Table 2. Final sand pH.^{z,y}

NH ₄ ⁺ : NO ₃ ⁻	pH _w ^x	pH _b
1:0	4.1 c	8.14 c
3:1	4.2 c	8.31 a
1:1	4.6 c	8.23 b
1:3	5.7 b	8.27 ab
0:1	6.6 a	8.28 ab
LSD (0.05)	0.76	0.07

^xData are the means of five observations.

^ypH_w = water pH; pH_b = buffer pH.

^zBeginning pH_w = 5.4.

drops below 4.5 (Barker and Mills, 1980). Darrow (1939) found NH₄⁺-fertilized Kentucky bluegrass (*Poa pratensis*) produced more shoots, roots, and rhizomes at pH 6.5 than at 5.5 or 4.5, while NO₃⁻-treated plants grew equally well at all three pH levels.

Since soil microbial activity promotes nitrification more rapidly than sand (Quastel and Scholefield, 1951), previous research (Eggens and Wright, 1985) indicating that high NH₄⁺ ratios decreased root growth may be viewed as misleading, since most putting greens do not consist of 100% sand. However, our results indicate N form can significantly influence initial root length and weight and root : shoot ratio of sodded creeping bentgrass on sandy loam soils. Bentgrass sod fertilized with NH₄⁺-N produced less root growth and darker green shoots. The ratio of 1:3 produced the most favorable root weights. Ratios of 1:1 and 3:1 produced about equally favorable root lengths. The similarity of our results with that of Eggens and Wright (1985) suggest the effect of N form on root growth occurs over a wide range of circumstances; some of the differences in the two studies were the plant densities (sod vs. single plants), soil type (sandy loam vs. sand), total applied N (265 vs. 3472 kg N/ha), soil pH, and mowing height. Previously NH₄⁺ : NO₃⁻ ratio was reported to have no effect on bentgrass root or shoot growth under field conditions (Markland and Roberts, 1969; Mazur and Hughes, 1976); however, these studies were conducted on established turf. The results reported here suggest further investigation should be made dealing with the use of NO₃⁻-N on greens established with bentgrass sod.

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Apple Tree Vigor Influences Flowering and Dry Weight after Paclobutrazol Application

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Abstract. Spur-type or nonspur 'Delicious' apple scions on either *Malus domestica* Borkh. (seedling) or M.26 rootstocks received paclobutrazol foliar sprays in one or two consecutive years or a soil drench in the year of planting. For each scion, total shoot, root shank, and tree dry weights measured in the 3rd year after planting were suppressed by all treatments. Trees on M.26 put less dry weight into rootstock wood after foliar sprays, but trees on seedling were not similarly affected. No treatment influenced fibrous root dry weight of the spur-type scion on seedling, while all treatments suppressed dry-weight gain of the same scion on M.26. All trees had higher root : shoot ratios and blossom densities 3 years after the soil drench and several had higher ratios after foliar sprays. Chemical name used: β-[(4-chlorophenyl)methyl]α-(1,1-dimethylethyl)-1-H-1,2,4-triazole-1-ethanol (paclobutrazol, PB).

Manipulation of vegetative and reproductive characteristics of apple trees can ensure regular cropping and reduce production costs. These characteristics may be modified by various physical means or by the application of chemicals, such as paclobutrazol (PB). Foliar and soil applications of PB can provide multi-year reductions in shoot growth (Stinchcombe et al., 1984; Tukey, 1983; Williams, 1984) and may also influence assimilate movement and source-sink relationships (Steffens and Wang, 1984; Wang et al., 1985).

Changes in shoot growth and movement of assimilates could modify tree form and fruiting capacity. Choice of apple tree scion

and rootstock may also affect tree architecture and precocity. Our study examined flowering and dry-weight distribution of young apple trees in the 3rd year after planting and PB application. Scion/rootstock combinations (stions) were selected to represent a wide range in scion spur-formation potential and rootstock vigor.

The four stions used in this study were: 'Classic Delicious' / *Malus domestica* Borkh. (seedling), 'Classic Delicious' / M.26, 'Redchief Delicious' (Campbell strain) / seedling, and 'Redchief Delicious' (Campbell strain) / M.26. 'Redchief Delicious' usually develops a more-compact tree canopy, forms more spurs per limb, and is generally more precocious than 'Classic Delicious'. The clonal rootstock M.26 dwarfs scion growth 50% to 60% and confers more precocity on a given scion than does seedling.

In Spring 1986, dormant 1-year-old, unbranched trees were planted in 1 vermiculite : 1 montmorillonite clay : 2 pine bark (by volume) in 57-liter pots. Because of space limitations, one tree of each rootstock was planted in each pot. Trees in each pot had either 'Classic Delicious' or 'Redchief Delicious' as the scion cultivar. All trees were planted with the graft union 5 cm above the soil line. Immediately after planting, trees

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Table 1. Number of blossom clusters per meter of 'Delicious' scion shoot length in Spring 1988.

PB treatment	Blossoms/m of total shoot length			
	Classic		Redchief	
	Seedling	M.26	Seedling	M.26
None	6.0	8.6	0.5	15.0
Foliar 1986	13.7 ^{NS}	35.2**	3.1 ^{NS}	43.1**
Foliar 1986 + 1987	2.9 ^{NS}	38.8**	1.2 ^{NS}	27.2*
Soil drench 1986	53.9**	57.5**	19.4**	57.4**

^{NS},*,**Nonsignificant or significant within each column at $P = 0.05$ or 0.01 , respectively ($n = 4$ replicates).

Table 2. Dry weight of 'Delicious' scions as influenced by strain and PB foliar or soil treatments.^z

PB treatment	Total shoot dry wt (g)		Root shank dry wt (g)		Total tree dry wt (g)	
	Classic	Redchief	Classic	Redchief	Classic	Redchief
None	336	166	170	127	654	404
Foliar 1986	182**	124*	96**	88**	378**	319*
Foliar 1986 + 1987	188**	119*	95**	88**	400**	312*
Soil drench 1986	84**	65**	75**	72**	231**	212**

^zTrees harvested on 30 Aug. 1988.

^{NS},*,**Nonsignificant or significant within each column at $P = 0.05$ or 0.01 , respectively ($n = 8$ replicates).

Table 3. Dry weight of 'Delicious' scions as influenced by rootstock and PB foliar or soil treatments.^z

PB treatment	Total shoot dry wt (g)		Total root dry wt (g)		Total tree dry wt (g)	
	Seedling	M.26	Seedling	M.26	Seedling	M.26
None	226	277	276	279	502	556
Foliar 1986	159*	146*	229 ^{NS}	163**	388*	309**
Foliar 1986 + 1987	192 ^{NS}	115**	256 ^{NS}	149**	448 ^{NS}	264**
Soil drench 1986	66**	84**	143**	151**	208**	235**

^zTrees harvested on 30 Aug. 1988.

^{NS},*,**Nonsignificant or significant within each column at $P = 0.05$ or 0.01 , respectively ($n = 8$ replicates).

Table 4. Fibrous root dry weight and root : shoot ratio of 'Delicious' scions as influenced by PB foliar and soil treatments.^z

PB treatment	Fibrous root dry wt (g)				Root : shoot ratio			
	Classic		Redchief		Classic		Redchief	
	Seedling	M.26	Seedling	M.26	Seedling	M.26	Seedling	M.26
None	195	101	117	102	1.15	0.90	1.80	1.51
Foliar 1986	131**	70 ^{NS}	158 ^{NS}	56*	1.48 ^{NS}	1.19 ^{NS}	1.97 ^{NS}	1.88*
Foliar 1986 + 1987	179 ^{NS}	55*	155 ^{NS}	55*	1.26 ^{NS}	1.50**	2.25*	1.69 ^{NS}
Soil drench 1986	84**	61 ^{NS}	87 ^{NS}	63**	2.50**	1.91**	2.68**	2.64**

^zTrees harvested on 30 Aug. 1988.

^{NS},*,**Nonsignificant or significant within each column at $P = 0.05$ or 0.01 , respectively ($n = 4$ replicates).

were headed-at 70 cm and disbudded, except for the top two buds. No additional shoot or root pruning was performed. Trees were kept outside for the duration of the study and received fertilization and pest control applications as needed. All trees were deflowered each year to prevent fruit set.

A $4 \times 2 \times 2$ split-split-plot factorial treatment arrangement was used, with four PB treatments as the main plots, two scion cultivars as subplots, and two rootstocks as sub-subplots. All treatments were replicated four times in a randomized complete-block design. Three separate sets of trees were prepared for destructive harvests, using a total of 192 trees.

PB treatments consisted of an untreated control, foliar sprays in the 1st year, foliar sprays in the 1st and 2nd years, and a single soil drench in the 1st year only. Yearly foliar

sprays comprised five applications of PB at 200 mg-liter⁻¹ (Cultar 2SC, ICI Americas, Greensboro, N.C.) plus 0.1% (v/v) Tween-20 surfactant (31.4 mg PB/0.8 liter per year) sprayed biweekly with a backpack sprayer, beginning when untreated trees had at least 8 cm of new growth. The single soil drench (426 mg PB/0.47 liter per pot) was made on the same day as the first foliar spray in 1986.

In spring of the 3rd year after planting, total shoot length accrued over 2 years and number of flower clusters per tree were recorded. Blossom density was calculated as the number of blossom clusters per tree per meter of total shoot length.

Destructive harvests were made on 13 Mar. 1987 (dormant season 1 year after planting), 7 Mar. 1988 (dormant season 2 years after planting), and 30 Aug. 1988 (active growth ≈ 2.5 years after planting). At harvest, tree

roots were flushed with water to separate the potting mix from the root system. Weights of fibrous roots, root shank, and shoot portions corresponding to each year of growth were measured after drying them at 50C in a forced-air oven to a constant weight. Shoot was defined as that portion of the tree axis above the graft union, and root shank as that portion below the union. Root : shoot ratio was calculated as rootstock divided by scion dry weight.

Analysis of variance was performed using the General Linear Models (GLM) procedure (SAS Institute, 1985) and mean separation was accomplished using the LSMEANS PDIF option (Freund and Littell, 1981).

Because of the large volume of data generated in this study, only the results of harvest 3 will be discussed.

Because PB is known to reduce vegetative growth, flowering data recorded 2 years after planting were adjusted for the amount of shoot growth on each tree. The soil drench resulted in the highest blossom densities within each scion class (Table 1). For either scion on seedling, foliar sprays had no effect on bloom density, but higher densities were observed after sprays were applied to either scion on M.26. Thus, inherent rootstock precocity seemed to dictate flower density response to foliar sprays, while scion precocity appeared less important. Other researchers have also reported higher blossom densities after PB application. One year after a soil injection, Dejong and Doyle (1984) observed more flower buds per unit shoot length on 'Fantasia' nectarine. Using large 'Richard Delicious'/seedling apple trees, Jones et al. (1988) found an increase in flower cluster density the year after PB applications were made at various times. Dheim and Browning (1988) found that PB sprays decreased apical dominance and increased floral initiation in two pear cultivars by shortening the plastochron (average time between the appearance of successive primordia within a bud).

For each scion, PB foliar or soil application resulted in lower total shoot, root shank, and tree dry weights, although the reductions in dry weight accumulation appeared smaller for 'Redchief' than for 'Classic' (Table 2).

Most treatments suppressed final total shoot dry weight of both scions on each rootstock, except for repeat sprays applied to scions on seedling, which had no effect (Table 3). In contrast, Blanco (1988) and Tromp (1987) noted enhanced apple tree shoot growth in the year after PB treatment. In our study, trees on M.26 had less total dry weight in root tissue (shank plus fibrous roots) after foliar sprays, but final root dry weight of trees on seedling was not influenced by either foliar spray treatment. Total root dry weight of trees on both rootstocks was lower than that of the control trees after the soil drench. All PB treatments suppressed total tree dry weight for trees on M.26, while only the 2-year foliar applications did not affect final tree dry weight for trees on seedling.

Fibrous root growth of 'Classic'/seedling was suppressed by 1986 foliar sprays or a

oil drench, while 'Classic'/M.26 trees showed no effect (Table 4). PB treatment did not influence fibrous root dry weight of 'Redchief'/seedling, but the soil drench and the 2-year foliar spray treatments suppressed fibrous root dry weight of 'Redchief'/M.26. El Hodairi et al. (1988) found that root dry weight of 12-week-old 'Delicious' seedlings was not affected by foliar sprays of 500 mg PB/liter, but root : shoot ratio was higher 28 days after application. In our study, fibrous shoots of all stions that received a soil drench were shorter and thicker than the roots of untreated trees.

Foliar spray treatments did not affect root : shoot ratio of the most vigorous stion, 'Classic'/seedling, but higher ratios were observed for the two intermediate-vigor stions after repeat sprays in 1987 (Table 4). The soil drench more than doubled the root : shoot ratio of 'Classic' on either rootstock, while increases for 'Redchief' on either rootstock were smaller. Early and Martin (1988) reported higher peach seedling root : shoot ratios 3 weeks after adding 0.34 μM PB to a nutrient solution culture. Wang et al. (1985) noted a shift in assimilate partitioning from leaf tissue to roots of PB-treated 'York Imperial' apple seedlings growing in nutrient solution culture for several weeks.

Changes in both shoot and rootstock dry weights in response to PB treatments reflect the characteristic coordination of growth among apple tree parts. The observed increase in root : shoot ratio indicated that some treatments preferentially reduced growth of the shoot relative to the root. Further studies are needed to more clearly elucidate the control mechanisms of dry weight allocation in apple trees.

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