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Recycled Waste Paper Mulch Reduces Available Container N[1]

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Abstract

Two experiments were conducted to determine the effects of pelletized recycled paper mulch on container plant nutrition. In experiment 1 with *Petunia floribunda* Hort. 'Midnight Madness', 9 g (0.32 oz) of Osmocote 14N–6.2P–11.6K (14–14–14) was applied over or under 2.5 cm (1 in) of recycled paper pellet mulch, or to plants with no paper mulch (control). Leachate samples were collected after microirrigation. Both treatments with paper mulch reduced nitrate (NO_3-N) and ammonium (NH_4-N) levels in container leachate, compared to the control 21 days after planting (DAP). Shoot dry weight was reduced 53% and 70% for plants fertilized under and over the mulch, respectively, compared to the non-mulched control. At the end of the experiment 40–48% of the total N applied over or under mulch was retained by the recycled paper mulch. In experiment 2 with *Petunia grandiflora* Hort. 'Ultra Blue', mulch and three methods of fertilizer application (over mulch, under mulch, and incorporated in the substrate) were compared. Leachate NO_3-N levels were reduced 72% or 68% with fertilizer placed over or under the mulch, respectively, when compared to a non-mulched topdressed treatment 21 DAP. When fertilizer was incorporated into the substrate, paper mulch reduced NO_3-N leachate levels 87% compared to the non-mulched treatment. There were no significant differences in leachate NH_4-N levels with fertilizer placed over or under the mulch when compared to a non-mulched control 21 DAP. When fertilizer was incorporated into the substrate, paper mulch reduced leachate NH_4-N levels 82% compared to the non-mulched control. Shoot dry weight was 84 or 49% lower with fertilizer placed over or under the mulch, respectively, when compared to the topdressed, non-mulched treatment. However, plants grown with fertilizer applied under the mulch were 213% larger than plants with fertilizer applied over the mulch. When fertilizer was incorporated into the substrate, paper mulch reduced shoot dry weight 41% when compared to non-mulched plants. There were no differences between shoot dry weights of plants grown in non-mulched treatments with topdress fertilization or fertilizer incorporated.

Index words: nitrate, ammonium, fertilizer application method, petunia.

Species used in this study: 'Midnight Madness' petunia (*Petunia floribunda* Hort. 'Midnight Madness'); 'Ultra Blue' petunia (*Petunia grandiflora* Hort. 'Ultra Blue').

Significance to the Nursery Industry

Recycling and reuse of waste products, including paper, is one of the major solutions for reducing landfill volumes and disposal costs. Many uses for recycled paper in the nursery industry have been evaluated, such as containers, substrate components and weed-control mulches. However, our studies show that recycled paper mulch will reduce available container nitrogen (N), especially when fertilizer is topdressed. Growth of petunia was generally reduced when plants were mulched with recycled paper pellets and topdressed with a controlled release fertilizer. Even when fertilizer was topdressed on the surface of substrate under the paper mulch petunia growth was reduced. When recycled paper mulch was used for weed control incorporating fertilizer into the substrate resulted in the greatest plant growth.

Introduction

Granular herbicide application is the primary method of weed control in container nurseries. However, granular application to spaced containers can be inefficient, with up to 80% of the herbicide lost, depending on plant spacing (6, 9). Many growers have turned to alternative methods of weed control, such as mulches, to reduce the environmental impact of pesticides in runoff water. Previous work has shown one inch of recycled paper pellets (Enviroguard, Tascon Inc., TX) to be as effective as Rout herbicide for control of prostrate spurge, *Euphorbia supina*, in container production or landscape settings (11, 12). Enviroguard pellets are manufactured by compressing ground newspaper using pelletizing equipment to form extruded paper pellets approximately 6.35 mm (0.25 in) in diameter and 38.1 mm (1.5 in) in length. These pellets have a C:N ratio of about 500:1 and swell to about twice the volume after saturating with water. Craig and Cole (5) evaluated a recycled paper product Wet Earth (Cerad Industries, Sand Springs, OK) as a container substrate component. Wet Earth (WE) is composed of 80% recycled paper, 18% diatomaceous earth, 1% CaO, and 1% humic acid by volume. Substrate mixes were: 100% pine bark (PB), 1:3 PB:WE, 1:1 PB:WE, 3:1 PB:WE, and 100% WE by volume. As the percentage of WE in substrate mix increased, *Spiraea* size and foliar N levels decreased, suggesting that recycled paper may have immobilized N. Smith et al. (11, 12) demonstrated that recycled paper mulch provides effective weed control; however, the work done by Craig and Cole (5) suggests that recycled paper may compete with plants for N.

Topdress fertilization of container grown plants is a common technique used by nursery growers. Application of fertilizer over a paper mulch with high C:N ratio may lead to immobilization of N and a negative impact on plant growth. The objective of this research was to compare N leaching and immobilization with different methods of fertilizer application when recycled paper pellets were used as mulch.

Materials and Methods

In the first experiment, *Petunia floribunda* Hort. 'Midnight Madness' liners from 48-cell packs were transplanted

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on April 29, 1998, into 2.8-liter (trade gallon) containers using a pine bark:sand substrate (7:1, by vol) amended with 3.0 kg (5 lb) dolomitic limestone and 0.9 kg (1.5 lb) Micromax per m^3 (yd^3). A common commercial fertilizer [Osmocote 14N–6.2P–11.6K (14–14–14), Scott's Chemical Co. Marysville, OH] was applied at 9 g (0.32 oz) per pot. Osmocote 14N–6.2P–11.6K (14–14–14) has longevity of 1–2 months when average substrate temperature is 90F (32.2C), and 2–3 months when average substrate temperature is 80F (26.7C). Approximately 41% of all nitrogen in Osmocote 14N–6.2P–11.6K (14–14–14) is in NO_3-N form and 51% is in NH_4-N form. Treatments included control (topdressed, no mulch), fertilizer applied over (topdressed) or fertilizer applied under 2.5 cm (1 in) of recycled paper pellets (145 g [5.1 oz]) (Enviroguard, Tascon Inc., Houston, TX). Treatments were arranged in a completely randomized design, with each treatment replicated 8 times. Plants were placed on a greenhouse bench and irrigated as needed with a microirrigation system (every 1–2 days), with 250 ml of water per container at the rate of 1 liter/min (0.25 gal/min). Average temperatures in the greenhouse were 67F (19C) minimum and 91F (32.8C) maximum. Data collected included NO_3-N and NH_4-N levels in leachate 13, 21, 27, and 35 DAP. Plastic trays were placed under each container to collect leachate. Leachate samples were collected after an irrigation with 250 ml of water. NO_3-N and NH_4-N levels in leachate were determined by microscale batch technique, and spectrophotometric measurements of samples in titer plates were taken using an Elx 808 plate reader (10). Plants were harvested 48 DAP to determine shoot dry weight, foliar N content, and total N absorbed by paper mulch. Foliar N content and total N absorbed by paper were determined using a modified Kjeldahl method (1). Foliar and paper samples were pretreated with salicylic acid for NO_3-N inclusion. Total paper N was determined by multiplying paper dry weight (131 g) by % N in paper at the end of the experiment. Data were subjected to analysis of variance using SAS (13) and mean separation by Duncan's multiple range test, $P = 0.05$.

The second experiment was conducted similarly to experiment one, except where noted. *Petunia grandiflora* Hort. 'Ultra Blue' plantlets were transplanted on September 18, 1998. Average temperatures in the greenhouse were 71F (21.7C) minimum and 95F (35C) maximum. The same fertilizer was applied at 18 g (0.64 oz) per container. Fertilizer was applied over a 2.5 cm (1 in) layer of recycled paper pellets, under the pellets, or incorporated in the substrate. Two non-mulched controls were included with fertilizer topdressed or incorporated in the substrate. Treatment arrangement was an incomplete factorial in a completely randomized design. Data collected included NO_3-N and NH_4-N levels in leachate 13, 21, 28, and 35 DAP and foliar color and flower number 49 DAP. Foliar color was determined on a 1–5 scale, where 1=yellow, 2=yellowish green, 3=light green, 4=medium green, and 5=dark green. Plants were harvested 56 DAP to determine shoot dry weight, foliar N content, and total N absorbed by paper.

Results and Discussion

Experiment 1. *Leachate N levels.* Leachate NO_3-N levels 13 DAP were reduced 87% or 56%, respectively, when fertilizer was applied over or under the mulch when compared to a non-mulched control treatment (Table 1). Leachate NH_4-N levels were reduced 86% by fertilizer applied over the mulch treatment compared to a non-mulched control treatment (Table 1). These results support previous work by Cole and Newell (3), who reported reductions in leachate NO_3 and NH_4 levels at the beginning of their experiment and reductions in leachate NH_4 levels throughout the experiment, when recycled paper products were mixed into the substrate. In our study 21 DAP leachate NO_3-N levels were almost negligible when fertilizer was applied over or under the mulch treatments, and leachate NH_4-N levels were reduced 97% or 95% when fertilizer was applied over or under the mulch, respectively, compared to the non-mulched treatment. At 27 DAP leachate NO_3-N and NH_4-N levels were reduced from 89% to 78% when fertilizer was applied over or under mulch, respectively, compared to the non-mulched treatment. Leachate NO_3-N and NH_4-N levels decreased from 27 DAP and, thereafter, to less than 0.2 ppm, regardless of treatment. Dissipation of NO_3-N and NH_4-N may be explained by high temperatures in the greenhouse, which likely accelerated release of the controlled release fertilizer.

Table 1. NO_3-N and NH_4-N levels in container leachate as affected by fertilizer application method and recycled paper mulch.

Treatments	NO_3-N (mg·L^{-1})			
	Leaching dates			
Method of application	13[z]	21	27	35
Fertilizer over mulch[x]	0.8b[y]	0.0b	0.2b	0.1b
Fertilizer under mulch	2.8b	0.2b	0.3b	0.1b
Control (no mulch)	6.3a	27.8a	1.8a	0.2a
	NH_4-N (mg·L^{-1})			
	Leaching dates			
Method of application	13[z]	21	27	35
Fertilizer over mulch[x]	0.5b[y]	0.2b	0.1b	0.1a
Fertilizer under mulch	1.7ab	0.3b	0.2b	0.1a
Control (no mulch)	3.7a	5.8a	0.9a	0.1a

[z]Days after planting.
[y]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.
[x]Osmocote 14N–6.2P–11.6K (14–14–14), 9 g/container.

Plant response. Shoot dry weight was suppressed with recycled paper mulch (Table 2). The greatest reduction occurred when fertilizer was applied over the mulch, with 70% less dry weight when compared to non-mulched plants, and 53% less when compared to plants grown with the fertilizer

Table 2. The effects of fertilizer application method and recycled paper mulch on dry weight, foliar N levels, and total N absorbed by recycled paper mulch 48 days after planting.

Method of application	Shoot dry weight (g)	Foliar N (%)	Paper N (mg/container)
Fertilizer over mulch[z]	5.4c[y]	3.3a	599a
Fertilizer under mulch	11.5b	3.6a	504b
Control (no mulch)	18.1a	3.8a	—

[z]Osmocote 14N–6.2P–11.6K (14–14–14), 9 g/container.
[y]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

Table 3. The effects of recycled paper mulch and fertilizer application method on NO_3 -N and NH_4 -N levels in container leachate, experiment 2.

		NO_3-N (mg·L^{-1})			
		Leaching dates[y]			
Treatments	**Fertilizer placement[z]**	**13**	**21**	**28**	**35**
Mulched	over	0.3c[x]	0.7c	0.5c	0.7b
	under	0.8c	0.8c	1.0c	0.8b
	incorporated	3.3b	1.7bc	3.1b	2.9a
Non-mulched	topdressed	2.9b	2.5b	2.9b	1.1b
	incorporated	11.8a	12.8a	9.3a	1.6ab
Contrast 'mulched vs non-mulched'		0.0001	0.0001	0.0001	NS[w]
		NH_4-N (mg·L^{-1})			
		Leaching dates[y]			
Treatments	**Fertilizer placement[z]**	**13**	**21**	**28**	**35**
Mulched	over	0.6c	0.9b	0.7c	0.4b
	under	0.9bc	1.0b	0.8c	0.4b
	incorporated	4.0b	2.6b	4.1b	3.3a
Non-mulched	topdressed	2.5bc	1.9b	2.9bc	0.8b
	incorporated	17.3a	14.4a	7.7a	1.2b
Contrast 'mulched vs non-mulched'		0.0001	0.0001	0.0002	NS[w]

[z]Osmocote 14N–6.2P–11.6K (14–14–14), 18 g/container.

[y]Days after planting.

[x]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

[w]Non-significant at the 0.05 level.

applied under the mulch. Neither fertilizer application method caused a significant reduction in foliar N levels when compared to control plants. However, while not significant, foliar N levels followed a trend similar to that of shoot dry weight data. Foliar N levels for non-mulched control plants were at the lower sufficiency range for petunia plants (3.8–7.6%) (7). Total N recovered in paper with fertilizer applied over or under mulch treatments was 599 or 504 mg N per container, respectively. Initially paper pellets contained 89 mg N per container and about 1.26 g of N was applied to each container, therefore 33–40% of the total N applied was in the paper mulch at the end of the experiment. Recycled paper pellets have a high C:N ratio (500:1), which explains N immobilization from topdress application, however, recycled paper mulch absorbed almost as much total N even when fertilizer was placed under the mulch. This condition may occur as a result of capillary upward movement of substrate solution, similar to the process that takes place when plants are watered through a capillary mat (8).

Experiment 2. *Leachate N levels.* Results of the second experiment generally concur with results in experiment 1. Leachate NO_3-N 13 DAP levels were reduced 90% or 72% when fertilizer was placed over or under the mulch, respectively, compared to the topdressed, non-mulched treatment (Table 3). When fertilizer was incorporated in the substrate,

Table 4. The effects of recycled paper mulch and fertilizer application method on dry weight, foliar color rating, flower number, foliar N content, and total N absorbed by paper mulch.

Treatments	**Fertilizer placement[z]**	**Shoot dry wt (g)**	**Foliar color[y]**	**Flower number[x]**	**Foliar N (%)**	**Paper N (mg/pot)[w]**
Mulched	over	1.6c[v]	3.1d	3.5c	4.4b	667a
	under	5.0b	3.8c	9.5b	4.5b	458b
	incorporated	6.0b	4.4ab	8.8b	5.1ab	294c
Non-mulched	topdressed	9.8a	4.8a	17.3a	4.6b	—
	incorporated	10.2a	4.1bc	15.8a	5.5a	—
Contrast 'mulched vs non-mulched'		0.0001	0.0001	0.0001	NS[u]	—

[z]Osmocote 14N–6.2P–11.6K (14–14–14), 18 g/container.

[y]Foliar color rating scale was determined on 1–5 scale, where 1=yellow, 2=yellowish green, 3=light green, 4=medium green, and 5=dark green.

[x]Recorded 49 days after planting.

[w]Total N in the paper, initially paper pellets contained 89 mg N/container.

[v]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

[u]Non-significant at the 0.05 level.

paper mulch reduced NO_3-N levels 72% compared to the incorporated, non-mulched treatment. Additionally, in non-mulched treatments NO_3-N levels were 75% lower with topdress fertilization when compared to the incorporated fertilizer treatment. These results concur with work by Cox (4) and Yeager et al. (15), who showed a higher N leachate concentration when a CRF was incorporated rather than surface-applied. In our experiment, leachate NO_3-N levels 21 DAP were reduced 72% or 68% when fertilizer was placed over or under the mulch, respectively, compared to the topdressed, non-mulched treatment. With fertilizer incorporation in the substrate, paper mulch reduced leachate NO_3-N levels 87% compared to the non-mulched treatment. Leachate NH_4-N levels 13 DAP were lowest when fertilizer was placed over or under the mulch and highest with incorporated non-mulched treatment (Table 3). Topdressed, non-mulched plants had 86% lower leachate NH_4-N levels compared to incorporated fertilizer, non-mulched plants. When fertilizer was incorporated in the substrate, paper mulch reduced NH_4-N levels 77% compared to the non-mulched treatment. A similar trend continued throughout the rest of the experiment. There were no differences between leachate NH_4-N levels 21 DAP when fertilizer was placed over or under the mulch compared to the topdressed, non-mulched treatment. When fertilizer was incorporated in the substrate, paper mulch reduced NH_4-N levels 82% compared to the non-mulched treatment. Although NO_3-N leachate levels from control treatments were below the general guideline of 15–25 ppm for controlled release fertilizers (14), they were comparable to the results obtained by Cashion and Yeager (2), who showed that NO_3-N leaching of Osmocote 18–6–12 (18N–2.6P–9.9K) was 8 to 11 ppm during the peak release. After 35 DAP, NO_3-N and NH_4-N leachate levels in control treatments declined to less than 3 ppm (data not shown).

Plant response. Shoot dry weight was greatest when plants were not mulched, regardless of fertilizer application method (Table 4). When plants were mulched, topdress application over the paper mulch reduced shoot dry weight 73% or 68% compared to mulched plants with fertilizer incorporated or applied under the mulch, respectively. Shoot dry weight was 84 or 49% lower when fertilizer was placed over or under the mulch, respectively, compared to topdressed, non-mulched plants. When fertilizer was incorporated in the substrate, paper mulch reduced shoot dry weight 41% when compared to the non-mulched control.

Foliar color was lightest when fertilizer was placed over the mulch. Placement of fertilizer under the mulch improved the foliar color rating by 18%. Best foliar color rating occurred when fertilizer was incorporated in the substrate and mulched, or topdressed without mulch. Flower number was lowest when fertilizer was placed over the mulch. Fertilizer placement under the mulch increased flower number by 171% compared to placement over the mulch. Fertilizer incorporation in the substrate with paper mulch reduced flower number 44% when compared to plants grown without mulch. Although foliar N levels were highest when plants were not mulched and fertilizer was incorporated, all treatments produced plants with foliar N levels well within the reported range (7).

N immobilization by paper mulch was affected by fertilizer placement. For example, topdressing of fertilizer over the mulch resulted in total paper N of 667 mg N/container, or about 23% of the total N applied, while fertilizer incorporation (with mulch) resulted in 294 mg of total N/container in the paper mulch, or about 8% of the total N applied.

In both tests paper mulch reduced N in leachate and plant growth regardless of fertilizer application method. However, in the second experiment fertilizer incorporation resulted in more N in leachate (both mulched and non-mulched treatments). This work has several implications for the use of recycled paper in container production of nursery crops. First, growers should realize that container nutrition can be affected when paper mulch is used as a weed control alternative, especially if fertilizer is topdressed. Incorporating the fertilizer reduces the amount of N retained by paper. This work suggests the potential of recycled paper in nutrient remediation of container effluent, with the potential to provide an environmentally friendly postharvest mechanism of prolonged fertilization in the landscape by recycling absorbed N. Additional work is currently being conducted to determine the fate of N absorbed by paper mulch.

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