Recycled Waste Paper as a Landscape Mulch[1]

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Abstract

Two studies were conducted to evaluate recycled waste paper mulch for landscape plantings. In the first study, two recycled paper products (pellet and crumble) were applied at three depths. Application of recycled paper mulch at a depth of 25 or 50 mm (1 or 2 in) controlled prostrate spurge. However, in experiment 1, all four bedding plant species exhibited stunting of roots and shoots. In the second study, three annual species were mulched with the two recycled paper products applied at 25 mm (1 in) depth and treated with phosphorus (P) at 0, 3.75, or 7.5 mg L^{-1} (ppm) to bind suspected excess aluminum (Al). When no P was added, growth of ageratum was approximately half that of the non-mulched control plants. Addition of P at either rate resulted in similar growth compared to control plants. Shoot dry weight of geranium was greater than that of the control plants with 7.5 mg L^{-1} of P. Shoot dry weight of marigold was unaffected by the addition of P. This research indicates that recycled paper mulch at a 25 mm (1 in) depth, provides weed control equal to or better than standard landscape treatments, and causes little or no growth suppression when amended with P.

Index words: non-chemical weed control, bedding plants, herbicide.

Herbicide used in this study: Ronstar 2G (oxadiazon)3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-di-methylethyl)-1,3,4-oxadiazol-2-(3H)-one.

Species used in this study: ageratum (*Ageratum houstonianum* Mill. 'Blue Puff'); marigold (*Tagetes erecta* L. 'Discovery'); geranium (*Pelargonium* x *hortorum* L.H. Bailey. 'Ringo' and 'Voyager'); and salvia (*Salvia splendens* F. Sellow ex Roem. & Schult. 'Top Burgundy').

Significance to the Nursery Industry

Mulching, primarily for weed control, is a common practice in the landscape and nursery industry. Two recycled waste paper products evaluated in this study have considerable potential for use as a landscape mulch when amended with phosphorus, with young herbaceous annuals. As moisture is absorbed, the recycled paper expands and bonds together, forming a mat that provides an effective non-chemical method of weed control. Use of recycled products addresses a national environmental concern by providing an alternative method for disposal of a post consumer by-product, thus enhancing the environmental image of the landscape and nursery industry.

Introduction

Waste disposal continues to be a critical problem facing municipalities across the United States. In 1989, the Environmental Protection Agency (EPA) mandated a 25% reduction in landfill disposal by 1995 and a total reduction of 75% by the year 2000 (16). To comply with these goals, many states are requiring a 30 to 60% reduction of municipal solid waste (MSW) entering landfills. Since about 40% of the MSW stream consists of paper and paper products, these materials have been targeted for reduction through recycling (6). Currently, the recycling market for paper is limited. Recycling of waste paper for horticultural use could reduce the bulk of MSW entering landfills.

One possibility is the use of recycled waste paper as a mulching material (5, 13). Mulching has been practiced for centuries to conserve moisture, suppress weeds, increase yields, aid in plant growth and survival, and reduce time spent on maintenance (1, 2, 14). Chopped newspaper has been used successfully for weed control with eggplants (5), conifer seedlings (17), sweet corn, soybeans, tomatoes (12) and strawberries (3).

Pellett and Heleba (13) evaluated chopped newspaper for weed control in nursery crops and reported newspaper mulch applied at 2.3 kg/m^2 (4.2 lb/yd^2) [~ 10 cm (4 in) depth], and 3.6 kg/m^2 (6.3 lb/yd^2) [~ 15 cm (6 in) depth], suppressed weed germination for two seasons without a negative effect on *Daphne burkwoodii* 'Carol Mackie'. However, a problem encountered in this study was the blowing of chopped paper during windy conditions. Rolling the paper with a lawn roller filled about 3/4 full of water reduced blowing of small pieces of paper; however, the nuisance created from blowing paper was considered unacceptable (13).

One approach to eliminating wind blown paper is reprocessing the paper into a more stable form. Two recent products, pelletized recycled paper or crumbled recycled paper (Tascon, Inc. Houston, TX), made from recycled waste paper have potential for use in the landscape without the nuisance of wind blown particles. Waste paper is ground with a hammer mill equipped with a series of three screens, the smallest screen is about 0.63 cm (1/4 in), then compressed using pelletizing equipment to form pellets about 3 mm × 25 mm (3/16 in × 1 in). To develop the crumble product, pellets are put through a granulator with variable pressure plates. Neither recycled paper product is composted (C:N ratio ~ 500:1) (7). In agronomic studies these products have provided an excellent source of carbon for increasing microbial activity, soil organic matter content, water infiltration, and controlling both winter and spring annual weeds (7). When the pellets were applied for wind erosion, cotton lint yields were increased, primarily by conserving soil water through reductions in evaporation from the soil surface (7). The ob-

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jective of our work was to compare these recycled paper products with traditional landscape weed control methods and to determine effects on growth of annual plants.

Materials and Methods

Two paper products, recycled paper pellets and recycled paper crumble (Tascon, Inc. Houston, TX) were evaluated in field studies conducted at Auburn University, AL. These recycled paper products consisted of about 75% newsprint, ≤ 5% advertisement inserts, ≤ 10% telephone books, ≤ 10% old magazines. The chemical analyses of different waste paper fractions and both recycled paper products are shown in Table 1. Chemical analyses of the waste paper fractions were determined by collecting paper products from home owners in Auburn and separating the paper products into five catagories. Analysis was conducted by the USDA/ARS lab at Auburn University. Grab samples were pulled from Tascon, Inc. during the manufacturing process for comparison. Analyses were not of products actually applied in this study.

Experiment 1. Prior to planting, plots [1.95 m^2 (7 × 3 ft)], were amended with non-composted pinebark, [screen size < 12.5 mm (0.5 in)], to a depth of 50–75 mm (2–3 in), and fertilized with 13N–5.3P–10.5K (13–13–13) fertilizer applied at 118 g N/m^2 (0.26 lb N/ft^2) and tilled. The pH of the plots ranged from 6.0 to 6.5 at a 0–7.5 cm (0–3 in) soil depth, and 5.5 to 6.0 at a 7.5–15.0 cm (3–6 in) soil depth. Finished plugs of four plant species: *Ageratum houstonianum* 'Blue Puff', *Tagetes erecta* 'Discovery', *Pelargonium* x *hortorum* 'Ringo' and *Salvia splendens* 'Top Burgundy' were planted May 4, 1995. One half of each plot was over seeded with 25 prostrate spurge seed, *Chamaesyce maculata* (L.) Small, and one half over seeded with 25 eclipta seed, *Eclipta prostrata* (L.) L., prior to mulch application. Treatments were applied on May 10, 1995, and included the two paper products, pellets and crumble, at 3 depths (12.5, 25, or 50 mm) (0.5, 1.0, or 2.0 in); pinebark at 50–75 mm (2–3 in) plus Geogard weedmat (Geotextiles, Inc., Opelika, AL), pinebark at 50–75 mm (2–3 in), Ronstar 2G (oxadiazon) applied at 4.4 kg ai/ha (4.0 lb ai/a), and a non-mulched control. The experimental design was a randomized block with 4 replications of 4 plants per species per treatment.

Percent weed control (0–100%, total ground surface area covered) and spurge and eclipta number in a .093 m^2(1 ft^2) was determined 30 and 60 days after treatment (DAT). Growth indices, determined by measuring height + two perpendicular widths / 3, and shoot dry weights were determined at 60 DAT. Soil moisture data were taken, 32, 39, and 46 DAT, using a Time Domain Reflectometry (TDR) soil moisture analyzer (Soilmoisture Equipment Corp. Santa Barbara, CA). Readings were taken at a depth of 15 cm (6 in).

Table 1. Chemical concentrations of different waste paper fractions.

Element	Fraction of waste paper					Recycle paper products[v]	
	Newsprint[z]	Container[y]	Phonebook[x]	Insert[z]	Junkmail[w]	Pellets	Crumble
				Macronutrients, ($mg\ kg^{-1}$)			
P	82	139	35	79	97	48	80
K	112	82	88	131	55	80	100
Ca	821	4,337	864	5,110	9,970	1,000	800
Mg	112	308	152	170	287	70	100
				Micronutrients, ($mg\ kg^{-1}$)			
Cu	23	17	6	32	12	34	23
Fe	136	298	57	223	159	21	57
Mn	31	29	45	28	6	44	31
Zn	51	57	5	151	10	116	51
B	2	7	1	3	16	1	13
Mo	4	8	2	11	6	1.8	0.5
				Non-essential nutrients, ($mg\ kg^{-1}$)			
Al	4,525	10,120	2,309	5,871	6,730	3,100	4,500
Na	900	555	230	619	822	600	900
Ba	17	20	19	28	20	12	17
Si	638	916	417	648	1,125		
				Heavy metals, ($mg\ kg^{-1}$)			
Co	0.2	2.5	0.1	0.3	1.0	0	0
Cr	1.5	5.1	0.8	2.2	4.0	0.7	1.5
Pb	8.4	22.4	6.3	14	15	7.0	8.4
Ni	0.7	0.9	0.3	0.4	0.5	0	0.7
Cd	0.2	0.2	0.3	0.2	0.1	0	0.3

[z]Local newspaper collected and separated into newsprint and insert advertisement.
[y]Food containers: cereal boxes and microwave dinner boxes.
[x]Telephone books collected during local recycling by Bell South and GTE.
[w]Junk mail: bulk rate mail collected for a one week period.
[v]Recycled paper products used in landscape experiments.

Table 2. Percent weed control, weed dry weight and moisture levels as influenced by mulch treatment.

Treatments	Depth	Weed control (%)		Moisture level (% by volume)		
Experiment 1	**(mm)**	**30 DAT[z]**	**60 DAT**	**32 DAT**	**39 DAT**	**46 DAT**
Crumble	12.5	95	92	25	24	25
Crumble	25	100	100	22	28	25
Crumble	50	100	100	23	25	23
Significance[y]		L*	NS	NS	NS	NS
Pellet	12.5	79	72	22	20	19
Pellet	25	84	75	22	24	23
Pellet	50	97	97	21	22	22
Significance		L*	L*	NS	NS	NS
PB+m[x]	50–75	100	100	20	21	21
PB	50–75	99	100	25	25	23
Ronstar[w]		85	76	23	21	15
Control[v]		48	35	23	21	17
LSD = 0.05		15.4	18.0	5.4	4.2	4.0

		Weed control (%)		Weed dry weight (g/plot)
Experiment 2		**20 DAT**	**45 DAT**	**45 DAT**
Crumble	50	99	97	0.4
Crumble	50	99	94	0.9
Crumble	50	99	96	0.4
Significance		NS	NS	NS
Pellet	50	98	98	0.4
Pellet	50	99	98	0.2
Pellet	50	99	98	0.7
Significance		NS	NS	NS
PB+m	50–75	100	100	0.0
PB	50–75	95	90	2.0
Ronstar		81	79	8.0
Control		59	53	30.0
LSD = 0.05		6.9	8.1	4.6

[z]Days after treatment.
[y]NS: non-significant; L *: Linear response at the 5% level.
[x]Pinebark plus Geogard weedmat.
[w]Ronstar applied at 4.4 kg ai/ha (4.0 lb ai/a).
[v]Non-mulched control.

Immediately after planting the beds were hand watered. Thereafter water was applied as needed using overhead irrigation.

Experiment 2. The second study was initiated to determine if the addition of P would correct the suspected problem of Al toxicity observed in the first study. Previous work with agronomic crops suggested that Al toxicity created similar stunting in corn and cotton (10, 11). Paper contains large amounts of Al because alum [$Al_2(SO_4)_3$] is used to fix the cellulose fibers in the formation of the paper (Table 1). Alum is also used during the processing of green logs to remove tars and resins from grinding equipment (7). Lu et al. (11) identified 3 Al fractions in waste paper; 1) a water soluble fraction that is adsorbed on the paper surface, 2) a chelating fraction for the cellulose fibers, and 3) a mineral fraction contained in the mineral kaolin which is used as a filler. They concluded that the water soluble fraction was the most active, influencing soil solution Al activity. When ground newspaper was equilibrated with water for 48 hours, the Al concentration was 6.2 mg L^{-1} (this soluble fraction will leach into the soil).

The most easily recognized symptom of Al toxicity is stunting of root and shoot growth and foliar chlorosis (8). We suspected Al toxicity was occurring with the stunted annual species and based the second experiment on these results.

The same plots were used, mulch from the first study was removed and beds were prepared as in experiment 1. Finished plugs in 48 count cell packs of 3 annual species: *Ageratum houstonianum* 'Blue Puff', *Tagetes erecta* 'Discovery' and *Pelargonium* x *hortorum* 'Voyager' were planted on September 7, 1995.

Table 3. The influence of mulch depth and P level on growth of annual species.

		Experiment 1[z]			
		Shoot dry weight (g/plant)			
Treatments	**Depth (mm)**	**Ageratum**	**Geranium**	**Salvia**	**Marigold**
Crumble	12.5	24.9	15.9	2.3	35.8
Crumble	25	12.3	11.6	1.7	27.6
Crumble	50	4.1	8.5	1.1	12.8
Significance[y]		L**	L*	NS	NS
Pellet	12.5	28.1	19.7	10.3	53.6
Pellet	25	16.6	12.5	3.0	40.9
Pellet	50	9.8	9.2	1.8	14.5
Significance		L**	L*	L***	L**
PB+m	50-75	28.7	21.3	6.4	67.2
PB	50–75	34.0	12.2	4.5	52.1
Ronstar[w]		45.9	17.5	7.1	64.8
Control[v]		54.8	19.6	5.3	57.8
LSD = 0.05		22.2	6.7	5.7	24.3
		Experiment 2[u]			
Treatment	**P level[t] ($mg\ L^{-1}$)**	**Ageratum**	**Geranium**	**Salvia**	**Marigold**
Crumble	0	6.3	9.6	—	36.5
Crumble	3.75	19.0	9.8	—	36.6
Crumble	7.5	12.8	13.2	—	32.2
Significance		NS	NS	—	NS
Pellet	0	5.5	7.5	—	37.7
Pellet	3.75	12.2	9.7	—	33.0
Pellet	7.5	10.5	11.0	—	34.5
Significance		NS	NS	—	NS
PB+m	0	10.4	9.6	—	32.7
PB	0	8.8	8.3	—	36.4
Ronstar	0	10.7	10.5	—	40.7
Control	0	12.5	8.5	—	39.2
LSD = 0.05		7.7	5.0	—	7.0

[z]Experiment 1 terminated 60 DAT (May 10–July 6). Experiment 2 terminated 45 DAT (Sept. 13–Oct. 30).

[y]NS: non-significant linear response; L*, L**, L*** : linear response at 5%, 1%, and 0.1% level, respectively.

[x]Pinebark plus Geogard weedmat.

[w]Ronstar (oxadiazon) applied at 4.4 kg ai/ha (4.0 lb ai/a).

[v]Non-mulched control.

[u]All recycled paper mulch applied at 25 mm depth.

[t]P source was triple superphosphate; ppm based on pounds of recycled paper per plot.

All paper mulches were applied to a depth of 25 mm (1 in) on September 13, 1995. Paper mulch treatments included pellets or crumble to which P was added at a rate of 0, 3.75, or 7.5 $mg\ L^{-1}$ in the form of triple superphosphate (0–46–0). Triple superphosphate was incorporated into the recycled paper by tumbling in a revolving mixer into which water was sprayed to encourage contact between paper and phosphate. Other treatments included pinebark to a depth of 50–75 mm (2–3 in), pinebark 50–75 mm (2–3 in) deep plus Geogard weedmat, Ronstar 2G (oxadiazon) applied at 4.4 kg ai/ha (4.0 lb ai/acre), and a non-mulched control. Each plot was over seeded with 25 prostrate spurge seed prior to mulch application.

Percent weed control (0–100%, total ground surface area covered) and spurge number in a .093 m^2 (1 ft^2) was determined at 21 and 45 DAT. Growth indices were determined (height + 2 perpendicular widths/3) at 45 DAT. At the time of termination, October 30, 1995, volume displacement of roots was determined using a volume displacement technique involving suspending roots in a cylinder approximately 25.4 cm × 50.8 cm (10 in × 20 in) filled with water. Water was displaced via a downspout, allowing for estimation of root volume (9). Shoot and root dry weights were determined as well as weed dry weights.

The experimental design was a randomized block design with 4 replications of the 3 plant species. The plant numbers per replication per treatment included 5 marigold, 4 ageratum and 3 geranium.

Statistical analyses were performed using the Statistical Analysis System (SAS), version 6.03 (SAS, 1989) for each experiment (15). The general linear models (GLM) procedure was used to estimate orthogonal polynomial contrast to determine whether the response to treatments was linear, quadratic or both. Unless otherwise noted, all statistical analyses are reported at $P < 0.05$.

Results and Discussion

Experiment 1. Weed control. Both recycled paper products provided effective weed control at 30 and 60 DAT with the exception of pellets at 12.5 mm (0.5 in) depth (Table 2). Pellets applied at 25 mm (1 in) depth, provided weed suppression similar to that of Ronstar herbicide. Recycled crumble at 12.5 and 50 mm (0.5 and 1 in) provided better control at 30 and 60 DAT than pellets at the same depth. At the 50 mm (1 in) depth pellets and crumble performed similarly. Our crumble data concurs with Pellet and Heleba (13) who reported chopped newspaper at a depth of 10 cm (4 in) provided almost complete weed suppression during the first growing season. Pine bark and pine bark + weedmat both provided 99% weed control at both dates. Ronstar, a preemergence applied herbicide, provided 85% and 76% weed control 30 and 60 DAT, respectively, which is similar to results reported by other researchers (4). All paper treatments were equal to or exceeded the herbicide treatment when measuring weed control. The effective weed control sustained by recycled waste paper provides a non-chemical weed control alternative for sensitive landscape areas while contributing to the recycling effort and reducing the bulk of MSW.

Moisture. By 46 DAT, all mulched plots had higher moisture levels than the non-mulched plots and all paper treatments with the exception of pellets at 12.5 mm (0.5 in) were different from the control (Table 2). Generally the paper mulches had slightly higher or similar moisture levels between 32 and 46 DAT whereas the non-mulched plots had lower moisture levels.

Shoot growth. Shoot dry weight of ageratum and geranium decreased linearly as recycled paper crumble mulch depth increased (Table 3). In the recycled paper pellets, all four species exhibited a linear decrease in shoot dry weight with an increase in mulch depth. Ageratum exhibited the greatest shoot dry weight reduction; compared to control plant shoot dry weight was 55%, 78%, and 93% less with crumble mulch treatments of 12.5, 25, and 50 mm (0.5, 1, and 2 in) depth respectively. Ageratum grown in pellet mulch treatments followed a similar trend to crumble mulch treatments.

The three treatments representing industry standards (pine bark mulch, pine bark mulch + weedmat, and Ronstar herbicide) also reduced ageratum shoot dry weight compared to the nontreated control plants, with the Ronstar herbicide treatment causing the least suppression. These data indicate all mulch treatments reduced ageratum shoot dry weight.

With marigold, shoot dry weights were similar among the three industry standard treatments and pelleted recycled paper at depths of 12.5 and 25 mm (0.5 and 1 in) and crumble at 12.5 mm (0.5 in). Growth indices data followed a similar trend to shoot dry weight data (data not shown).

Root growth. At termination, the plants were dug and the roots examined. Roots in those plots receiving 25 or 50 mm (1 or 2 in) paper mulch, regardless of type, had suppressed

Table 4. The influence of mulch and P level in experiment 2 on root dry weight and root volume of three annual species.

		Root dry weight (g/plant)			Root volume (cm^3)		
Treatment[z]	P Levels ($mg\ L^{-1}$)[y]	Ageratum	Geranium	Marigold	Ageratum	Geranium	Marigold
Crumble	0	2.9	2.5	18.9	14.5	8.8	50.4
Crumble	3.75	6.9	3.6	17.5	25.4	11.8	47.3
Crumble	7.5	3.4	3.8	14.6	15.2	14.0	39.6
Significance[x]		NS	NS	L*	NS	NS	L*
Pellet	0	2.1	3.5	19.8	10.7	10.5	60.9
Pellet	3.75	3.5	3.2	17.5	18.8	12.4	50.2
Pellet	7.5	4.1	3.0	18.1	20.9	11.2	47.8
Significance		NS	NS	NS	L*	NS	NS
Ronstar[w]	0	3.9	2.4	14.7	12.1	9.0	41.6
PB+m[v]	0	3.4	2.7	17.6	25.3	11.2	50.0
PB	0	4.6	2.4	21.6	20.2	7.4	62.3
Control[u]	0	5.4	2.1	6.2	20.1	6.2	51.0
LSD = 0.05		3.0	1.3	7.2	7.5	5.2	13.1

[z]All recycled newspaper mulches applied at depth of 25 mm.

[y]P source was triple superphosphate; $mg\ L^{-1}$ based on kg (lb) of recycled paper per plot.

[x]NS: non-significant; L*: linear response significant at the 5% level.

[w]Ronstar (oxadiazon) applied at 4.4 kg ai/ha (4.0 lb ai/a).

[v]Pinebark plus Geogard weedmat.

[u]No mulch applied.

root growth. When compared to the control and other mulch treatments, root systems were stunted and lacked fine branches. These symptoms and previous reports of Al toxicity with recycled waste paper were the principal justifications for applying P in experiment 2.

Experiment 2. Weed control and weed dry weight. All mulch treatments provided effective weed control (90% plus) 20 and 45 DAT (Table 2). Ronstar herbicide provided about 80% weed control 45 DAT. Weed dry weight was less for all mulch treatments compared to the Ronstar treated plot and non-mulched control treatment plots. For example, weed dry weight for any paper treatment did not exceed 0.85 g/plot whereas Ronstar plots had 7.6 g/plot and the control 30.2 g/plot (Table 2).

Shoot growth. When no P was added to the paper products ageratum growth was about half that of the control plants (Table 3). Addition of P at 3.75 and 7.5 mg L^{-1} to crumble paper increased ageratum growth 200 and 103 percent respectively compared to 0 mg L^{-1} P crumble mulched plants. Addition of P at 3.75 and 7.5 mg L^{-1} to pelleted paper increased ageratum growth 121% and 90% compared to no P plants. The addition of P did not affect the growth of geranium or marigold. These data are consistent with the first study where ageratum was the most sensitive to recycled paper mulches and the other species were less affected. Growth indices again followed a similar trend to shoot growth data (data not shown).

Root dry weight. Root dry weight of ageratum with crumble or pellet at 3.75 or 7.5 mg L^{-1} P were similar to that of control plants (Table 4). Root dry weight of geranium was greatest with crumble at both P levels, and root dry weight in geranium mulched with pellets and no P were greater than root dry weight of control plants. With marigold, there was a linear response with root dry weight decreasing as P levels in crumble increased.

Root volume. Root volume of ageratum in crumble was unaffected by P (Table 4). The treatment producing the least root volume in ageratum was pellets with 0 mg L^{-1} P. All paper treatments with ageratum resulted in similar root volume to control plants, with the exception of plants mulched with pellets at 0 mg L^{-1} P. Both paper products treated with 3.75 and 7.5 mg L^{-1} P had greater root volume in geranium than the control. Marigolds grown with either recycled paper product had similar root volume compared to control plants. With crumble paper mulch there was a linear decrease in marigold root volume with increasing P levels.

These data show paper mulches provide effective weed control, conserve moisture, and cause little or no growth suppression when amended with P. The paper mulches stayed in place during the growing season, resisting both wind and water erosion, and were easy to remove for the next planting. Further research is needed to determine more specific management practices appropriate for recycled paper products and to determine the effects of long term application and/or incorporation. Effects on more established annuals, herbaceous perennials, and woody ornamentals also need to be ascertained.

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