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Influence of Intensity and Duration of Cool White Fluorescent Lighting and Fertilizer on Growth and Quality of Foliage Plants[1]

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***Abstract. Brassaia actinophylla* Endl., *Chamaedorea elegans* Mart., *Dieffenbachia maculata* (Lodd.) G. Don 'Exotica', *Dracaena marginata* Lam., and *Ficus benjamina* L. were grown for 1 year under 13 or 26 μE $m^{-2}sec^{-1}$ from Cool White fluorescent lamps for 12, 18, or 24 hours daily durations. Increasing light duration to 24 hours daily decreased quality of all plants tested, with *Brassaia, Chamaedorea,* and *Dieffenbachia* being most affected. The primary symptoms resulting from constant light were foliar chlorosis and decrease in plant quality, although necrotic spotting appeared at times. By experiment termination, best plants overall were associated with 26 μE $m^{-2}sec^{-1}$ light for 12 or 18 hours duration and poorest with 26 μE $m^{-2}sec^{-1}$ light and 24 hours duration. A second factorial experiment with *Dieffenbachia* and *Dracaena* tested effects of 3 fertilizer levels (0, 0.67, or 1.30 g Osmocote/3 months per 15-cm pot) under 2 light intensities (13 or 26 μE $m^{-2}sec^{-1}$) and 2 light durations (12 or 24 hours) on plant quality. Higher fertilizer levels had a limited effect on plant quality, while influence of light intensity and duration was similar to the initial experiment.**

Foliage plants acclimatized to interior environments are being produced and sold by the foliage industry. Systems to produce these plants have been discussed previously (8, 9, 10, 11, 12, 13, 19). Interior-scrapers have in recent years raised questions concerning the possible effects continuous lighting might have on foliage plants used in airports, shopping malls, or other areas where lighting is provided 18 hr or more daily.

Arthur (2), in 1936, discussed effects of continuous light on a wide variety of plants. Symptoms of continuous light exposure ranged from chlorosis to necrosis and, in some cases, plant death. Tomato responded negatively to continuous light, and Hillman (16) conducted many experiments to further elucidate the phenomenon. He found that young tomato leaves were most affected, and observed chlorosis occurred as soon as 9 days after placement under continuous light when a constant temperature was maintained. However, alternating day-night temperature prevented symptom development in tomato even under continuous light. Hillman postulated that alteration of temperature allowed the plant to maintain its natural rhythm in spite of an environment changed to supply continuous light. Effects of continuous light on rhythmicity have been discussed by Hastings (15) who found that continuous light decreased rhythmicity and appeared to be accumulative with increased time and/or light intensity. More recently, Epel (14) found that continuous fluorescent light inhibited division of green algae, but did not appear to influence photosynthetic growth.

Cathey et al. (4, 5, 6) have conducted extensive research on artificial lighting of woody and herbaceous plants, but their work has been related primarily to light source and photoperiodic responses. When Cathey et al. (7) increased light duration to 16 hr daily, *Dizygotheca* and *Pilea* increased in height and *Zebrina* increased in weight. Recently, Biran and Kofranek (3) examined the influence of several lighting regimes on storage quality of foliage plants. Under a regime of 24 days light and 24 days dark, they observed abnormal growth or death of *Philodendron,* but these effects were not observed with *Asparagus* or *Tradescantia.*

Since data on effects of continuous light for long periods is limited, these experiments were established to determine foliage plant growth response and quality when grown under varying light intensities and durations with different nutritional regimes.

Materials and Methods

Experiment 1. A 2 × 3 factorial experiment in randomized block design with 6 replications was established Aug. 27, 1977, using 10–15-cm rooted plants in 6.2-cm^2 pots. Plants evaluated were *Brassaia actinophylla* (schefflera), *Chamaedorea elegans* (parlor palm), *Dieffenbachia maculata* 'Exotica' (dumbcane), *Dracaena marginata* (red edge dracaena), and *Ficus benjamina* (weeping fig). Plants were repotted in 15-cm-diameter pots containing 3 Florida sedge peat:1 builder's sand (v/v) amended with 0.6 kg Perk (a micronutrient blend manufactured by Estech General Chemical Corp., Chicago, Ill.), 4.2 kg dolomite and 3 kg/m^3 Osmocote 14–6–12 (N–P–K). After potting, plants were grown for 1 month in a shaded glass greenhouse receiving 215 μE $m^{-2}sec^{-1}$ natural illumination, with temperatures ranging from 18°–32°C and irrigated twice a week. On September 27, plants were moved to environmental rooms with constant temperatures of 24° ± 1° summer (April–September), 21° ± 1° winter (October–March), and a relative humidity of 40% ± 10%. Plants were watered 2 times per week to the point of leaching. Fertilizer was reapplied April 20 and July 26, 1978, with 1.3 g Osmocote 14–6–12 (N–P–K) per 15-cm pot.

Environmental room light intensity treatments were 13 or 26 μE $m^{-2}sec^{-1}$ provided by 40 watt Cool White fluorescent lamps. Light duration treatments were 12, 18, or 24 hr per day.

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Plant height was determined initially. At 6 and 12 months the following data was determined: foliar color was graded on a 1–5 scale where 1 = light green, 3 = moderate green, and 5 = dark green color; plant quality was rated on a scale of 1–5 where 1 = poor, not salable; 3 = good, salable; and 5 = excellent quality, and height was measured from the soil line to apex. At termination of the experiment, Oct. 2, 1978, fresh weight of shoots and roots was obtained. Twelve month data are presented in this paper, since 6 months data exhibited the same trends. Data were analyzed by analysis of variance and treatment differences measured by single degrees of freedom.

Experiment 2. In an effort to better understand the nature of yellowing and/or necrosis, and decrease in overall plant quality from increasing light duration, a second experiment was conducted which also included fertilizer as a variable. Plants in experiment 2 were selected because they responded negatively (dumbcane) or positively (red edge dracaena) to increased light. This 2 × 2 × 3 factorial experiment in randomized block design was established May 30, 1978. Well-rooted *Dieffenbachia maculata* 'Exotica' (dumbcane) and *Dracaena marginata* (red edge dracaena) plants about 15 cm tall were potted in 15-cm-diameter pots containing 2 Florida sedge peat:1 pine bark:1 cypress shavings (v/v/v) amended with 1.8 kg Perk and 4.2 kg dolomite/m^3. Four grams Osmocote 14–6–12 (N–P–K)/pot was surface applied at potting. As in experiment 1, plants were grown in a shaded greenhouse where they received 215 $\mu E\ m^{-2}sec^{-1}$ until July 6. They were then moved to environmental rooms, receiving the same temperatures and relative humidities as experiment 1.

Interior holding light intensities were 13 or 26 $\mu E\ m^{-2}sec^{-1}$ with light duration treatments of 12 and 24 hr per day. Fertilization treatments were equivalent to 0, 224, or 448 kg $N–P_2O_5–K_2O$/ha per year, and were surface applied at 0, 0.65, or 1.30 g Osmocote 14–6–12 (N–P–K)/15-cm pot per 3 months. Fertilizer treatments were applied, 3, 6, and 9 months after plants were placed in interior holding rooms.

Data were obtained as in experiment 1 except at termination. A total chlorophyll assay was made (1), as was an estimation of total nonstructural carbohydrates prepared by treating most recent fully expanded leaves with invertase, amyloglucosidase, and takadistase. Aliquots were analyzed for reducing sugar according to Somogyi's (18) adaption of Nelson's (17) copper reduction test. Data were analyzed as in experiment 1.

Results and Discussion

Experiment 1. Increasing light intensity from 13 to 26 $\mu E\ m^{-2}sec^{-1}$ increased height of red edge dracaena, but had no effect on schefflera, parlor palm, weeping fig, or dumbcane (Table 1). Considerable growth occurred with all genera during the 1 year experiment and ranged between 3 and 20 cm depending on plant genus and treatment. As light duration was increased, only red edge dracaena increased in height. Height, in general, was not a good growth parameter for foliage plants. After placement in interior plantings, some height increases were unsatisfactory because they were due primarily to internodal elongation, and this measurement does not consider horizontal increase in size.

Plant quality is a subjective grade but is used in this paper to relate to the overall conformity of the plant, fullness or density, leaf size, position, and color, and thus, aesthetic quality for its intended purpose. Plant quality decreased with increased light intensity for dumbcane, increased for red edge dracaena and

Table 1. Influence of light intensity and duration on growth and quality of 5 foliage plants after 1 year under an interior environment, experiment 1.

Light		Schefflera					Parlor palm				
Intensity $\mu E\ m^{-2}sec^{-1}$	Duration (hr)	Total ht increase (cm)	Color grade[z]	Plant quality[y]	Fresh wt (g) Tops	Fresh wt (g) Roots	Total ht increase (cm)	Color grade[z]	Plant quality[y]	Fresh wt (g) Tops	Fresh wt (g) Roots
13		9	4.1	4.2	249	25	10	4.2	4.2	115	58
26		10	3.6	3.8	280	37	14	3.3	3.4	127	78
	12	8	4.5	4.4	247	27	14	4.4	4.6	114	52
	18	9	4.2	4.4	278	30	12	3.8	3.8	117	59
	24	11	2.8	3.1	269	37	11	3.2	3.0	133	93
Interaction effects											
13	12	3	4.4	4.1	200	22	10	4.3	4.4	101	46
	18	9	4.4	4.6	284	27	12	4.3	4.4	123	53
	24	13	3.5	3.9	263	27	9	4.0	3.7	121	74
26	12	13	4.6	4.8	295	32	17	4.4	4.8	127	59
	18	9	4.1	4.3	272	32	11	3.3	3.1	110	64
	24	8	2.2	2.3	274	47	13	2.4	2.4	144	112
Significant effects											
Light intensity (LI) linear		NS	**	*	**	**	NS	**	**	NS	*
Light duration (LD) linear		NS	**	**	NS	*	NS	**	**	*	**
quadratic		NS	**	**	NS	NS	NS	NS	NS	NS	NS
LI (linear) × LS (linear)		NS	**	**	**	NS	NS	**	**	NS	NS
LI (linear) × LD (quadratic)		NS	NS	NS	*	NS	NS	NS	**	*	NS

[z]1 = light green, 3 = moderate green and 5 = dark green color.
[y]1 = poor, not salable; 3 = good, salable; and 5 = excellent quality.
NS, *, **Nonsignificant (NS) or significant at 5% (*) or 1% (**) level.

weeping fig, and interacted with light duration on schefflera and parlor palm (Table 1).

As light duration increased, a linear decrease occurred in quality of schefflera, parlor palm, and dumbcane, with no change in red edge dracaena or weeping fig (Table 1). The decreases in quality noted for several of these species would not be aesthetically acceptable in interior spaces where plants are viewed up close. The interactions on plant quality of light intensity and duration observed for schefflera and parlor palm show effects of long duration were more severe at the higher light intensity. In some cases, necrosis was observed on schefflera and parlor palm that received 26 $\mu E\ m^{-2}sec^{-1}$ light for 24 hr duration. Such data are in agreement with the findings of Hillman (16) and Arthur (2).

Plant color grade decreased on all plants except ficus as light intensity increased (Table 1), although it interacted with light duration on schefflera and parlor palm. Color would not have been commercially acceptable for schefflera and parlor palms receiving 24 hr light daily at 26 $\mu E\ m^{-2}sec^{-1}$ intensity. Color grade decreased linearly as light duration increased for all plants, although it was also quadratic between 12 and 18 hr duration for schefflera, red edge dracaena, and weeping fig. Color was acceptable for all plants when they received light of 12 to 18 hr duration; it was only when they received continuous light that a large decrease in color occurred.

Fresh weight of tops and roots was variable with increased light intensity or duration (Table 1). Fresh weight of tops increased for schefflera and weeping fig, decreased for dumbcane, and did not change for parlor palm or red edge dracaena when light intensity was increased (Table 1). However, root weight increased dramatically for all but dumbcane. As light duration increased, there was a linear increase in root weight of schefflera, parlor palm, dumbcane, and weeping fig, while no change occurred in red edge dracaena.

Data generated in this experiment indicated an increase in light intensity or duration was often beneficial, or at least not deleterious to increase in fresh top or root weight of interior plants. However, the effect of increased intensity, and especially duration, often affected aesthetic quality to the point that plants were unsatisfactory for interior use.

Experiment 2. Height increased for dumbcane and red edge dracaena as light duration and fertilizer levels increased, while height decreased for dumbcane and increased for red edge dracaena as light intensity increased (Table 2). Light intensity interacted with light duration and fertilizer level on both plants for plant quality and color grade. Increasing light intensity increased quality of dumbcane at 12 hr duration, but had no effect at 24 hr duration. With red edge dracaena, plant quality was poorest at high light intensity at 24 hr duration (Table 2).

Increasing the fertilizer increased plant quality, but the interaction with light intensity and not duration indicates its major benefit was to improve quality under higher light intensity, rather than influence quality reduction due to greater light duration for both dumbcane and red edge dracaena.

Foliar color grade of dumbcane was severely decreased at both light intensities when light duration was extended to 24 hr per day. The effect was less on red edge dracaena. These data are in agreement with data from experiment 1, where effect of increased light duration was more severe on dumbcane than on red edge dracaena.

Table 1 (continued)

Dumbcane					Red edge dracaena					Weeping fig				
Total ht increase (cm)	Color grade[z]	Plant quality[y]	Fresh wt (g) Tops	Roots	Total ht increase (cm)	Color grade[z]	Plant quality[y]	Fresh wt (g) Tops	Roots	Total ht increase (cm)	Color grade[z]	Plant quality[y]	Fresh wt (g) Tops	Roots
16	4.5	4.3	582	168	7	4.8	3.2	104	45	16	3.1	3.6	69	23
15	3.8	3.7	529	166	15	4.6	4.4	111	70	17	3.2	4.1	92	41
15	4.6	4.5	564	158	9	5.0	3.7	113	53	15	3.6	3.8	68	24
14	4.2	3.9	525	148	10	4.9	3.9	98	59	17	3.4	4.0	77	36
17	3.6	3.7	578	194	14	4.3	3.8	112	60	18	2.4	3.7	96	37
15	4.9	4.6	581	157	6	5.0	2.9	118	41	11	3.4	3.4	56	20
14	4.5	4.2	551	156	6	4.9	3.2	88	43	20	3.3	3.8	70	23
18	4.0	4.2	613	190	8	4.5	3.6	105	50	17	2.5	3.6	83	27
15	4.2	4.4	547	158	13	4.9	4.5	108	64	18	3.8	4.3	81	28
15	4.0	3.6	498	141	13	4.9	4.6	108	74	14	3.5	4.2	85	48
16	3.1	3.2	542	198	20	4.1	4.0	119	70	19	2.4	3.8	109	47
NS	**	**	**	NS	**	*	**	NS	**	NS	NS	**	**	**
NS	**	**	NS	*	**	**	NS	NS	NS	NS	**	NS	**	**
NS	NS	NS	NS	*	NS	**	NS	NS	NS	NS	**	NS	*	NS
NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS
NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Influence of light intensity and duration and fertilizer level on growth and quality of dumbcane and red edge dracaena after 1 year under an interior environment, experiment 2.

Light		Fertilizer level (g 14N–6P–12K/15-cm pot-3 mos)	Dumbcane			Red edge dracaena		
Intensity $\mu E\ m^{-2}sec^{-1}$	Duration (hr)		Total ht increase (cm)	Plant quality[z]	Color grade[y]	Total ht increase (cm)	Plant quality[z]	Color grade[y]
13			25	2.8	3.0	23	3.7	4.4
26			12	3.2	3.2	28	3.5	3.7
	12		12	3.9	4.0	23	3.7	4.5
	24		25	2.1	2.2	28	3.5	3.6
		0.0	14	2.7	2.8	22	3.1	3.5
		0.7	20	3.0	3.3	26	3.8	4.4
		1.4	22	3.1	3.3	28	4.0	4.6
Interaction effects								
13	12	---	20	3.6	3.7	20	3.6	4.7
	24	---	29	2.0	2.3	26	3.8	4.2
26	12	---	28	4.3	4.3	25	3.9	4.3
	24	---	16	2.0	2.1	30	3.2	3.1
13	---	0.0	20	2.8	3.0		3.4	4.1
	---	0.7	27	2.8	3.1	21	3.8	4.4
	---	1.4	27	2.7	2.9	24	3.8	4.8
26	---	0.0	8	2.6	3.5		2.8	2.8
	---	0.7	13	3.3	3.5	22	3.7	3.8
	---	1.4	17	3.6	3.7	28	4.0	4.4
Significant effects								
Light intensity linear			**	**	**	**	*	**
Light duration linear			**	**	**	**	*	**
Fertilizer level linear			**	**	**	**	**	**
quadratic			NS	NS	**	NS	NS	NS
Light intensity × light duration			NS	**	**	NS	**	**
Light intensity × fertilizer level linear			NS	**	**	NS	**	**

[z]1 = poor, not salable; 3 = good, salable; and 5 = excellent quality.
[y]1 = light green, 3 = moderate green, and 5 = dark green color.
NS, *, **Nonsignificant (NS) or significant at 5% (*) or 1% (**) level.

Increase in light intensity decreased N, P, K, Mg, and Fe levels in tissue of dumbcane while increasing Ca and Mn (Table 3). It had much less effect on red edge dracaena, only decreasing N and increasing Ca and Mn (Table 3). Such data are typical when increasing light levels by 320 to 640 $\mu E\ m^{-2}sec^{-1}$ in production areas (13).

An increase in light duration had less effect than light intensity on tissue levels (Table 3). Decreases in tissue P and K occurred in dumbcane as duration increased from 12 to 24 hr daily, while N and Fe increased and K, Ca, and Mn decreased in dracaena. Fertilizer levels, except for generally increasing tissue nutrient levels from 0 to 0.7 or 1.4 g, had no major effect on tissue content. Thus, when considering the overall impact of added N–P–K on improving plant quality, one must conclude that increasing the rate did not ameliorate the decrease in plant quality due to increased light duration.

Lastly, chlorophyll levels of leaves increased linearly as fertilizer levels were increased in both dumbcane and red edge dracaena (Table 4). Increasing light duration decreased chlorophyll levels of dumbcane and may be associated with decreased tissue Mg level. An interaction of light intensity and fertilizer indicated chlorophyll was depressed most in red edge dracaena at low or medium fertilizer level at 26 $\mu E\ m^{-2}sec^{-1}$.

Carbohydrate analysis did not indicate statistical differences among treatments and, therefore, appears to indicate that adequate photosynthesis was occurring in all treatments, even though plant quality was very poor under continuous illumination. Dumbcane contained an average of 72 mg carbohydrate/gm dry weight while red edge dracaena contained 116.

High carbohydrate levels in red edge dracaena may be responsible for sustaining this plant during post production and providing better plant appearance compared to dumbcane under the same conditions. However, plants such as dumbcane may undergo membrane or enzyme degradation at high light intensities and long light durations which may lead to poor plant quality and leaf chlorosis regardless of carbohydrate level.

Table 3. Influence of interior light intensity and duration and fertilizer level on elemental tissue content of dumbcane and red edge dracaena after 1 year under an interior environment, experiment 2.

Treatment	Dumbcane									Red edge dracaena								
	Leaf element content (%)					Dry wt basis (ppm)				Leaf element content (%)					Dry wt basis (ppm)			
	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn
Light intensity ($\mu E\ m^{-2}sec^{-1}$)																		
13	2.71	0.39	1.16	1.20	0.96	15	77	139	43	3.50	0.56	1.20	1.42	2.08	12	125	543	184
26	2.16	0.23	0.65	1.60	0.75	16	59	236	32	3.07	0.46	1.21	1.62	2.16	12	127	639	180
Light duration (hr)																		
12	2.50	0.37	1.05	1.40	0.91	15	72	223	43	3.07	0.46	1.27	1.68	2.09	12	117	635	183
24	2.37	0.25	0.76	1.39	0.80	16	65	222	32	3.50	0.56	1.14	1.36	2.15	12	135	546	181
Fertilizer level (g/15-cm pot–3 mo)																		
0	2.12	0.26	0.90	1.58	0.77	16	66	145	40	2.92	0.58	1.10	1.70	2.17	12	115	663	229
0.7	2.60	0.31	0.96	1.37	0.88	16	68	140	38	3.36	0.41	1.18	1.47	2.01	12	122	573	175
1.4	2.58	0.35	0.85	1.23	0.91	15	72	160	34	3.57	0.55	1.33	1.37	2.19	11	140	537	143
Significant effects																		
Light intensity linear	**	*	**	**	*	NS	**	**	NS	**	NS	NS	*	NS	NS	NS	**	NS
Light duration linear	NS	*	*	NS	NS	NS	NS	NS	NS	**	NS	*	*	NS	NS	*	**	NS
Fertilizer level linear	**	*	NS	**	*	NS	NS	NS	NS	**	NS	*	*	NS	NS	*	**	**
Fertilizer level quadratic	*	NS	NS	NS	*	NS	NS	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS

NS, *, **Nonsignificant (NS) or significant 5% (*) or 1% (**) level.

Table 4. Influence of light intensity and duration and fertilizer level on chlorophyll level of dumbcane and red edge dracaena after 1 year under an interior environment, experiment 2.

Light		Fertilizer level (g 14N–6P–12K/15-cm pot–3 mo)	Chlorophyll (mg/cm^2)	
Intensity $\mu E\ m^{-2}sec^{-1}$	Duration (hr)		Dumbcane	Red edge dracaena
13			.046	.060
26			.046	.053
	12		.049	.060
	24		.043	.053
		0.0	.041	.051
		0.7	.045	.062
		1.4	.053	.061
Interaction effects				
13	12	0.0	.040	.057
	24	0.7	.049	.060
		1.4	.050	.061
26	12	0.0	.042	.046
	24	0.7	.041	.052
		1.4	.055	.060
Significant effects				
Light intensity linear			NS	**
Light duration linear			*	**
Fertilizer level linear			**	**
Fertilizer level quadratic			NS	NS
Light intensity (linear) × Fertilizer level (linear)			NS	**

NS, *, **Nonsignificant (NS) or significant 5% (*) or 1% (**) level.

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Early Season Root and Shoot Growth of 'Golden Delicious' Apple on Four Rootstocks as Affected by Pruning at Planting[1]

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Abstract. **Apple trees (*Malus domestica* Borkh. cv. Smoothee Golden Delicious) on 4 rootstocks Malling (M) 9, Malling-Merton 106/M 9, MM 106, and seedling, received 4 pruning treatments at planting: no pruning, shoot pruned to 70 cm above graft union and branches removed, root pruned to 1/3 its original volume, or shoot and root both pruned as above, to determine effects on early shoot and root growth. Shoot pruning stimulated rapid new shoot growth and resulted in the highest new shoot relative growth rate and new shoot/total shoot dry weight ratio. Also, shoot pruning, with and without root pruning, resulted in very little root dry weight increase up to 8 weeks after planting, indicating a competitive inhibition of root growth by rapid new shoot growth. Root pruning, with and without shoot pruning, stimulated the greatest amount of new, white root formation soon after planting, but these contributed very little to root dry weight. Shoot- and root-pruned trees had the lowest shoot and root dry weights with all rootstocks. Pruning treatments significantly altered the root/shoot ratios of trees on M 9 and MM 106/M 9, but not on MM 106 and seedling. Shoot pruning of trees on M 9 caused the greatest deviation of root/shoot ratio from unpruned, heavily favoring shoot growth.**

Current apple orchard establishment recommendations include pruning the shoot back to 70–75 cm at planting (3, 4). This practice stimulates new lateral shoot growth for the primary purpose of selecting scaffold limbs to develop the tree's fruiting structure. The effect of this treatment on new root growth after planting and its subsequent effect on the root/shoot ratio of different rootstocks/scion combinations has not been studied in detail. In earlier reports, it was shown that moderate shoot pruning at planting increased new shoot production and decreased new root growth while maintaining a constant root/shoot ratio (6, 10). Preston (11) found that pruning the leader and lateral shoots at planting decreased total root weight compared to pruning only the leader or no pruning. His results showed a greater difference between treatments with M 7a rootstock than with the more vigorous M 16, indicating a rootstock-pruning interaction. Preston also found that severe root pruning alone reduced shoot growth, but shoot pruning alone produced the same effect (12). Root growth was not measured. A recent report (9) showed that moderate root pruning stimulated root growth of apple seedlings grown in liquid culture, while severe root pruning decreased growth.

The importance of an optimum root/shoot ratio in woody plants and the constancy of this ratio has been well-established (7). Root-shoot relationships in various apple rootstock/scion combinations have been studied extensively (1, 14, 15). Apple root/shoot ratio can be changed by such factors as soil moisture (2) and applied hormones (13). However, there is some doubt as to whether these changes resulted simply from changes in plant size, rather than from actual differences in relative growth of root and shoot (8). The balance between growth rate of root and shoot with increasing plant weight can be described by the equation of allometric growth (8):

$$\log R = a + b \log S,$$

where R = root dry weights, S = shoot dry weight, and a and b = constants. The constant b has also been referred to as K in growth analysis formulas (5) and is the slope of the line generated by this equation. Ledig and Perry (8) state that if the slope is not different, then differences in root/shoot ratio are merely a reflection of differences in total plant weight. They also point out that the alteration of the slope generally requires drastic treatment and does not appear to favor healthy growth.

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