surface of mulch (low paper with tackifier), 4) 3.6 kg/m^2 newspaper (high paper, 6.3 lb/yd^2 ≈ 15 cm or 6 in depth), and 5) 3.6 kg/m^2 newspaper with tackifier (high paper with tackifier). After applying fluffed newspaper mulch, all plots were irrigated with approximately 1.5 cm (0.6 in) of water and rolled with a lawn roller [61 cm (24 in) wide, 45.7 cm (18 in) diameter] approximately ¾ full of water.

On May 27, 1993, the 1992 low and high paper treatments were re-mulched with 1.4 kg/m^2 (2.6 lb/yd^2 ≈ 7.5 cm or 3 in depth) of fluffed chopped newspaper without tackifier. All plots were irrigated and rolled to hold the paper in place as previously described.

Weeds in each plot were counted on June 17, July 16 and September 9, 1992. Three random areas 0.09 m^2 (1 ft^2) were counted in the non-mulched plots and the numbers averaged for the three samples and multiplied by the number of square feet per plot to estimate the total number of weeds per plot. All weeds were counted in the mulched treatments. Weeds, predominately annuals including foxtail (*Setaria* species), crabgrass (*Digitaria* species), and lambsquarter (*Chenopodium album*), were removed by hand after each count.

Gaillardia and *Physostegia* stems and leaves were harvested at 7.5 cm (3 in) above ground on August 20, 1992, and dry weights were determined [dried seven days at 55C (131F) and weighed] as a measure of growth. Total length of *Daphne* stems was measured on August 28, 1992. During the second season, *Daphne* stems and leaves were harvested August 24, 1993, at one cm above ground, and dry weights were determined as a measure of growth.

Soil samples, 5 cm (2 in) deep, were taken after the second season (May 6, 1994) from the non-mulched and the low paper treatment which did not receive tackifier nor additional mulch in 1993. The purpose was to determine the effects of leaching and/or mulch decomposition on metals and plant nutrients in the top soil layer. Fifteen core samples were composited from each of two replicates of the two treatments and analyzed for plant nutrients and heavy metals (9).

Experiment 2. Five mulch treatments were applied on May 27, 1993 to three taxa, *Gaillardia* , *Physostegia* and *Salix caprea* which had been planted from containers, three days earlier, 0.3 m (1 ft) apart in rows 0.9 m (3 ft) apart. After field planting, all plants were fertilized as in 1992.

Treatments were applied in a randomized block design with four replications of eight *Salix* and six each of *Gaillardia* and *Physostegia*. Treatments applied to 7 m^2 plots were 1) no mulch, 2) 2.3 kg/m^2 newspaper (low paper, 4.2 lb/yd^2 ≈ 10 cm or 4 in depth), 3) 3.6 kg/m^2 newspaper (high paper, 6.3 lb/yd^2 ≈ 15 cm or 6 in depth), 4) 9.7 dm^3/m^2 native softwood bark (low bark, 494 in^3/yd^2 ≈ 5 cm or 2 in depth), and 5) 19.4 dm^3/m^2 native bark (high bark, 988 in^3/yd^2 ≈ 10 cm or 4 in depth). After applying fluffed chopped newspaper mulch, the plots were irrigated and rolled as in 1992.

Weeds in each plot were counted on July 19, August 16, and September 17, 1993 as in Experiment 1 and all were removed from the plots after each count. Dry weights were determined for stems and leaves of *Gaillardia* and *Physostegia* cut 7.5 cm (3 in) above the ground level and

Salix cut 2 cm (0.8 in) above ground level in late August 1993.

Ten soil cores 15 cm (6 in) deep were made on November 11, 1993 at the end of the first growing season from two replicates of each treatment. The cores from each replicate were composited and analyzed as two samples for plant nutrients as discussed for 1992 (9).

Soil and air temperatures were measured daily during June and July, 1993 at 5:30 AM and 3:30 PM by copper-constantin thermocouples and recorded by Honeywell Multipoint Recorder. Ambient air temperature was measured at 1.5 m height in a ventilated shelter and soil temperatures under each treatment were measured at 2.5 and 7.5 cm deep (1 and 3 in, resp.).

Results and Discussion

Experiment 1. Tackifier treatments had no effect of weed control therefore the data was combined with non-tackifier treatments of the same rate of mulch. Paper mulch resulted in almost complete weed suppression during the first growing season and acceptable weed control during the second season (Table 1). Both paper mulch rates resulted in less than five weeds/m^2 on each sampling date in 1992. Additional paper mulch applied in May of the second season, 1993, provided better weed suppression than for plots mulched only during the first season. However, the high first year mulch rate provided acceptable weed control during the second year without additional mulch. The low paper treatment without further remulching had more than two times higher weed numbers on second season sampling dates than low and high remulched treatments or the first year high mulch treatment. Application of the tackifier after rolling wet paper inhibited the paper from blowing better than paper without tackifier although the latter remained in place well enough to give weed suppression (author's observation). Applying the tackifier to non-rolled newspaper in a separate, unreported experiment stabilized paper pieces from blowing, however, in windy locations, whole sections of intact mulch were turned over.

Table 1. Effect of chopped newspaper and bark mulches on number of weeds[z]/m^2.

Treatments[y]	Weed counts			
Experiment 1—1992	**June 9**	**July 16**	**September 9**	
No mulch (N)	1969.0	323.8	203.6	
Low paper (Lp)	0	3.4	4.0	
High paper (Hp)	0	2.4	1.4	
Contrasts[x]				
N vs. Lp + Hp	**	**	**	
Lp vs. Hp	NS	*	**	
Experiment 1—1993	**June 15**	**July 14**	**August 16**	**September 17**
No mulch (N)	1471.1	745.4	151.6	108.5
Low paper, 1992 (Lp)	15.6	35.6	11.0	9.6
High paper, 1992 (Hp)	2.7	8.5	4.4	4.6
Low paper 1992, remulch (Lpr) 1993	0	3.7	0.8	1.5
High paper 1992, remulch (Hpr) 1993	0	0.5	0.2	0.3
Contrasts				
N vs. Lp + Hp	**	**	**	**
Lp vs. Hp	*	*	*	*
Lp vs. Lpr	**	**	**	**
Hp vs. Hpr	**	**	**	**
Lpr vs. Hpr	NS	**	*	*
Lp + Hp vs. Lpr + Hpr	**	**	**	**
Experiment 2—1993	**July 19**	**August 16**	**September 17**	
No mulch (N)	1183.2	380.3	280.8	
Low paper (Lp)	7.3	2.9	1.2	
High paper (Hp)	1.7	0.7	0.4	
Low bark (Lb)	54.9	13.8	5.0	
High bark (Hb)	3.5	2.7	1.2	
Contrasts				
N vs. Lp + Hp	**	**	**	
N vs. Lb + Hp	**	**	**	
Lp vs. Hp	**	**	*	
Lp. vs. Hb	**	**	**	
Lp + Hp vs. Lb + Hb	**	**	*	

[z]Means of four replicates.

[y]Newspaper treatments applied in 1992 and 1993 were: Low paper = 2.3 kg/m^2 (≈ 10 cm or 4 in depth), High paper = 3.4 kg/m^2 (≈ 15 cm or 6 in depth), irrigated with 1.7 cm (0.67 in) water, then rolled with a lawn roller. Remulch treatment was applied as 1.4 kg/m^2 (≈ 5 cm or 2 in depth) on May 27, 1993, irrigated and rolled. Bark treatments applied in 1993 were low bark = 9.7 dm^3/m^2 (≈ 5 cm or 2 in depth), high bark = 19.4 dm^3/m^2 (≈ 10 cm or 4 in depth).

[x]NS = nonsignificant, * = significant at p = .05, ** = significant at P = .01.

Table 2. Effect of chopped newspaper mulches on the stem and foliage growth[z] of three species.

Treatments[y]	1992			1993
	Gaillardia	Physostegia	Daphne (cm)	Daphne (gr)
No mulch	51.6	28.8	16.0	51.5
Low paper (Lp)	41.9	28.2	16.9	82.7
Low paper, tackifier (Lpt)	37.5	30.3	19.7	—
High paper (Hp)	40.9	25.7	17.3	87.0
High paper, tackifier (Hpt)	34.3	28.8	17.0	—
Low paper, remulch (Lpr)	—	—	—	73.0
High paper, remulch (Lpr)	—	—	—	78.5
Contrasts[x]				
No mulch vs. Lp + LPt + Hp + Hpt	**	NS	NS	—
Lp + Hp vs. Lpt + Hpt	NS	NS	NS	—
Lp vs. Hp	NS	NS	NS	—
Lpt vs. Hpt	NS	NS	NS	—
No mulch vs. Lp + Lpr + Hp + Hpr	—	—	—	**
Lp vs. Lpr	—	—	—	NS
Hp vs. Lpr	—	—	—	NS

[z]Stem and leaf dry weights (g) for Gaillardia and Physostegia and total lengths (cm) for Daphne in 1992 and stem and leaf dry weights (g) for Daphne in 1993, means of four replicates.

[y]Lp and Lpt = 2.3 kg/m^2 (≈ 10 cm or 4 in depth), Hp and Hpt = 3.6 kg/m^2 (≈ 15 cm or 6 in depth), Lpr, Hpr = remulch in 1993 at 1.4 kg/m^2 (≈ 7.5 cm or 2 in depth).

[x]NS = nonsignificant, ** = significant at P = 0.01.

Newspaper mulch had no effect on *Daphne* stem length after the first season, but after the second season of growth, *Daphne* stem and leaf dry weight were higher for mulched plots than for non-mulched plots (Table 2). Remulching in 1993 had no effect on *Daphne* stem and leaf dry weight. Stem and leaf dry weight of *Gaillardia* was less for paper mulched plots than for non-mulched plots after the first season of growth (Table 2). *Physostegia* leaf and stem dry weight were not affected by any treaments after the first season (Table 2). Growth measurements for all three taxa were similar for tackifier treated newspaper plots and untreated plots after one season.

Soil tests after two growing seasons for Experiment 1, May 1994, showed little differences in phosphorus, potassium, calcium, magnesium, iron or boron between the mulched plots and non-mulched plots. There were small differences in the heavy metals of aluminum, cadmium, chromium, copper, nickel, lead or zinc between mulched and non-mulched plots. The soil test data are consistent with Munn (7) who showed no difference in heavy metals between newspaper-mulched and non-mulched plots.

Experiment 2. Two rates of chopped newspaper and the high rate of bark resulted in weed suppression during the growing season with less than 8 weeds/m^2 on each sampling date (Table 1). The low rate of bark allowed considerable weed growth (55 weeds/m^2 on July 19). Compared to non-mulched plots all mulch treatments suppressed weed numbers throughout the growing season

Gaillardia growth (stem and leaf dry weight) after three months showed lesser growth when mulched with bark than with newspaper. There were no differences in dry weight of *Physostegia* or *Salix* between the bark and the newspaper mulched plots. The high bark mulch treatment reduced leaf and stem dry weight for these two taxa compared to the low bark rate. *Physostegia* had lower dry weight in the high paper mulch treatment than in the low paper mulch treatment, however growth was similar with these two treatments for *Gaillardia* and *Salix*. Overall, growth of the three taxa were similar between mulched and non-mulched plants. *Gaillardia* which had reduced growth in paper mulched plots in Experiment 1 had similar growth with paper-mulched and non-mulched plots in Experiment 2. Temperatures at soil depths of 2.5 and 7.5 cm (1 and 3 in, resp.) were similar under both bark and paper mulches (data not shown). Both bark and paper mulch reduced the soil temperature elevation on warm summer days (Fig. 1). All mulch treatments moderated maximum soil temperatures on July 5, 1993 by more than 10C (18F) when non-mulched soil increased to 36C (96.8F). Soil temperatures at 7.5 cm (3 in) depth in non-mulched plots were higher than air temperatures on July 5 (Fig. 1). When the non-mulched soil temperature on July 5 increased to 36C (96.8F), the temperatures under low and high paper were 24 and 22.5C (75.2 and 72.5F resp.). Low and high bark temperatures at the same time were 25 and

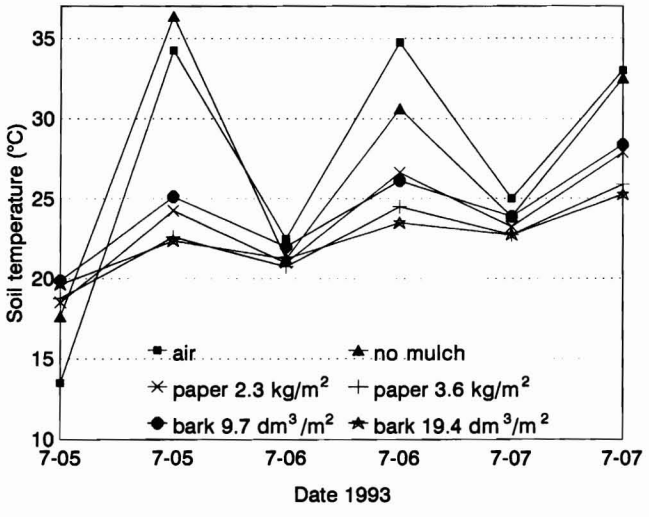

Fig. 1. Soil temperatures at 7.5 cm (3 in) deep under summer mulches at 5:30 AM and 3:30 PM July 5 to 7, 1993.

22.5C (77 and 72.5F resp.). The moderation of soil temperatures under paper mulch is supported by Munn who observed that newspaper mulch of vegetable crops reduced midday summer soil temperatures (7).

Newspaper mulch may be considered unattractive, therefore not suitable near retail sales areas or for some landscape sites. Small pieces of paper from chopped newspaper mulch are often blown from the mulch surface creating a nuisance. Application of a tackifier may reduce blowing paper. Some recycling operations have equipment to shred newspapers into long narrow pieces. A mulch of shredded paper may resist blowing better than chopped paper because the long shreds tend to bind together. Our mulching trials with small amounts of shredded paper supported this observation.

The economics of paper mulch for weed control in commercial nurseries needs to be considered. We estimate that 1000 ft^2 may be mulched by hand with one hour of labor. A labor rate of $7.50/hr would cost $7.50/1000 ft^2 or $327/A for application of newspaper mulch from bales. Irrigation for wetting the paper and rolling to compress the paper may require an additional 50% labor cost. If newspaper cost $2.00/60 lb bale the cost for the lower rate of newspaper mulch used in this study would be $15.56/1000 ft^2 (467 lb) or $683/A (10.2 tons). The cost of the higher rate used in this study would be $23.34/1000 ft^2 (701 lb) or $1025/A (15.3 tons). The cost of paper may be highly variable depending on paper source and cost of chopping or shredding and baling. Methods for mechanical application may be possible. Adaptation of equipment that is used for mulching new turfgrass seeding may have promise for applying paper mulch.

We have successfully rototilled old paper mulch into the soil with mechanical rear-mounted tractor-drawn tillers. With continued use of newspaper mulch, we expect that higher nitrogen fertilization would be advantageous for the growth of newspaper mulched crops since paper has a high carbon/nitrogen ratio.

We believe that newspaper as an alternative weed control mulch may have a future in production of nursery crops. Further study is necessary to determine effect on various crops. The primary benefits are more than one season of weed control with one application, avoidance of herbicide usage and reduced summer soil temperatures. Other potential benefits include gradual increase in soil organic matter, reduced soil erosion and reduced soil moisture loss.

Literature Cited

1. Boyce, B.R. and D. Heleba. 1991. Mulching strawberries with chopped newspaper—a preliminary trial. HortScience 26:481 (Abstract).

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

3. Cashau. G.R. 1988. Soybean-based ANPA-INK. Soybean Utilization Alternatives—Symposium—February 16–18. Sponsored by the Center for Alternative Crops and Products. Pp. 195–301.

4. Cooper, Kate. 1989. Livestock bedding from newsprint: A statewide status report. Recycling Coordinator Newsletter. July. Wisc. Dept. of Nat. Res., Madison.

5. Elfving, D.C., C.A. Bache and D.J. Lisk. 1979. Lead content of vegetables, millet and apple trees grown on soils amended with colored newsprint. J. Agric. Food Chem. 27:138–140.

6. Johnson, E.L. and E.A. Ott. 1982. Use of shredded paper as a bedding material. Dept. of An. Sci. Res. Rep. AL-1981-1, Fla. Agr. Exp. Sta., Gainesville.

7. Munn, D.A. 1992. Comparisons of shredded newspaper and wheat straw as crop mulches. HortTechnology 2:361–366.

8. Pellett, N. and D. Heleba. 1994. Comparison of chopped newspaper with microfoam for winter protection of container-grown nursery stock. Hort Technology 4:55–57.

9. Sims, J.T. and A. Wolf, Editors. 1991. Recommended soil testing procedures for the northeastern United States. Northeastern Regional Publication No. 493. Del. Agr. Exp. Sta., Newark.

10. Wooten, T.E. and R.S. Helms. 1981. Paper mulches for vegetation control in Christmas tree plantations. Forestry Bull. No. 23. Dept. of Forestry, Clemson Univ.