GROWTH AND NUTRIENT CONCENTRATION IN FLOWERING DOGWOOD AFTER NITROGEN FERTILIZATION AND DORMANT ROOT PRUNING[1]

by Stuart L. Warren

Abstract. Flowering dogwood, *Cornus florida*, seedlings were grown with 3 levels of nitrogen (25, 75 or 150 mg/L applied three times a week) after removal of 0, 25, 50 or 75% of the root system (by weight). Roots were removed in an inverted cone to simulate root loss that might be experienced during transplanting. Forty-five and 90 days after budbreak, seedlings were harvested. Leaf area and top dry weight increased quadratically with increasing nitrogen. Root dry weight and relative growth rate (RGR) decreased with increasing nitrogen. Leaf area and top and root dry weights decreased with increasing root pruning. After 45 and 90 days, root RGR increased linearly with increasing root pruning. Percent nitrogen increased in all plant parts with increasing nitrogen. In general, %P, %K, %Ca and %Mg decreased with increasing nitrogen in all plant parts. Percent P in new stem and root, %K in root and %Mg in new stems and roots increased with increasing root pruning.

Only a small percentage of the original root system is moved with a transplanted tree (32). Thus, rapid root regeneration and adequate soil moisture are the most important factors for the successful establishment of transplanted trees (31). New root growth results from elongation of intact and initiated laterals and adventitious roots (24,30). Cultural practices can have a significant impact on root regeneration and growth following transplanting. Current recommendations include preparing a large soil area with adequate drainage combined with irrigation, fertility and mulch (4,10). Not all arborists agree that newly planted trees should be fertilized (10) and there are few studies on the effect of fertilizer on tree root growth (1). Smith (27) demonstrated that fertilizer enhanced tree root growth and density, while Coutts and Philipson (5, 6) reported that a high nutrient regime stimulated root growth in Sitka spruce (*Picea sitchensis*) and lodgepole pine (*Pinus contorta*). Even though these studies were conducted using trees with undisturbed root systems, the results suggested that fertilizer might enhance root regeneration. However, Brouwer (3) and others (13,14,23) reported that an increasing nutrient supply tended to increase top growth relative to root growth, increasing the top : root (T:R) ratio. This would not favor survival for a newly planted tree since the T:R ratio is already out of balance due to loss of roots at transplanting. Tree root response to fertilizer after recent root loss has not been examined.

Generally, root pruning increases root growth rate (17,22). Each species has a characteristic T:R ratio, which remains constant in a stable environment and increases progressively with age and size (16). Root loss temporarily increases this ratio. The plant's reaction is to restore the balance by increasing root growth (7,22,26).

Studies on nutrient uptake and concentration in root pruned plants are few and contradictory (9). Richards and Rowe (22) reported that root pruned peach seedlings tended to have higher levels of N, P, K, Ca and Mg than those plants not pruned. In contrast, Rohrig (25) found lower N, P and K concentration in root pruned red oak seedlings compared to unpruned plants.

Few studies have been conducted to determine how plants that have experienced recent root loss respond to fertilizer. The objective of this study was to determine the effect of root pruning and N fertilization on growth and mineral concentration of flowering dogwood, *Cornus florida* .

[1] Use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of the products named, nor criticism of similar ones not mentioned. Technical assistance of William Reece, Everett Whitman and Staff of the Mountain Horticultural Crops Research Station is gratefully acknowledged. This research was supported, in part, by a grant from the International Society of Arboriculture.

Materials and Methods

In September 1986, a Hayesville clay loam soil (clayey, oxidic, mesic, typic hapludult) was fumigated with methyl bromide, 4.9 kg/100 m^2, and amended to meet the pH and fertility levels recommended for tree seedlings (29). Mature seeds of flowering dogwood were collected locally in Fletcher, N.C. during Fall, 1986 and planted Dec. 3, 1986 at a 7.6 x 7.6 cm spacing. Ammonium nitrate (33% N) was surface applied at 38 kg/100 m^2 on June 29, 1987 and May 25, 1988. Seedlings were dug by hand on March 5, 1989. All soil was washed from the root system. Fresh weight of tops (above ground tissues) and roots (below ground tissues) were estimated using the technique of Young and Werner (33). A random sample of 40 seedlings was removed to determine actual fresh and dry weight (70°C for 96 h) of the top and roots. With these data the following regression equations were developed to predict the initial dry weight of the tops and roots of the seedlings to be used in the study:

[1] Top dry weight (g) = -0.311 + [0.494 x top fresh weight (g)], $R^2 = 0.94$

[2] Root dry weight (g) = 0.312 + [0.443 x root fresh weight (g)], $R^2 = 0.91$

To insure seedling uniformity, seedlings were selected by weight, height and trunk diameter before potting into 11.4 liter (#3) containers with a sand substrate. Seedlings were stored in the dark at 4°C until May 16, when the seedlings were moved out of the cooler and into the greenhouse under natural light and day/night temperatures of 24 and 15°C, respectively.

The experiment, a 3 x 4 factorial in a randomized complete block design with 10 replications, was conducted at the Mountain Horticultural Crops Research Station, Fletcher, NC. The two main factors were 3 concentrations of nitrogen (25, 75 or 150 mg/l) and 4 amounts of root pruning (0, 25, 50 or 75% removed by weight). Roots were removed in an inverted cone to simulate root loss that might be experienced during typical transplanting. Budbreak (day 0) occurred when the tips of the leaves in the terminal bud were visible. Beginning at day 0, two liters of nutrient solution (Table 1) were applied to each tree on Monday, Wednesday and Friday mornings. Containers were watered in the afternoon on Monday, Wednesday and Friday, and twice daily on the remaining days. Plant height and trunk diameter were measured on day 0 and every 14 days thereafter.

At day 0, 10 seedlings were harvested to determine initial nutrient concentrations. Four replicates were harvested 45 days later (also referred to as harvest 1), with the remaining replicates (six) harvested at 90 days (also referred to as harvest 2). At each harvest, seedlings were washed free of sand and separated into roots and top. Each top was subdivided into new stem growth (formed during current growing season), old stem (referred to as stem) and leaves. Leaf area was measured with a LI-COR 3100 (LI-COR, Lincoln, Neb.) leaf area meter. All plant material was dried at 70°C for 5 days, weighed and ground to pass a 40-mesh sieve. Each tissue sample (1.25 g) was combusted at 490°C for 6 hr. The resulting ash was dissolved in 10 ml 6 N HCl and diluted to 50 ml with distilled deionized water. Concentrations of P, K, Ca and Mg were determined by inductively coupled plasma emission spectroscopy. Nitrogen was determined using 10 mg samples in a Perkin Elmer 2400 CHN elemental analyzer.

Leaf, new stem, stem and root dry weights were used to calculate the following: top dry weight (sum of leaf, new stem and stem dry weights) and T:R ratio (top dry weight : root dry weight). At each harvest, nutrient content for leaves, new stem, stem and roots and relative growth rates (RGR)

Table 1. Concentration and source of nutrients in the nutrient solution.

Nutrient	Source	Concentration (mg/l)
N	NH_4NO_3	25 to 150
P	H_3PO_4	25
K	K_2SO_4	75
Ca	$CaCl_2$	50
Mg	$MgSO_4$	50
S	$K_2SO_4 + MgSO_4$	82
B	H_3BO_4	0.5
Cu	$CuCl_2$	0.02
Fe	Iron chelate	5
Mn	$MnSO_4$	0.5
Mo	$NaMO_4$	0.01
Zn	$ZnCl_2$	0.5

were calculated (20). Treatment effects were determined by analysis of variance and regression analysis.

Results and Discussion

Initial mean values of selected parameters are shown in Table 2. Height growth was not affected by root pruning or N concentration until 42 and 56 days after budbreak, respectively (data not shown). Seedling height increased curvilinearly with increasing N, with maximum height at 75 mg/l (data not shown). Nitrogen concentration did not affect trunk diameter growth, but root pruning reduced trunk diameter growth ($P < 0.01$) by 42 days after budbreak. Trunk diameter decreased linearly with increasing root pruning (data not shown).

At harvest 1, N did not affect any measured parameter (Table 3). In contrast, N affected all parameters except stem RGR at harvest 2. Root pruning significantly affected all parameters except new stem dry weight at harvest 1 (Table 3). Due to the similar responses to root pruning at harvest 1 and 2, only data for harvest 2 will be presented, excluding relative growth rates. The nitrogen x root pruning interaction was not significant at either harvest.

Leaf area, leaf dry weight, new stem and stem dry weights increased curvilinearly in response to N, with the maximum at 75 mg/l (Table 4). Root dry weight and root RGR decreased with increasing N. This is in agreement with Brouwers (3) and Ingestad (14) who showed that increasing N concentration decreased root growth. This is supported by the increase in T:R ratio with increasing N (Table 4). While an enriched nutrient environment does enhance root growth and density (5, 27), results from this study demonstrated that heightened N levels decreases root growth following root pruning. Nitrogen is still required to maintain plant processes (28) and N deficiency could be detrimental. However, these results suggest that N application should be minimized during the first season after transplanting.

Table 2. Initial mean values of selected parameters for 2-year-old dogwood seedlings (height, 47.6 cm; diameter, 7.5 mm).

Parameter	Stem	Root	T:R[z]
Estimated dry weight (g)	10.1	7.5	1.7
Nutrient concentration (%)[y]			
N	0.86	1.54	
P	0.12	0.31	
K	0.31	0.59	
Ca	1.25	0.58	
Mg	0.19	0.32	

[z]T:R = top dry weight : root dry weight.
[y]Average of 10 trees on a dry weight basis.

Table 3. Response of dogwood leaf area, dry weight, stem and root relative growth rates (RGR) and top : root ratio (T:R) to N concentration and root pruning 45 and 90 days after budbreak.

	Dry weight					RGR		T:R
Source of variation	Leaf area	Leaf	Stem	New stem	Roots	St	Rt	
Harvest 1								
Nitrogen (N)	NS[z]	NS	NS	NS	NS	NS	NS	NS
Pruning (P)	**	**	**	NS	**	**	**	**
N x P	NS	NS	NS	NS	NS	NS	NS	NS
Harvest 2								
Nitrogen	**	**	**	*	*	NS	**	**
Pruning	**	**	**	*	**	**	*	*
N x P	NS	NS	NS	NS	NS	NS	NS	NS

[z]NS,*,** Nonsignificant or significant at $p \leq 0.05$ or $p \leq 0.01$, respectively.
St = stem, Rt = roots

Leaf area, dry weights of leaves, new stem, stem and roots decreased with increasing root pruning (Table 4). Ninety days after removing 25%, 50% or 75% of the root system, root dry weight was reduced 7%, 52% and 68% respectively, compared to the unpruned control. T:R ratio increased with increasing root pruning. After 90 days, the T:R ratio for 0% and 25% root pruned were identical, however, the T:R ratio for 50% and 75% root pruned trees had not recovered. Time needed to restore the plant's balance varies greatly based upon percent root loss, age of plant and species. Richard and Rowe (22) reported that peach seedlings have similar T:R ratios 25 days after root pruning while Monterey pine (*Pinus radiata*) seedlings recovered in 80 days (26).

At harvest 1 (45 days), stem RGR decreased

Table 4. Response of dogwood leaf area, dry weight, root relative growth rate (RGR) and top : root ratio (T:R) to N concentration and root pruning 90 days after budbreak.

Nitrogen rate	Leaf area	Leaf	New stem	Stem	Root	RGR Root	T:R
(mg/l)	(cm^2)		Dry weight (g)			(mg/g/day)	(g/g)
25	2296	12.4	3.8	12.6	27.3	13.1	1.1
75	2878	13.2	5.0	13.5	25.5	12.6	1.2
150	1614	9.6	2.8	10.5	14.2	8.1	1.6
Linear[z]	*	*	*	*	*	*	*
Root pruning	Leaf area	Leaf	New stem	Stem	Root		T:R
(%)	(cm^2)		Dry weight (g)				(g/g)
0	3082	15.3	5.6	13.9	32.7		1.1
25	2612	14.5	5.0	12.8	30.5		1.1
50	2115	10.1	3.1	12.0	15.6		1.6
75	1241	7.2	1.8	10.0	10.4		1.8
Linear[z]	**	**	**	**	**		**
Quadratic	NS	NS	NS	NS	NS		NS

[z]NS,*,** Nonsignificant or significant at $p \leq 0.05$ or $p \leq 0.01$, respectively.

linearly with increasing root pruning (Table 5). Stem RGR decreased 307% at 75% pruning compared to 0% pruned. Root RGR increased linearly with increasing root pruning. Root RGR at 75% root pruned increased 185% compared to 0% root pruned. This is in agreement with other studies which have demonstrated that after root loss, growth is redistributed in favor of the roots (2, 17, 21). In any given situation a functional equilibrium exists between the top and root, and when any external factor disturbs this equilibrium, the plant reacts to re-establish the balance (3). The greater the shift in T:R ratio the greater the growth enhancement of the removed part (22). Thus, root RGR increased with increasing root loss. Root growth appears to be at the expense of stem growth. In apple, early season root growth is made from carbohydrate reserves in the stem and roots (18). In this study, root pruning removed much of the carbohydrates stored in the roots which would leave the stem as the major source of carbohydrates for new root growth. At harvest 2, stem RGR decreased with increasing root pruning, however, the stem was no longer losing dry weight (RGR was positive). Root RGR increased with increasing root pruning but, the 25% and 50% root pruning treatments were only 5% and 9%, greater than 0%, respectively, while the 75% root pruned

Table 5. Root pruning effects on dogwood stem and root relative growth rates 45 and 90 days after budbreak.

Root pruning	Relative growth rate (mg/g/day) Harvest 1 Stem	Harvest 1 Root	Harvest 2 Stem	Harvest 2 Root
0	-1.5	4.6	4.5	9.8
25	-3.3	4.7	4.2	10.3
50	-3.8	7.1	3.4	10.7
75	-6.1	13.1	1.9	14.1
Linear[z]	**	**	**	*
Quadratic	NS	**	NS	NS

[z]NS,*,** Nonsignificant or significant at $p \leq 0.05$ or $p \leq 0.01$, respectively.

Table 6. Root pruning and nitrogen effects on dogwood nutrient concentration 90 days after budbreak.

Source of variation	Nutrient concentration (% dry weight)									
	Leaf					New stem				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Nitrogen	**[z]	*	NS	**	NS	**	NS	**	**	NS
Pruning	*	*	**	*	NS	NS	**	NS	NS	**
N x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Stem					Root				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Nitrogen	**	NS	**	NS	**	**	**	**	*	**
Pruning	NS	NS	NS	NS	NS	**	**	**	NS	*
N x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]NS,*,** Nonsignificant or significant at $p \leq 0.05$ or $p \leq 0.01$, respectively.

was 44% greater than 0%. This illustrates that root growth rate returns to values similar to the unpruned control as the plant approaches a balanced T:R ratio.

Tissue nutrient concentration and content produced similar statistical trends so only nutrient concentration will be presented. In addition, N concentration and root pruning affected tissue nutrient concentration in each plant part similarly at harvest 1 and 2, so only data from harvest 2 will be presented. Table 6 indicates which factors induced significant responses for each nutrient in each plant part. Percent N increased in leaf, new stem, stem and root with increasing N (data not presented). Similar results were reported by Coutts and Philpson (5) and Ingestad (15). Percent P in leaf; %K in new stem, stem and root; %Ca in leaf, new stem and root; and %Mg in the root decreased with increasing N (data not presented). Ingestad (15) reported similar results in leaves, stems and roots of birch, *Betula verrucosa*.

Percent leaf N, P and Ca decreased curvilinearly in response to root pruning, with the minimum at 25% root pruning (Table 7). Percent P in new stem and root; %K in root; %Mg in new stem and root increased with increasing root pruning. Similarly, Richards and Rowe (22) reported that root pruned plants tended to have higher levels of N, P, K, Ca

Table 7. Root pruning effects on nutrient concentration of dogwood 90 days after budbreak.

% Root pruning	Leaf				New stem		Root			
	N	P	K	Ca	P	Mg	N	P	K	Mg
0	1.60	0.15	0.90	1.62	0.11	0.29	0.96	0.17	0.62	0.39
25	1.48	0.13	0.89	1.44	0.10	0.30	1.07	0.19	0.71	0.46
50	1.53	0.14	0.75	1.46	0.12	0.32	1.03	0.21	0.75	0.51
75	1.76	0.15	0.66	1.63	0.14	0.37	1.43	0.27	0.95	0.52
Linear[z]	NS	NS	**	NS	**	**	**	**	**	*
Quadratic	*	*	NS	*	NS	NS	NS	NS	NS	NS

[z]NS,*,** Nonsignificant or significant at $p \leq 0.05$ or $p \leq 0.01$, respectively.

and Mg than unpruned controls. Geisler and Ferree (9) speculated that as roots regenerate, uptake of some nutrients may increase. Uptake of P, Ca and Mg takes place at or near the root tip (11). If root morphology is important in P, Ca and Mg uptake, then root pruning might affect their levels. In this study, %P and %Mg increased in new stem and root with increasing root pruning. Perhaps root pruning enhanced new root initiation, resulting in higher P and Mg levels. In contrast, %Ca in all plant parts, excluding leaf, and %P in leaf and stem was not affected by root pruning. Humphries (12) speculated that root pruning could lead to nutrient deficiencies due to reduced uptake. In this study, only foliar %K decreased with increasing root pruning, suggesting that growth reductions resulting from root pruning were not due to nutrient deficiencies created by root loss.

Most woody plants have the capacity to enhance root growth after root loss. The external N concentration can alter this response; as the external level of N increases, root growth decreases. While N is essential for proper plant performance results from this study suggest that N should be applied conservatively during the first year of newly planted trees since an elevated N environment decreases root growth. This decreased root growth may negatively impact transplant survival and prolong the establishment period.

Literature Cited

1. Atkinson, D. 1980. *The distribution and effectiveness of the roots of tree crops.* Hort. Rev. 2:424-490.
2. Benjamin, L.R. and M.Y. Wren. 1980. *Root development and source-sink relations in carrot, Daucus carota L. II. Effects of root pruning on carbon assimilation and the partitioning of assimilates.* J. Expt. Bot. 31:1139-1146.
3. Brouwer, R. 1962. *Nutritive influences of the distribution of dry matter in the plant.* Neth. J. Agric. Sci. 10:399-408.
4. Corley, W.L., 1984. *Soil amendments at planting.* J. Environ. Hort. 2:27-30.
5. Coutts, M.P. and J.J. Philipson. 1976. *The influence of mineral nutrition on the root development of trees. I. The growth of sitka spruce with divided root systems.* J. Expt. Bot. 27:1102-1111.
6. Coutts, M.P. and J.J. Philipson. 1977. *The influence of mineral nutrition on the root development of trees. II. Plasticity of root growth in response to changes in the nutrient environment.* J. Exp. Bot. 28:1071-1075.
7. Ferree, D.C. 1989. *Growth and carbohydrate distribution of young apple trees in response to root pruning and tree density.* HortScience 24:62-65.
8. Ferree, D.C. 1992. *Time of root pruning influences vegetative growth, fruit size, biennial bearing, and yield of 'Jonathan' apple.* J. Amer. Soc. Hort. Sci. 117:198-202.
9. Geisler, D. and D.C. Ferree. 1984. Response of plants to root pruning. pp155-188. In: J. Janick (ed.). Hort Reviews, vol. 6, AVI, Westport, Conn.
10. Harris, R.W. 1992. Arboriculture: Integrated management of landscape trees, shrubs, and vines. Prentice Hall, Englewood Cliffs, NJ. 674 pp.
11. Harrison-Murray, R.S. and D.T. Clarkson. 1973. *Relationship between structural development and the absorption of ions by the root system of Cucurbita pepo.* Planta 114:1-16.
12. Humphries, E.C. 1958. *Effect of removal of a part of the root system on the subsequent growth of the root and shoot.* Ann. Bot. 22(86):251-257.
13. Ingestad. T. 1960. *Studies of the nutrition of forest trees seedlings. III. Mineral nutrition of pine.* Physiol. Plant. 13:513-533.
14. Ingestad. T. 1979. *Nitrogen stress in birch seedlings. I. Growth technique and growth.* Physiol. Plant. 45:137-148.
15. Ingestad. T. 1979. *Nitrogen stress in birch seedlings. II. N, K, P, Ca, and Mg nutrition.* Physiol. Plant. 45:149-157.
16. Kramer, P.J. and T.T. Kozlowski. 1979. Physiology of Woody Plants. Academic Press, New York.
17. Maggs, D.H. 1964. *Growth-rates in relation to asimilate supply and demand.* J. Expt. Bot. 15:574-583.
18. Maggs, D.H. 1965. *Growth rates in relation to asimilate supply and demand: II. The effect of particular leaves and growing regions in determining the dry matter distribution in young apple trees.* J. Expt. Bot. 16:387-404.
19. Mullin, R.E. 1973. *Root and top pruning of white spruce at the time of planting.* For. Chron. 49:134-135.
20. Radford, P.J. 1967. *Growth analysis formulae - their use and abuse.* Crop Sci. 7:171-175.
21. Randolph, W.S. and S.C. Wiest. 1981. *Relative importance of tractable factors affecting the establishment of transplanted holly.* J. Amer. Soc. Hort. Sci. 106:207-210.
22. Richards, D. and R.N. Rowe. 1977. *Effects of root restriction, root pruning and 6-benzylaminopurine on the growth of peach seedlings.* Ann. Bot. 41:729-740.
23. Richardson, S.D. 1953. Root growth of Acer pseudoplatanus L. in relation to grass cover and nitrogen deficiency. Meded. Landbouwhogesch Wageningen 53:74-97.
24. Richie, G.A. and J.R. Dunlap. 1989. *Root growth potential: its development and expression in forest tree seedlings.* N. Z. J. For. Res. 10:218-248.
25. Rohrig, E. 1977. *Wurzelschnitt an Eichensamlingen.* Forst. Archiv. 48:24-28.
26. Rook, D.A. 1971. *Effect of undercutting and wrenching on growth of Pinus radiata D. Dan. seedlings.* J. Appl. Ecol. 477-490.
27. Smith, P.F. 1965. *Effect of nitrogen source and placement on the root development of Valencia orange trees.* Proc. Fla. State Hort. Soc. 78:55-59.
28. Tolley-Henry, L. and C.D. Raper, Jr. 1986. *Nitrogen and dry-matter partitioning in soybean plants during onset of and recovery from nitrogen stress.* Bot. Gaz. 147:392-399.
29. Tucker, M.R. and R. Rhodes. 1987. Crop fertilization based on N.C. soil tests. N.C. Dept. Agric., Circular 1.

30. Vanstone, D.E. and W.G. Ronald. 1981. *Comparison of bareroot verses tree spade transplanting of boulevard trees.* J. Arboric. 7(10):271-274.
31. Watson, G.W. 1983. *Root regeneration of shade trees following transplanting.* J. Environ. Hort. 1:50-52.
32. Watson, G.W. 1986. *Cultural practices can influence root development for better transplanting success.* J. Environ. Hort. 4:32-34.
33. Young, E. and D.J. Werner. 1984. *A nondestructive method of measuring shoot and root fresh weights.* HortScience 19:554-555.

Associate Professor
Department of Horticultural Science
North Carolina State University
Raleigh, NC 27695-7609

Résumé. Des semis de cornouillers à fleurs (*Cornus florida*) étaient cultivés avec trois concentrations différentes d'azote (25, 75 ou l50 mg/L, appliqué trois fois par semaine) après leur avoir éliminé 0, 25, 50 ou 75% de leur système racinaire. Les racines enlevées l'étaient en forme de cône inversé afin de simuler la perte de racines qui serait survenue après une opération de transplantation. Quarante-cinq jours et 90 jours après l'éclosion des bourgeons, chaque partie des semis désignés était récoltée. La surface foliaire, la masse sèche de la cime et le taux de croissance relative de la cime décroissaient avec l'augmentation d'azote. La surface foliare et les masses sèches de la cime et des racines diminuaient avec l'augmentation du taux d'élimination des racines. Après 45 ou 90 jours, selon le cas, le taux de croissance relative des racines s'accroissait de manière linéaire avec un taux supérieur d'élimination des racines. Le pourcentage d'azote présent dans chacune des parties de la plante augmentait avec une plus forte concentration d'azote dans le milieu de culture. En général, les pourcentages de phosphore, de potassium, de calcium et de magnésium diminuaient avec l'augmentation d'azote, et ce, pour chacunes des parties de la plante. Avec l'augmentation du taux de taille des racines, le pourcentage de phosphore et de magnésium dans les nouvelles tiges et racines, et celui du potassium dans les racines, augmentaient.

Zusammenfassung. Sämlinge des Hartriegels *Cornus florida*, wurden mit 3 verschiedene Mengen Stickstoff aufgezogen (25, 75 order 150 mg/L dreimal wöchentlich angewandt) nach Entfernung von 0, 25, 50 oder 75 Gewichtsprozent des Wurzelsystems. Wurzeln wurden wie bei einer Verpflanzung entfernt, um den Wurzelverlust nachzuahmen, der während einer Umpflanzung erfolgt. 45 und 90 Tage nach Knospenausbruch wurden Sämlinge von jedem Pflanzenteil geerntet. Blattfläche, Trochengewicht und relative Wachstumsrate (RGR) nahmen mit steigender Stickstoffmenge ab. Das Verhältnis von oberirdischen und unterirdischen Wachstum nahm bei steigender Stickstoffmenge zu. Blattfläche-, Spitzen- und Wurzeltrochkengewichte nahmen mit vermehrter Wurzelbeschneidung ab. Nach 45 und 90 Tagen stieg die RGR der Wurzel mit vermehrter Wurzelbeschneidung linear an. Der Stickstoffanteil nahm in allen Pflanzenteilen mit steigender Stickstoffmenge zu. Im allgemeinen nahm der Prozentsatz von P, K, Ca und Mg bei steigender Stickstoffmenge in all Pflanzenteilen ab. Der Prozentsatz von P und Mg in Stamm und Wurzel und von K in den Wurzeln nahm mit stärkerer Wurzelbeschneidung zu.