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Nitrogen Level and Time of Mechanized Summer Shearing Influence Long-term Performance of a High-density 'Redskin' Peach Orchard

Christopher S. Walsh[1], Francis J. Allnutt[2], Anita N. Miller[3], and Arthur H. Thompson[4]
Department of Horticulture, The University of Maryland, College Park, MD 20742

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Abstract. **'Redskin' peach (*Prunus persica* Batsch.) trees, planted at a high-density spacing (3 × 5 m), were fertilized annually with urea at rates of 45, 90, or 135 kg·ha^{-1}. Trees were trained to a trapezoidal hedge by annual, mechanized, summer pruning. Within each fertilizer plot, subplots of five summer-pruning treatments were applied. Single pruning treatments were made at 120 days after full bloom (DAFB) and 150 DAFB. Paired pruning treatments were applied 30 + 60 DAFB, 60 + 120 DAFB, and 60 + 150 DAFB. Pruning at 120 DAFB alone, and in combination with pruning at 60 DAFB, decreased trunk cross-sectional area (TCA), fruit soluble solids content, and weight, while increasing the percentage of surface that was red. Pruning at 30 DAFB followed by a second pruning at 60 DAFB decreased leaf Ca concentration in comparison to pruning treatments applied later in the season. Increasing N fertilization also decreased leaf Ca. Year, N level, and pruning treatments gave a statistical interaction on mean fruit weight and yield.**

Peach trees grown in the mid-Atlantic region of the United States are excessively vigorous under most commercial situations. Since there are currently no acceptable size-controlling peach rootstocks, growers rely on heavy, annual dormant hand-pruning to control tree size. To minimize the cost of hand-pruning, growers are also using mechanized summer pruning. While this practice has been used commercially for more than 2 decades, few replicated studies have investigated the long-term effects of summer pruning on tree growth and productivity.

Studies of mechanically pruned trees at high densities have shown increased early yields (Bargioni et al., 1983; Chalmers et al., 1978; and Leuty and Pree, 1980). However, long-term studies were less conclusive, as many of the locations where the work was done had poor bud survival from mid-winter cold temperatures (Emerson and Hayden, 1975; Hartman and Hill, 1984), which led to erratic cropping. Studies have also compared the seasonal effects of summer pruning and dormant pruning on fruit quality and bud survival. Marini (1985) noted that summer pruning and topping treatments had an inconsistent effect on fruit size and quality, yield, or date of maturity, suggesting a potential interaction of treatment and season. In addition, observations on winter injury may have confounded the issue (Marini, 1986). In studies of non-bearing, potted peach trees, Rom and Ferree (1985) found that an increase in shoot regrowth occurred at the expense of other growth components following green pruning. This regrowth led to the eventual restoration of "functional equilibrium" within the pruned trees. Despite many comparisons of pruned and unpruned trees, there is little known on the role of the timing used on tree development. This study was conducted to test the effect of the time of summer pruning on tree growth, long-term productivity and fruit quality over the range of N fertility commonly used in commercial peach orchards.

Materials and Methods

Field plot design. The peach orchard used in this study was planted in 1979 at the Western Maryland Research and Education Center, in Keedysville. 'Redskin' trees on Halford rootstock were set at a 3 × 5-m spacing (667 trees/ha; 271 trees/acre). The soil series at this location is Hagerstown loam (typic hapludalf, fine, mixed, mesic), which is a well-drained, limestone-derived soil well-suited for fruit production.

Nine whole plots, consisting of 20 'Redskin' trees each and surrounded by a buffer-row of 'Redhaven' trees, were used for fertility management. Three whole plots each received 45, 90, or 135 kg·ha^{-1} (≈40, 80, and 120 lb N/acre) applied annually as urea.

Mechanized summer pruning was begun in the third leaf (1981). Within each whole plot, summer-pruning treatments were applied to sub-plots that contained four 'Redskin' trees and two 'Redhaven' buffer trees in a row. Summer pruning treatments were made annually at 30, 60, 120 and/or 150 DAFB beginning in the third leaf (Table 1).

Pruning at 30 or 60 DAFB removed leaves and shoots before

Table 1. Description of treatments used in the 'Redskin' peach summer pruning trial.

	Prunings		
Pruning treatment	Number during growing season	Approximate days after full bloom (DAFB)	Approximate calendar date
1	2	30 + 60	15 May + 15 June
2	2	60 + 120	15 June + 15 Aug.
3	2	60 + 150	15 June + 15 Sept.
4	1	120	15 Aug.
5	1	150	15 Sept.

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[1]Associate Professor.
[2]Faculty Research Assistant, Western Maryland Research and Education Center, Keedysville, MD 21756.
[3]Graduate Research Assistant. Presently Assistant Professor, Dept. of Horticulture, Oregon State Univ., Corvallis, OR 97331.
[4]Emeritus Professor.

full canopy development. Pruning trees at 120 DAFB removed much of the fully mature canopy ≈2 weeks before harvest. At 150 DAFB, pruning removed the canopy ≈3 weeks before natural defoliation. While new growth developed rapidly following pruning at 30 and 60 DAFB, no regrowth was seen after pruning at 120 or 150 DAFB. Pit-hardening typically occurs at ≈50 DAFB in 'Redskin', and final swell begins at 100 to 105 DAFB.

Trees were trained to a trapezoid hedge configuration using a tractor-mounted cutter bar (Durand-Wayland Co., La Grange, Ga.). Tree height was maintained at 2.4 m by a cut made horizontal to the ground. The cutter bar was then set at 0.9 m from the trunk, and angled at 17° from vertical to create a hedge that was slightly narrower at the top than at the bottom.

Measurement of fruit yield and quality. Fruit were harvested annually during the third through the sixth leaf (1981–1984). Firm-ripe fruits from each subplot were harvested two or three times each season, and the total annual fruit yield was measured in the field.

On each harvest date, a 20-fruit subsample was removed randomly from each of the subplots. Subsamples were brought to the laboratory, weighed, and assessed for percentage of the fruit surface that was red (SR). The percentage was estimated by the same observer by placing fruits of each subsample with the stem-end down and the suture facing the observer in four rows of five fruits each. SR was estimated for each row of five fruits, and the mean percentage was then computed for the subsample.

In 1984, a 5-g slice of tissue from the stylar tip to the stem end was taken from each of the 20 fruit and frozen immediately at −20C. Samples from each plot and harvest date were analyzed later for soluble solids concentration (SSC) and flesh color. SSC determinations were made on free-run juice with a Bausch and Lomb temperature compensated (20C) refractometer after the samples had been thawed at 0C. Flesh color measurements were made using a Spectrogard Color System color difference meter (Gardner/Neotec, Silver Spring, Md.). No visible browning of the fruit flesh or juice was noted during the time needed to make these determinations.

Trunk circumference (TC) measurements were made after leaf-fall in 1984 at 20 cm above the soil-line. From these measurements, trunk cross-sectional areas (TCA) were computed for each tree. Long-term efficiency data were then calculated as the ratio of 4-year cumulative yield to the TCA. Seasonal efficiency data were also calculated as the ratio of 1984 yield to TCA.

Mineral nutrition. Before the 120 DAFB shearing in 1984, 50 mid-shoot leaves were harvested from each subplot. About 12 leaves were taken at a height of 1.8 m from each tree. Leaves were sampled by a research technician who was unfamiliar with the treatments, so as to avoid sampling bias. Leaf samples were air-dried and analyzed for the following elements: N, P, K, Ca, and Mg. Analyses were performed by the Tissue Analysis Laboratory of the Dept. of Agronomy at the Univ. of Maryland using standard methods (Steckel and Flannery, 1971).

Statistical analyses. Statistical analyses were performed using the SAS GLM procedure. Arithmetic mean values for the measured dependent variables were first calculated for each season of the study. These cumulative mean values were then subjected to an analysis of variance (ANOVA).

The linear and quadratic response to N level (whole plot treatments) was tested against the Error A term. Pruning treatments and the pruning × N interaction were tested against the Error B term. Data were analyzed as a split-plot in time and space. Where significant year × treatment interactions were observed, ANOVAs based on year-by-year changes were also run. Single-degree-of-freedom planned comparisons were used to test for significance among treatments, as suggested by Chew (1980) and Little (1978).

Results

Tree size and fruit quality. The effect of N fertilization was not significant at $P = 0.05$. Single-degree-of-freedom analysis for the linear effect of N approached significance, however ($P = 0.06–0.10$), for each of these dependent variables. This lack of statistical significance (at $P = 0.05$) for N level may be attributed to the split-plot experimental design used, which can frequently lead to a non-significant result when testing for whole-plot significance.

Pruning treatments influenced TCA, SSC, and area that was red (Table 2). Treatments that included a pruning at 120 DAFB (treatments 2 and 4) differed from those that were not pruned at 120 DAFB (treatments 1, 3, and 5). Pruning at 120 DAFB alone, or in combination with 60 DAFB, significantly decreased TCA and SSC, but increased SR.

Pruning at 60 + 120 DAFB decreased tree TCA when compared to pruning at 120 DAFB alone. This difference occurred without any significant difference in SR. A single pruning at 150 DAFB produced trees with a greater TCA than when trees were pruned at 60 + 150 DAFB. A significant increase in SSC was also noted in trees that were pruned once at 150 DAFB. Fruits from trees pruned at 150 DAFB had the highest SSC levels of any treatment in the study.

Color measurements of flesh wedges showed no statistical differences in 'L' or 'a' values (data not shown). Measurements of the 'b' coordinate showed small, but statistically significant, differences arising from treatment. The mean 'b' coordinate for fruits from trees receiving a single shearing was 24.8, while the value for fruits receiving two annual shearings was 23.7 (F value = 10.16, P = 0.004).

Mineral nutrient content of leaves. Increasing the level of N increased leaf N concentration and decreased leaf Ca concentration (Table 3). Nitrogen level did not affect P, Mg, or K levels (data on Mg and K not shown). Nitrogen levels were consistent with previously published data (Ballinger et al., 1966). Pruning at 30 + 60 DAFB increased leaf P concentration, but decreased Ca concentration when compared to leaves from trees pruned at 60 + 150 DAFB or 150 DAFB alone. In addition, a single summer pruning at 150 DAFB decreased leaf N levels when compared to summer pruning at 60 and 150 DAFB.

Interaction of nitrogen level, time of summer pruning, and year on fruit size and cumulative yield. There was a significant interaction between year, N level, and time of summer pruning on fruit weight and cumulative yield. The interaction of N level, treatment, and year (F = 3.41, $P = 0.003$) on fruit weight arose from a change in significance of N level and in rank among treatments over time (Table 4). Initially, there was no difference among pruning treatments. However, in 1983 and 1984, treatments 1 and 2 switched ranks. ANOVA of the 3-year mean fruit weight results showed a significant decrease in weight between treatments 2 and 4, which received pruning alone, or in combination at 120 DAFB, and the mean of the other three treatments.

The interactions of N level, treatment, and year on yield were highly complex. A significant treatment × year interaction, and N × treatment × year interaction were found. Initially, neither fertilizer level nor treatment affected yield (Table 5). In 1983 and 1984, a large change in the performance of treatment 4 was noted. In addition, in 1984 N level interacted with treatment.

Table 2. Effect of summer pruning treatment on tree trunk cross-sectional area (TCA) and fruit quality of 'Redskin' peach.

			Fruit quality	
Treatment	Pruning time (DAFB)	TCA (cm^2)	Soluble solids concn (°Brix)	Portion of red surface (%)
1	30 + 60	83.8	11.8	44
2	60 + 120	71.8	10.9	47
3	60 + 150	83.0	11.2	40
4	120	79.4	10.7	49
5	150	102.4	12.4	36
ANOVA				
Nitrogen		NS	NS	NS
Treatment		**	***	*
T2 vs. 4		*	NS	NS
T3 vs. 5		**	***	NS
T1 vs. 3+5		NS	NS	NS
T2+4 vs. 1+3+5		*	***	**
N × T interaction		NS	NS	NS

NS, *, **, ***Nonsignificant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

Table 3. Effect of nitrogen fertilization level and summer pruning treatment on the mineral content of 'Redskin' peach leaves.

	Mineral element (% dry wt)		
Treatment	N	P	Ca
Nitrogen level (kg·ha^{-1})			
45	2.75	0.170	2.45
90	3.15	0.211	2.26
135	3.30	0.192	2.20
Pruning			
1 (30+60 DAFB)	3.21	0.186	2.01
2 (60+120 DAFB)	3.13	0.177	2.30
3 (60+150 DAFB)	3.20	0.173	2.31
4 (120 DAFB)	2.91	0.164	2.46
5 (150 DAFB)	2.89	0.153	2.44
ANOVA			
Nitrogen	*	NS	*
N linear	**	NS	**
N quadratic	NS	NS	NS
Treatment	*	*	*
T2 vs. 4	NS	NS	NS
T3 vs. 5	*	NS	NS
T1 vs. 3+5	NS	*	**
T 2+4 vs. 1+3+5	NS	NS	NS
N × T interaction	NS	NS	NS

NS, *, **, ***Nonsignificant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

Table 4. Interaction of nitrogen level, pruning treatment, and year on 'Redskin' peach fruit weight.

	Fruit wt (g)			
Treatment	1982	1983	1984	Cumulative mean
Nitrogen level (kg·ha^{-1})				
45	146	126	200	157
90	147	125	215	172
135	167	120	222	170
Pruning				
1 (30+60 DAFB)	146	127	200	158
2 (60+120 DAFB)	161	123	219	168
3 (60+150 DAFB)	156	130	237	175
4 (120 DAFB)	154	112	185	151
5 (150 DAFB)	149	127	218	165
ANOVA				
Nitrogen	**	NS	NS	NS
Treatment	NS	**	**	***
Nitrogen × treatment	NS	NS	NS	NS

NS, *, **, ***Nonsignificant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

During that season, yields were greatest at 90 kg N in single-shearing plots (treatments 4 and 5). In contrast, yields in plots receiving more than one pruning (treatments 1, 2, and 3) were greatest at 135 kg N. Cumulative yield figures were similar to those observed in 1984. No significant difference in cumulative yield efficiency or annual yield efficiency was measured, however (data not shown).

Discussion

Peach tree and fruit development is a complex process that is still poorly understood. In this study, TCA, SSC, and SR were interrelated variables. TCA correlated positively with SSC ($r = 0.3025$, $P = 0.04$) and negatively with SR ($r = -0.7147$, $P = 0.0001$). This suggests that a potential trade-off exists with summer pruning. While preharvest pruning (120 DAFB) can be used to increase light penetration into the canopy and improve SR (Marini, 1985; Table 2), it appears to decrease total carbohydrate availability needed for fruit quality and tree growth.

Delwiche and Baumgardner (1983) suggested that tristimulus colorimeter differences and fruit maturity could be judged by measurements of the Hunter 'a' coordinate. This measures changes from green to red. No significant differences in 'L' or 'a' values were noted among treatments; visually determined SR and 'a' values shown were highly correlated ($r = 0.31$, $P = 0.01$). A slight, but significant, decrease in 'b' value was noted with pruning at 120 DAFB. These data infer that, although SR was increased by pruning before harvest, flesh yellowness was decreased. Sims and Comin (1963) suggested that changes in flesh yellowness occured with maturation and correlated with an improvement of quality. SSC and 'b' values were also correlated ($r = 0.37$, $P = 0.01$). Since these small differences in 'b' values appear to be related to differences in fruit quality, it is

Table 5. Interaction of nitrogen level, pruning treatment, and year on 'Redskin' peach fruit yield.

Treatment	Yield (kg/tree)				
	1981	1982	1983	1984	Cumulative
Nitrogen level ($kg \cdot ha^{-1}$)					
45	11.6	15.2	17.4	24.3	68.5
90	13.4	16.7	20.8	29.6	80.5
135	15.6	14.8	23.8	24.3	78.5
Pruning					
1 (30 + 60 DAFB)	13.9	16.3	21.9	26.6	78.7
2 (60 + 120 DAFB)	13.6	14.2	17.5	21.4	66.7
3 (60 + 150 DAFB)	12.5	16.4	21.0	22.8	72.7
4 (120 DAFB)	12.7	14.0	18.3	31.4	76.4
5 (150 DAFB)	15.0	16.6	24.8	28.1	84.5
ANOVA					
Nitrogen	NS	NS	NS	NS	NS
Treatment	NS	NS	***	*	***
Nitrogen × treatment	NS	NS	NS	*	**

NS,*,**,***Nonsignificant or significant at P = 0.05, 0.01, or 0.001, respectively.

suggested that, while pruning at 120 DAFB increased SR, flesh yellowness and overall quality were decreased.

Treatment effects on mean fruit size and long-term productivity were more complex. Differences in fruit weight and yield may be caused by treatments differentially affecting fruit growth rate at various times during the season (Batjer and Westwood, 1958; Byers et al., 1984). Single-pruning treatments generally decreased fruit size (Table 4), which could have occurred merely by retaining weak wood and removing vigorous wood with a single pruning.

Decreased leaf Ca and increased leaf P were noted in trees pruned at 30 + 60 DAFB, suggesting that early season canopy removal may have affected a range of critical developmental processes. Both early season fruit development and root uptake of Ca may require high amounts of photosynthate. Pruning at 30 + 60 DAFB may have caused a severe reduction in photosynthate at times that are critical in fruit, seed, and root development (Faust, 1979; Kirkby, 1979). Application of N fertilizers (such as urea) that release ammonium are known to affect Ca levels in various ways (Shear, 1975). For example, acidification of ammonia to nitrate can promote the rapid leaching of Ca. In addition, ammonium ions can reduce Ca uptake through competitive absorption.

Theoretically, the expected optimum overall timing for a summer-pruning treatment would be during Stage II. Chalmers and van den Ende's (1979) observations of peach fruit growth showed a decreasing rate of dry weight gain by the fruit during FWII/DWII and FWIII/DWII. This time spans the period between the endosperm attaining full size and the embryo attaining full size. In studies of dry-weight partitioning in bearing peach trees, Miller and Walsh (1988) observed an increased absolute growth rate in peach shoots and wood during Stage II.

The optimum timing pattern for mechanized pruning in this study appeared to be 60 + 150 DAFB. It avoided reduced leaf Ca levels, measured in trees pruned at 30 + 60 DAFB, but produced high-quality fruit of desirable size. We do not suggest that commercial growers abandon hand-pruning. Rather, we suggest that mechanized pruning may be most useful during Stage II, when dry matter allocation to shoot growth is greatest. From these results, mechanized pruning at 60 DAFB, coupled with dormant hand-pruning, might be the most useful for commercial peach production. This timing parallels the work of Mitchell and Chalmers (1982), who noted an increase in yield by reduced-irrigation scheduling during Stage II. During early Stage II, total carbohydrate needs of the crop are relatively low, as fruit numbers have been greatly diminished by both June drop and hand-thinning (Byers et al., 1984; Lombard and Mitchell, 1962). At that time, the re-allocation of carbohydrate to new shoot growth following mechanized pruning may have less deleterious effects on the crop and tree, but yet control tree size.

It also appeared that when trees are pruned more than once annually, N fertilizer needs were greater. While trees pruned twice did not display a yield increase plateau, those pruned once did.

Full production was attained rapidly in this study due to the high-density system used, which agrees with previous reports (Bargioni et al., 1983; Chalmers et al., 1978). It is interesting to note, however, that our annual yields of $\approx 10\ t \cdot ha^{-1}$ (which is less than 200 bushels per acre) differed little from those reported by Rogers (1967) for unirrigated peach trees grown on standard spacings in western Maryland. Tree efficiency also was low. In 1984, yield efficiency ranged from only 0.08 $kg \cdot cm^{-2}$ to 0.33 $kg \cdot cm^{-2}$. While these are typical for peach trees (Layne and Tan, 1984), they are relatively low when compared to other deciduous tree fruits. To increase peach orchard efficiency, it appears that improved mechanisms to increase the allocation of dry matter to the fruit are needed.

Literature Cited

Ballinger, W.E., H.K. Bell, and N.F. Childers. 1966. Peach nutrition, p. 276–390. In: N.F. Childers (ed.). Fruit nutrition. Hort Publications, New Brunswick, N.J.

Bargioni, G., F. Loreti, and P.L. Pisani. 1983. Performance of peach and nectarine in a high density system in Italy. HortScience 18:143–146.

Batjer, L.P. and M.N. Westwood. 1958. Size of Elberta and J.H. Hale peaches during the thinning period as related to size at harvest. Proc. Amer. Soc. Hort. Sci. 72:102–105.

Byers, R.E., C.G. Lyons, Jr., T.B. Del Valle, J.A. Barden, and R.W. Young. 1984. Peach fruit abscission by shading and photosynthetic inhibition. HortScience 19:649–651.

Chalmers, D., B. van den Ende, and L. van Heek. 1978. Productivity and mechanization of the Tatura trellis orchard. HortScience 13:517–521.

Chalmers, D. and B. van den Ende. 1979. A reappraisal of the growth and development of peach fruit. Austral. J. Plant Physiol. 2:623–624.

Chew, V. 1980. Testing differences among means: correct interpretation and some alternatives. HortScience 15:467–470.

Delwiche, M.J. and R.A. Baumgardner. 1983. Ground color measurements of peach. J. Amer. Soc. Hort. Sci. 108:1012–1016.

Emerson, F.H. and R.A. Hayden. 1975. High density "tree walls". HortScience 10:550.

Faust, M. 1979. Interaction between nutrient uptake and photosynthesis, p. 193–199. In: D. Atkinson, J.E. Jackson, R.O. Sharples, and W.M. Walker (eds.). Mineral nutrition of fruit trees. Butterworths, London.

Hartman, F.O. and R.G. Hill, Jr. 1984. Response of peach trees to various planting distances. Fruit Var. J. 37:108–112.

Kirkby, E.A. 1979. Maximizing calcium uptake by plants. Commun. Soil Sci. Plant Anal. 10:89–113.

Layne, R.C. and C.S. Tan. 1984. Long-term influence of irrigation and tree density on growth, survival and production of peach. J. Amer. Soc. Hort. Sci. 109:795–799.

Leuty, S.J. and D.J. Pree. 1980. The influence of tree population and summer pruning on productivity, growth and quality of peaches. J. Amer. Soc. Hort. Sci. 105:702–705.

Little, T.M. 1978. If Galileo had published in HortScience. HortScience 13:504–506.

Lombard, P.B. and A.E. Mitchell. 1962. Anatomical and hormonal development in Redhaven peach seeds as related to the timing of napthaleneacetic acid for fruit thinning. Proc. Amer. Soc. Hort. Sci. 80:163–171.

Marini, R.P. 1985. Vegetative growth, yield and fruit quality of peach as influenced by dormant pruning, summer pruning, and summer topping. J. Amer. Soc. Hort. Sci. 110:133–139.

Marini, R.P. 1986. Defoliation, flower bud cold hardiness, and bloom date of peach as influenced by pruning treatments. J. Amer. Soc. Hort. Sci. 111:391–394.

Miller, A.N. and C.S. Walsh. 1988. Growth and seasonal positioning of dry matter in eight-year-old 'Loring' peach trees. J. Amer. Soc. Hort. Sci. 113:309–314.

Mitchell, P.D. and D.J. Chalmers. 1982. The effect of reduced water supply on peach tree growth and yields. J. Amer. Soc. Hort. Sci. 107:853–856.

Rogers, B.L. 1967. Peaches in Maryland: A decade of soil moisture and irrigation studies. Univ. Md. Agr. Expt. Sta. Bul. A-148:1–29.

Rom, C.R. and D.C. Ferree. 1985. Time and severity of summer pruning influences on young peach tree net photosynthesis, transpiration, and dry weight distribution. J. Amer. Soc. Hort. Sci. 110:455–461.

Shear, C.B. 1975. Calcium-related disorders of fruits and vegetables. HortScience 10:361–365.

Sims, E.T., Jr., and D. Comin. 1963. Evaluation of objective maturity indices for Halehaven peaches. Proc. Amer. Soc. Hort. Sci. 82:125–130.

Steckel, J.E. and R.L. Flannery. 1971. Simultaneous determination of phosphorus, potassium, calcium and magnesium in wet digestion solutions of plant tissue by Auto Analyzer, p. 83–96. In: L.M. Walsh (ed.). Instrumental methods for analysis of soils and plant tissue. Soil Sci. Soc. Amer., Madison, Wis.

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Nutrition and Yield of Young Apple Trees Irrigated with Municipal Waste Water

G.H. Neilsen[1], D.S. Stevenson[1], J.J. Fitzpatrick[2], and C.H. Brownlee[3]

Agriculture Canada Research Station, Summerland, B.C. V0H 120, Canada

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Abstract. **'Macspur McIntosh' and 'Red Chief Delicious' apple (*Malus domestica* Borkh.) on M.7a rootstock were subjected to treatments involving all combinations of two types of irrigation water (well-water or municipal effluent) from 1983, the year of planting, through 1987 and three rates of N fertilization (0, 200, 400 g NH_4NO_3/tree per year), from 1984 through 1987. The zero N treatment was increased to 100 g NH_4NO_3/tree per year in 1986 due to low vigor of these trees. Effluent irrigation increased leaf N, P, and K concentration in 4 of 5 years for 'McIntosh', while leaf N, P, and K increased in 1, 4, and 2 years, respectively, for 'Delicious'. Effluent irrigation increased trunk diameter increment in all years and fruit number and yield in 1985–86 for both cultivars. No major horticultural limitations to the use of effluent irrigation were observed. Nitrogen fertilization increased leaf N in 3 years for 'McIntosh' and 2 years for 'Delicious', while leaf P and K were decreased at the highest N rate in 2 years for each cultivar. Nitrogen fertilization did not increase trunk diameter and increased fruit number and yield only in 1986 after 3 years of a zero N treatment. The results implied a role for P in the establishment and early growth and yield of young apple trees.**

Successful growth of several crops (5, 6, 12), especially trees (10, 11), has been achieved after wastewater application, despite the possibility of plant damage from toxicity (8) or salinity (23). It has been suggested that, under proper management, wastewater irrigation of fruit trees could produce economic gains of 25% to 30% (2). Despite this suggestion, and a recent workshop to stimulate the use of wastewater in horticulture (20), few case studies have been reported concerning the consequences of wastewater application on fruit trees.

Although the chemical composition of wastewater varies between locations, it is recognized as a possible important source of the major plant nutrients, such as N, P, and K (4, 8). Irrigation with wastewater could thus be similar in effect to continuous fertigation with a dilute concentration of several important plant nutrients. In the Okanagan Valley of British Columbia, replanting problems and slow growth, especially of newly planted apples, has been recognized as a potential limitation to the successful development of high-density apple orchards. Several solutions are currently being researched, including the use of fertilizers containing P at planting time (15, 22). Local wastewater is already known to be an effective source of P for the production of vegetables (18).

We, therefore, assessed the effects of irrigation of apples with secondary municipal effluent through a project initiated by the rural town of Osoyoos, B.C., Canada. Emphasis was placed on comparing the nutrition, growth, and yield of apple trees established under wastewater and well-water irrigation and under a range of N fertilization.

The experimental site was located on a virgin Osoyoos loamy sand (Typic Haploxeroll). Land leveling had removed parts of the surface soil over much of the area. The exposed soil had properties typical of the B horizon of a virgin Osoyoos loamy sand with low organic matter content (organic C, 0.15%), coarse texture (70% to 80% sand), and limited water-holding capacity [15% (w/w) content at 33 kPa]. The pH (0.01 M $CaCl_2$) of composite soil samples from 0- to 15-cm depth collected in 1983 from both blocks averaged 7.0.

Experimental blocks of 'Macspur McIntosh' and 'Red Chief

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[1]Research Scientist.

[2]Research Technician.

[3]Retired Assistant Director, British Columbia Ministry of Agriculture and Fisheries, 1873 Spall Road, Kelowna, B.C. V1Y 4R2, Canada.