HORTSCIENCE 26(12):1492-1494. 1991.

Nitrogen Partitioning by 'Chester Thornless' Blackberry in Pot Culture

Hermen Malik[1] **and Douglas D. Archbold**[2]
Department of Horticulture and Landscape Architecture, University of Kentucky, Lexington, KY 40546-0091

C.T. MacKown[3]
U.S. Department of Agriculture–Agricultural Research Service, Department of Agronomy, University of Kentucky, Lexington, KY 40546-0091

Additional index words. nitrogen isotope, nutrition, *Rubus*

Abstract. **Partitioning patterns of fertilizer N in container-grown 'Chester Thornless' blackberry *(Rubus* spp.) were determined over two growing seasons following application of $^{15}NH_4{}^{15}NO_3$. The roots and primocane tissues comprised the majority of the plant biomass each year. The N concentrations of primocane and floricane leaves were lower in 1988 than 1989, but were higher than in any other tissues each year. Foliar N values were followed by those for fruit, roots, and canes.** As **determined by isotope partitioning ratios, primocane cane, leaf, and fruit ^{15}N enrichment from fertilizer N was higher than in other tissues in 1988. In 1989, when only stored ^{15}N was available, the floricane was the most enriched, followed by the fruit and roots. Thus, newly acquired N was allocated to primocane tissues, fruit, and roots. Stored fertilizer N was allocated to all tissues from the roots and floricanes, but a significant amount remained in the floricanes. After two seasons. the plants retained only 27% of the total fertilizer N initially acquired.**

Rates of N application to thornless blackberry depend on plant age and vigor, site characteristics, and other factors (Lipe and Martin, 1984). Increasing N rates increased primocane production, thickening and lengthening of canes, and yield per cane and plant (Archbold et al., 1989; Martin et al., 1980; Nelson and Martin, 1986). Foliar N levels, used to assess plant nutrient status, varied from 20 to 30 $mg \cdot g^{-1}$ although sampling date, genotype, and plant age may contribute to significant variation (Clark et al., 1988). The N content of the other plant tissues are unknown.

The redistribution of N in deciduous fruit crops is seasonally related (Titus and Kang, 1982). Stored and fertilizer N accumulate in actively growing tissues early in their development, and the levels in mature tissues remain constant, with some N turnover during the growing season. During autumnal senescence, N is transported to overwintering storage sites. The N is often stored in roots or the permanent shoot tissues. Fruit can be a significant N sink, perhaps obtaining most N from storage pools (Weinbaum et al., 1984).

These general trends, while characteristic of deciduous fruit crops, may not be accurate for the unique growth habit of *Rubus* spp. such as thornless blackberry. The biennial cane life and perennial root system of *Rubus* spp. (Moore and Skirvin, 1990), as well as sustained growth into the autumn and slow acclimation (Kraut et al., 1986), differ from most deciduous fruits, such as apple. In contrast to other deciduous fruit species, all of the shoot tissue older than 2 years, a common site of N storage in fruit trees (Ludders, 1981; Titus and Kang, 1982), is dead and is removed by annual pruning.

No information on N cycling patterns in thornless blackberry or other *Rubus* spp. is available. Thus, fertilizer recovery and allocation, storage pools and rates of turnover, seasonal partitioning patterns, quantities retained in senescent and pruned tissues, and the sink strength of the fruit are unknown. Due to the significant role N plays in thornless blackberry production, a greater understanding of its use by the crop is warranted to maximize the efficient use of fertilizer N. However, due to the size of the plant, its cropping potential, and the cost of ^{15}N-labelled fertilizer, this preliminary study with container-grown plants was performed to provide a basis upon which to study long-term recovery and partitioning patterns in a field situation. The objective of this work was to study partitioning of fertilizer N over two successive growing seasons to gain insight into allocation patterns of newly acquired and storage N.

Ten newly micropropagated (MP) and ten l-year-old 'Chester Thornless' blackberry *(Rubus* spp.) plants were obtained from a commercial nursery and were planted in Pro-Mix BX (Premier Brands, Stamford, Corm.) on 25 May 1988 in 15-liter containers with a top diameter of 27 cm. 'The unpruned 1-year-old plants were grown in 2-liter pots in the same medium with no supplemental N, other than that in the soil medium, the year before the experiment. Soil applications of $^{15}NH_4{}^{15}NO_3$ (5.9 atom percent, uniformly enriched) were applied on 15 and 29 June 1988. On each date, each l-year-old plant received 0.5 g of fertilizer in 25 ml of water, and each MP plant received 0.25 g in 12.5 ml of water. The plants were placed outdoors and watered daily, except when rainfall was adequate. The containers drained freely when water volume exceeded the water-holding capacity of the growth medium.

Ripe fruits were harvested from bearing plants, frozen, lyophilized, and weighed each year. On 15 Oct. 1988, five plants of each group were randomly selected for harvest. The dead floricanes of the remaining plants were removed, and the roots were cleaned thoroughly under a gentle flow of tap water to remove the planting medium. These plants were then repotted into new pots with fresh medium as above, overwintered in an outdoor protected enclosure, and uncovered in May 1989 for the second growing season. Plants were watered as in 1988 and received no supplemental N other than that in the fresh medium. The remaining plants were harvested on 1 Nov. 1989.

At harvest, plants were separated into component tissues (roots, primocanes, floricanes, primocane and floricane leaves, and dead leaves) and washed under running tap water. After oven drying the tissues at 70C for a minimum of 3 days, dry weights were obtained. Tissues were ground to pass a 40-mesh (0.60 mm) screen, and aliquots were taken for analysis of total N by the Kjeldahl

Table 1. Component tissue dry weights and total N concentrations of pot-grown 'Chester Thornless' blackberry plants at the end of two successive seasons.

Component tissue	1988 Dry wt (g)	1988 N ($mg \cdot g^{-1}$)	1989 Dry wt (g)	1989 N ($mg \cdot g^{-1}$)
Roots	52.0 ± 3.9[z]	5.9 ± 0.2	78.4 ± 6.8	9.4 ± 0.7
Primocane	35.7 ± 3.1	4.9 ± 0.3	44.7 ± 21.9	8.7 ± 0.6
Floricane	4.1 ± 0.2	3.7 ± 0.1	18.3 ± 3.8	3.9 ± 0.2
Primocane leaves	35.8 ± 1.6	8.3 ± 0.6	35.5 ± 12.5	21.0 ± 2.0
Floricane leaves	1.8 ± 0.4	9.3 ± 1.5	8.4 ± 2.1	12.7 ± 2.6
Dead leaves	4.2 ± 0.4	7.1 ± 0.2	3.1 ± 1.0	11.3 ± 1.4
Fruit	4.1 ± 0.8	8.2 ± 0.4	5.4 ± 1.8	10.5 ± 0.1

[z]Mean ± SE

Received for publication 28 Jan. 1991. The investigation reported in this paper (no. 90-10-179) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked ***advertisement*** solely to indicate this fact.

[1]Graduate Research Assistant.
[2]Associate Professor.
[3]Plant Physiologist and Adjunct Associate Professor.

Table 2. Isotope partitioning ratios[z] of fertilizer N over two seasons from $^{15}NH_4{}^{15}NO_3$ applied to pot-grown 'Chester Thornless' blackberry at the start of the first season.

X. Tissue	Isotope partitioning ratios[z] X:1	X:2	X:3	X:4	X:5	X:6	X:7
			1988				
1. Roots	---	0.81	1.37	0.70	1.06	1.35	0.60
2. Primocane	1.24	---	1.70	0.72	1.32	1.68	0.74
3. Floricane	0.73	0.59	---	0.51	0.78	0.99	0.44
4. Primocane leaves	1.43	1.39	1.95	---	1.56	1.92	0.85
5. Floricane leaves	0.95	0.76	1.29	0.64	---	1.27	0.56
6. Dead leaves	0.74	0.60	1.01	0.52	0.78	---	0.44
7. Fruit	1.68	1.36	2.20	1.18	1.78	2.28	---
			1989				
1. Roots	---	1.22	0.51	1.25	1.04	1.00	0.94
2. Primocane	0.82	---	0.42	1.02	0.85	0.82	0.77
3. Floricane	1.94	2.38	---	2.45	2.04	1.96	1.85
4. Primocane leaves	0.80	0.98	0.41	---	0.83	0.80	0.75
5. Floricane leaves	0.95	1.16	0.49	1.19	---	0.96	0.90
6. Dead leaves	1.00	1.22	0.51	1.25	1.05	---	0.94
7. Fruit	1.06	1.29	0.54	1.33	1.11	1.06	---

[z]N isotope partitioning ratios were calculated from mean atom percent excess ^{15}N values, or the percent ^{15}N above natural abundance levels, for each component tissue. To convert ratios to mean atom percent excess ^{15}N values, use a root atom percent excess ^{15}N value of 1.04 in 1988 and 0.50 in 1989. The overall SE was 0.07 in each year.

procedure. Due to the difficulty in appropriately grinding seeds, they were excluded from the analysis. After Kjeldahl digestion, the ^{15}N enrichment of digest aliquots was determined with a CEC 21-614 mass spectrometer (MacKown et al., 1987).

Means and SE of the mean were calculated for component tissue dry weights and N content. To determine fertilizer N partitioning ratios among component tissues, mean atom percent excess ^{15}N values for each component tissue were compared. Atom percent excess ^{15}N values are the percent ^{15}N values above natural enrichment levels, or excess MN from the ^{15}N-labelled fertilizer. Due to the similarity between values for MP and 1-year-old plants, only data from the 1-year-old plants are presented since they include values for floricanes and fruits for both years.

The roots and primocane tissues comprised the bulk of the plant biomass each year (Table 1). Floricane and primocane leaves had similar concentrations of total N in 1988. Foliar N content, <10 $mg \cdot g^{-1}$, was lower than previously reported (20 to 30 $mg \cdot g^{-1}$ for midseason in field-grown plants (Archbold et al., 1989; Clark et al., 1988), possibly a result of significant autumnal export. Dead leaves, primarily from floricanes, had a N concentration slightly less than live foliage. Cane N concentrations were generally lowest, with values for floricanes lower than those for primocanes. Nearly 90% of the total biomass and N was in the roots, primocanes, and primocane leaves.

Isotope partitioning ratios have been used to determine allocation of fertilizer N among component plant tissues (Weinbaum et al., 1984). A ratio of 1.00 indicates uniform partitioning of fertilizer N between the plant tissues being compared, while other ratios indicate unequal allocation. In 1988, the newly acquired fertilizer N was preferentially allocated to new growth sites (Table 2). Isotope partitioning ratios for primocanes and their leaves vs. the other vegetative tissues were >1.00. However, fruit ratios were the highest, indicating that fruit were the strongest sink for newly acquired fertilizer N. The floricanes and associated leaves, although proximal to the fruit, had very low ratios when compared with the other tissues. Dead leaves had values similar to floricane leaves. While the partitioning ratios for roots were intermediate, root biomass was highest, making them a significant storage site.

Foliar N concentrations of the component blackberry tissues were generally higher in 1989 than 1988 (Table 1), suggesting a deficiency occurred the first year. Primocanes and primocane leaves had higher N concentrations than their respective floricane tissues, while roots, fruit, and dead leaves had similar N concentrations in 1989. The amounts in foliage may reflect the natural loss of N during senescence of floricanes, while primocane leaves may retain their N later into the season (Kraut et al., 1986). Similar to the distribution in 1988, > 80% of the total biomass and N was in the roots, primocanes, and primocane leaves.

During 1989, fertilizer N allocation patterns represent redistribution of root and primocane fertilizer N acquired during the first year of growth, since the growing medium was replaced after the first year. The floricanes (1988 primocanes) retained considerably more fertilizer N than the other tissues, as indicated by their partitioning ratios (Table 2). Thus, there was little N turnover or remobilization in the floricanes. New vegetative growth was the least enriched of all tissues, with ratios <1.0 for primocanes and their leaves, in contrast to their 1988 values. Ratios for fruit were >1.00 when compared with all other tissues, except floricanes, although they were lower than in 1988. Blackberry fruit may import less storage N than newly acquired N each year, as ratios differed for fruit vs. floricanes each year. Higher ratios for fruit in 1989 would have been observed had they imported more floricane-stored fertilizer N. While apple *(Malus domestics* Borkh.) fruit also import significant amounts of newly acquired N (Atkinson et al., 1980; Grasmanis and Nicholas, 1971), storage N in almond *(Prunus dulcis* Mill.) trees contributed more than newly acquired N to the N pool of developing fruit (Weinbaum et al., 1984).

The total amount of fertilizer-derived ^{15}N per plant declined considerably between 1988 and 1989 (data now shown). In 1988, there was 541 µmol/plant, and by the end of the 1989 season, there was 144 pmol/plant, or 27% of that initially acquired. More than 280 µmol, or 70% of the decline, was removed from the plants by floricane pruning, leaf loss, and fruit harvest. Root loss from senescence and during the medium change may account for the remaining 30% of the decline, as the roots were a major storage site.

Newly acquired fertilizer N was partitioned primarily to primocanes, primocane leaves, and the fruit crop. Limited redistribution of stored fertilizer N in 1989 was observed. Floricane-retained N would cease to be a source of stored N upon cane senescence. Although the roots retained most of the remaining fertilizer N after two seasons, it was only 15% of that initially acquired. The experimental conditions in this study, including pot culture, nutrient-limited conditions, and no supplemental N provided in 1989 other than that in the soil medium, may have had significant effects on plant growth and total and fertilizer N partitioning patterns. Nonetheless, the data suggest a significant loss of plant N each year from storage and from that newly acquired as a result of fruit harvest and leaf and floricane senescence.

Literature Cited

Archbold, D. D., J.G. Strang, and D.M. Hines. 1989. Yield component responses of 'Hull Thornless' blackberry to nitrogen and mulch. HortScience 24:604-607.

Atkinson, D., M.G. Johnson, D. Mattam, and F.R. Meron. 1980. The influence of soil management on the uptake of nitrogen by fruit trees. J. Sci. Food Agr. 31:845-846.

Clark, J. R., J.B. Buckley 111, and E.W. Hellman. 1988. Seasonal variation in elemental concentration of blackberry leaves. HortScience 23:1080.

Grasmanis, W. and D.J.D. Nicholas. 1971. Annual uptake and distribution of ^{15}N-labelled ammonia and nitrate in young Jonathan/MM104 apple trees grown in solution cultures. Plant & Soil 35:95-112.

Kraut, J. L., C.S. Walsh, and E.N. Ashworth. 1986. Acclimation and winter hardiness patterns in Eastern thornless blackberry. J. Amer. Soc. Hort. Sci. 111:347-352.

Lipe, J.A.. and L.W. Martin. 1984. Culture and management of blackberries in the United States. HortScience 19:190-193.

Ludders, P. 1981. Effects of time and amount of nutrient additives on nutrient status and distribution on fruit quality, p. 165-172. In: D. Atkinson, J.E. Jackson, R.O. Sharples, and W.M. Wailer (eds.). Mineral nutrition of fruit trees. Butterworths, Boston.

MacKown, C.T., P.D. Brooks, and M.S. Smith. 1987. Diffusion of nitrogen-15 Kjeldahl digests for isotope analysis. Soil Sci. Soc. Amer. J. 51:87-90.

Martin, L. W., E. Nelson, and M.H. Chaplin. 1980.

Plant and fruit measurements of 'Meeker' red raspberry related to pruning and nitrogen application. Acts. Hort. 112:157–161.
Moore, J.N. and R.M. Skirvin. 1990. Blackberry management, p. 215-224. In G.J. Galletta and D.G. Himelrick (eds.). Small fruit crop management. Prentice Hall, Englewood Cliffs, N.J.
Nelson, E. and L.W. Martin. 1986. The relationship of soil-applied N and K to yield and quality of 'Thornless Evergreen' blackberry. HortScience 21:1153-1154.
Titus, J.S. and S.M. Kang. 1982. Nitrogen metabolism, translocation, and recycling in apple trees. Hort. Rev. 4:204-246.
Weinbaum, S.A., I. Klein, F.E. Broadbent, W.C. Micke, and T.T. Muraoka. 1984. Effects of time of nitrogen application and soil texture on the availability of isotonically labeled fertilizer nitrogen to reproductive and vegetative tissue of mature almond trees. J. Amer. Soc. Hort. Sci. 109:339-343.

HortScience 26(12):1494-1495. 1991.

High Dolomitic Lime Rates Induce Mouse-ear Symptoms in Container-grown Pecan Trees

Gary J. Keever and William D. Goff
Department of Horticulture and Alabama Agricultural Experiment Station, Auburn University, AL 36849

Mark S. West
Department of Research Data Analysis and Alabama Agricultural Experiment Station, Auburn University, AL 36849

Additional index words. Carya illinoensis, little-leaf, manganese, fertilization, soil amendments, pH

Abstract. Pecan ***[Carya illinoensis*** **(Wangenh.)** C. **Koch] trees were grown in containers in a pine bark and sand medium amended with O, 3.0, 5.9, 8.9, or 11.9 kg dolomitic limestone/m^3. Mouse-ear symptom expression, characterized by small, rounded, cupped, and slightly wrinkled leaflets, increased linearly as dolomitic lime rate increased. Plant growth was best at 3.0 kg dolomitic lime/m^3, which resulted in a growth medium pH of 4.3.**

"Mouse-ear" has been used to describe abnormal growth in pecan trees characterized by small, rounded, cupped, and slightly wrinkled leaves (Gammon and Sharpe, 1956). In orchards, it has been associated with soil pH of 6.5 to 8.0 and was thought to be caused by Mn deficiency (Gammon and Sharpe, 1956). Later research (Gallaher and Jones, 1976; Grauke et al., 1983; Worley, 1979) reported similar symptoms in non-Mn-deficient trees, or a low correlation between Mn and symptom expression (Goff and Keever, 1991), suggesting a more complex or different problem. Gallaher and Jones (1976) suggested Ca deficiency as a cause, but their research showed higher Ca, Mn, Fe, Cu, Zn, and Mo and less Mg in leaf and stem tissue from affected trees. Worley (1979) reported elemental concentrations of normal and mouse-eared leaflets differed among cultivars, with inconsistencies in element concentrations of affected leaflets occurring for particular cultivars and locations. Grauke et al. (1983) observed higher N, P, Ca, S, and Mn and lower Fe in mouse-eared than normal leaves from container-grown trees. The results of this work suggested that high N levels were lowering the N : S ratio and that correspondingly high levels of S may be needed for normal growth.

Pink bark-based media are standard in the container industry in the southeastern United States for ornamental and fruit trees. Published research indicates excellent growth of containerized pecans in a pine bark : sand medium (Acock and Overcash, 1983). Working with trees grown in a pine bark-based medium, Goff and Keever (1991) demonstrated that repotting pecan trees with severe mouse-ear symptoms into media amended with little or no dolomitic lime (lime) alleviated the symptoms. This "curative effect" of little or no lime suggested that a study of lime rates should be conducted to determine if symptom expression could be induced on previously healthy plants by high applications of lime. The purpose of this experiment was to evaluate effect of rate of lime application on inducing mouse-ear symptoms in previously healthy pecan trees grown in a pine bark-based medium.

Pecan seedlings grown from open-pollinated 'Elliott' nuts were used in the experiment. Ten nuts per 11.4-liter container were planted in July 1989, in a milled 5 pine bark : 1 sand medium (v/v) amended with (kg-m-') 8.3 Osmocote 18N-2.6P-10.0K (Grace-Sierra, Milpitas, Calif.), 1.2 gypsum, 0.9 Micromax (Grace-Sierra), and 3.6 dolomitic limestone.

In Jan. 1990,84 of the seedlings described above were selected for uniform caliper and height to be used in the experiment. Trunk caliper 5 cm above the soil line and plant height were recorded on 16 Jan. 1990. Plants of similar caliper were assigned to a given block. Treatments were O, 3.0, 5.9, 8.9, or 11.9 kg of 100 mesh or finer dolomitic limestone/m^3 (0N-0P-0K-20Ca-8.0Mg). The

Table 1. Effects of dolomitic lime rates in a pine bark and sand potting medium on mouse-ear symptoms, growth of container-grown pecan trees, and medium pH.

Lime rate (kg·m^{-3})	Mouse-ear rating[z]	Leaflet length (cm)	Leaf length (cm)	Caliper increase[y] (%)	Ht increase[y] (%)	Medium pH
0 + Ca + Mg[x]	1.1	9.6	31.8	57	110	4.0
0	1.2	8.5	29.6	35	89	3.9
3.0	1.2	10.0	32.1	73	116	4.3
5.9	3.3	5.5	20.8	76	94	4.7
8.9	2.9	6.5	23.6	54	92	4.7
11.9	3.8	3.4	17.4	59	84	4.9
SEM	0.25	0.64	2.33	10.8	11.3	0.106
Significance			P > *F*			
Lime	0.0001	0.0001	0.0004	0.1512	0.5245	0.0001
Linear[w]	0.0001	0.0001	0.0008	0.2300	0.0682	0.0056
Quadratic	0.0296	0.3118	0.3125	0.9043	0.4988	0.4569
0 vs. 3 kg·m^{-3}	0.9844	0.1175	0.4691	0.0221	0.1318	0.1166
0 + Ca + Mg vs. 0[x]	0.8607	0.2801	0.5412	0.1799	0.3168	0.6235

[z]All ratings and measurements were made on 23 July 1990, 6 months after potting trees into treatment media. Rating scale: 1 = no mouse-ear symptoms, 5 = severely mouse-eared.
[y]$(Caliper_{final} - Caliper_{initial}) Caliper_{initial} \times 100$ = % caliper increase. Same method was used for determining % height increase.
[x]This treatment at 0 kg lime/m^3 had supplemental Mg and Ca topdressed monthly.
[w]Regression analysis was for the range of 3–11.9 kg·m^{-3}.

Received for publication 15 Feb. 1991. Alabama Agricultural Experiment Station Journal Series no. 11-912893P. Appreciation is expressed to Cathy Browne, Leslie Brasher, and Dan Land for their assistance with [his experiment. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.