CURRENT STATUS OF MINERAL NUTRITION RESEARCH IN 'FUJI' APPLE

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INTRODUCTION

In recent years, 'Fuji' apple has become highly popular with consumers because of its excellent flavor. Thus, there is an increasing trend in 'Fuji' production in the Northwestern USA to meet market demand. The fruit, however, has poor red skin color which makes them less attractive for fresh market. Rootstock and leaf and fruit concentrations of nitrogen (N) and calcium (Ca) are among the most important preharvest factors that influence tree growth, fruit quality, and storage life in apples (Bramlage et al., 1985; Fallahi and Simons, 1993 a and 1993 b; Fallahi et al., 1996; Ferguson and Watkins, 1989; Greene and Smith, 1979; Poovaiah et al., 1988; Sharples, 1980).

Our objective was to study the effects of various amounts of ground and foliar applications of N on tree growth, yield, fruit quality, and leaf mineral nutrition and seasonal mineral fluctuations in 'Fuji' apple.

MATERIALS AND METHODS

Experimental Orchard: 'Red Fuji' (B.C-2) apple (*Malus domestica* Borkh.) trees on M.7 EMLA, M.9 NAKBT337, and M.26 EMLA were planted in the spring of 1991 at 2.4 m x 4.9 m spacing at the University of Idaho Parma Research and Extension Center experimental orchard, north of Parma, Idaho, USA. The soil is a sandy loam with about 7.5 pH. Trees were irrigated with a pressurized system laid along the rows, with one micro-jet set for every tree on the row.

Ground Application of Nitrogen: In the ground application experiment, the experimental design was a complete randomized block split-split-plot with rootstocks as main plots and five levels of ground applied N (urea with 46% N) as sub-plots and two times of application (spring and fall) as sub-sub plots with 4 two-tree plots per replication. For spring application, each level of the five quantities of N was split in half. One half was applied in early spring and the second half was applied in late spring of 1992 through 1997 seasons. In 1992, the rate of actual N per tree per year was 27.2 g, 77.0 g, 126.9 g, 176.9 g, and 226.7 g. In 1993 through 1997, the rate of actual N per tree per year was 31.7 g, 99.7 g, 167.8 g, 235.8 g, and 303.9 g.

Foliar Application of Nitrogen: In this experiment, the influence of three foliar applications and one ground application nitrogen on tree growth, precocity, fruit quality at harvest and after storage, and leaf mineral concentrations in young 'Fuji' apple trees on the above-mentioned rootstocks were studied.

In both ground and foliar-applied experiments, yields were recorded, and samples of fruit were evaluated for fruit color, average fruit weight, soluble solid concentrations (SSC), starch, and firmness at harvest and after storage, and leaves were analyzed for various mineral elements as described by Fallahi et al. (1996).

Seasonal mineral fluctuations: Leaf mineral fluctuations in 'Fuji' on M.9 NAKBT337 and M.7 EMLA were studied over 2 growing seasons to determine the best time for leaf sampling and to predict the "minimal" flux of all nutrients based on early-season leaf analyses. In this part of experiment, leaves were samples every 7 to 14 days from the above-mentioned orchard. Samples were only taken from the trees receiving 99.7 g actual N per tree in Fall. In this report, only seasonal fluctuations of leaf N and K are reported.

RESULTS AND DISCUSSION

Ground Application of Nitrogen:

Trees on M.7 EMLA rootstock were the most vigorous with the largest trunk cross sectional area in 1992, 1993, and 1994, and trees on M.9 NAKBT337 were the smallest (Data Not Shown). Trees on M.26 EMLA were smaller than those on M.7 EMLA but larger than those on M.9 NAKBT 337. Yield and yield efficiency in M.9 NAKBT337 and M.26 EMLA were higher than those on M.7 EMLA three years after planting. Trees on M.7 EMLA rootstock had larger fruit size than those on M.9 NAKBT 337 or M.26 EMLA in 1994 (Data Not Shown). This could be due to lower production, thus higher leaf to fruit ratio of trees on M.7 EMLA in 1994. Trees on M.7 EMLA had a higher leaf percent dry weight, potassium (K), and copper (Cu) than those on other rootstocks in 1993 and 1994 (Data not shown). The trees on this rootstock had not reached their full production, thus a lower number of fruit could have resulted in more K accumulation in the leaf (Fallahi and Simons, 1993b). Trees on M.7 EMLA had a leaf N concentration of 2.33% with 0.37 lbs of N, while trees on M.9 NAKBT337 and M.26 EMLA had 2.34 or 2.33% leaf N with only 0.22 lbs of ground-applied N (Table 1). This is because trees on M.7 EMLA have more extended tree canopy than those on the other two rootstocks, thus it takes higher N to change its leaf N concentration.

Table 1.
Effects of rootstock & applied N interactions on "Fuji" color

Rootstock	M9	M9	M9	M26	M26	M26	M7	M7	M7
Applied N (lb/tree)	0.07	0.22	0.37	0.07	0.22	0.37	0.07	0.22	0.37
Leaf N (%)	2.23	2.34	2.44	2.18	2.33	2.39	2.10	2.23	2.33
Color Rating*	3.80	3.19	2.89	3.55	2.55	2.53	3.88	3.48	2.90

*Color Rating: 5=Red; 1=Green

Tree growth was not affected by different N quantities in 1992 and 1993. In 1994, trees with the least N application were smaller in size. Severity of sunburn was not affected by the amount of N application. The lowest N application resulted in smaller and firmer fruit with more red color, but lower SSC at harvest (Table 2) and after storage (data not shown).

Table 2.
Effects of various amounts of nitrogen on fruit quality at harvest and leaf minerals in 'BC-2 Fuji' apple in 1994.[z]

Actual N (g/tree)	Fruit Avg wt (g)	Color (1-5)	Soluble solids (% Brix)	Firmness (N)	Leaf minerals (dry wt. basis)			
					N (%)	K (%)	Mg (%)	Mn (ppm)
31.7	270 b	3.4 a	14.7 b	82 a	2.20 c	1.54 a	0.28 c	57 c
99.7	288 a	2.9 b	14.8 ab	78 ab	2.39 b	1.37 c	0.30 b	75 d
167.8	295 a	2.7 b	15.2 a	77 b	2.44 ab	1.41 bc	0.30 b	90 c
235.8	288 a	2.9 b	15.0 ab	79 ab	2.47 a	1.41 bc	0.31 b	129 b
303.9	280 ab	2.4 c	15.1 ab	79 ab	2.46 ab	1.49 ab	0.33 a	148 a

[z]Mean separation within columns by Duncan's Multiple Range Test at 0.05.

Fruit red color was decreased with every incremental increase in N application (Tables 2 and 3) because leaf N was increased in these applications (Tables 2). Leaf magnesium (Mg) and manganese (Mn) also increased, but leaf K decreased with every incremental increases in N application up to 235.8 g actual N/tree (Table 2), perhaps because of the antagonism effects between N (as NH_4^+) and K, and synergism effects between N and Mg and Mn.

Table 3.
Effects of various amounts of nitrogen on 'Fuji' fruit quality at harvest in 1996.

Amount (lbs/tree)	yield per tree (kg)	Fruit Ave wt (g)	Color[x] (1-5)
0.07	43.2 b	214.3 a	3.66 a
0.22	45.1 ab	217.8 a	3.06 b
0.37	47.8 ab	214.4 a	2.73 c
0.52	49.9 a	218.3 a	2.57 cd
0.67	40.7 b	216.7 a	2.29 d

[x]Mean separation within columns by Duncan's Multiple Range Test at 0.05.

This long-term experiment showed that the optimum concentrations of leaf N for production of high quality fruit are between 1.88% to 2.14 % dry weight in off years (years with light crops) and between 2.20% to 2.40% dry weight during on years (Data not shown).

Foliar Application of Nitrogen: Trees that received a total of 197 g urea (90.6 g actual N) as a ground application over three growing seasons had greater trunk cross-sectional area (TCA), yield per tree, and yield efficiency than trees which received one of three rates of foliar applications. Trees receiving ground-applied or foliar-applied urea at the highest rate had the heaviest fruit. Fruit firmness was greatest in the lowest foliar treatment. Ground application resulted in greater than average leaf N in 1994 and the greatest leaf Ca and lowest percentage leaf dry weight, leaf K, Zn, and Cu in both 1993 and 1994. Trees on M.9 NAKBT337 were more precocious and smaller in size than those on M.7 EMLA. Trees on M.7 EMLA had lower yield efficiency and greater leaf K than trees on either M.9 NAKBT337 or M.26 EMLA.

Mineral Fluctuation:

The results for 1995 and 1996 seasons are shown in Figures 1 and 2. The minimal flux in ‘Fuji’ leaf N took place between late June and late August. There was a small rise in the demand for N in the leaf in late August (Fig. 1). The rise in leaf N perhaps corresponds with an increased photosynthesis activity in ‘Fuji’. Leaf K decreased as the growing season progressed. The decline in leaf K was very sharp (Figure 2). This result suggests that K should be amended to ‘Fuji’ trees, particularly in the years that a heavy crop is harvested, and when N fertilizer as urea is repeatedly applied.

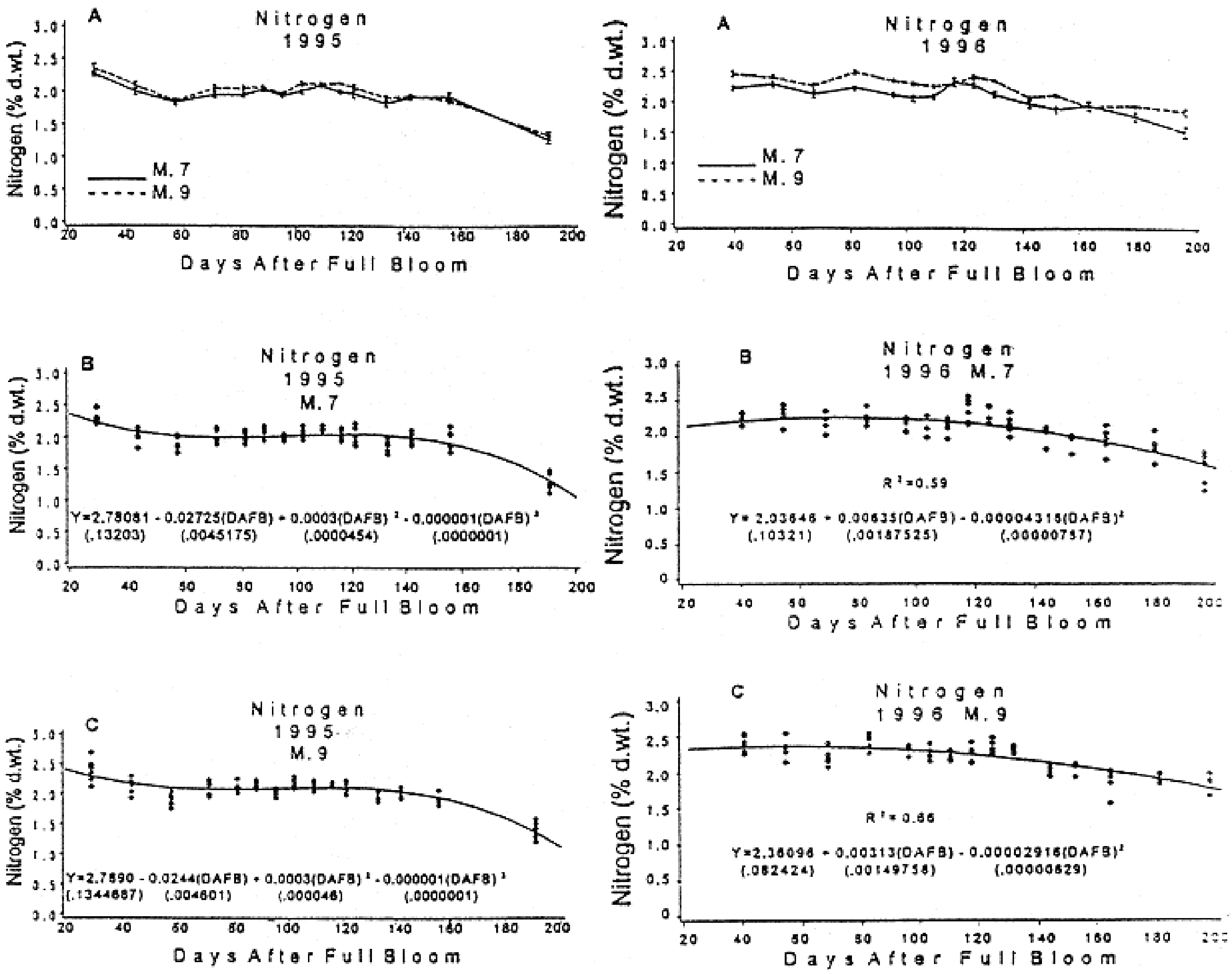

Figure 1. ‘Fuji’ leaf nitrogen in 1995 (left) and 1996 (right). Left: 1995 seasonal trends (A), and cubic polynomial regression equations for M.7 EMLA (B) and for M.9 337(C). Right: 1996 seasonal trends (A), and quadratic regression equations for M.7 EMLA (B) and for M.9 337 (C). Bars represent ± 1 standard deviation from sample means. Numbers in parentheses represent the standard errors of the estimates. August 1, 1995 = 95 DAFB; August 1, 1996 = 100 DAFB.

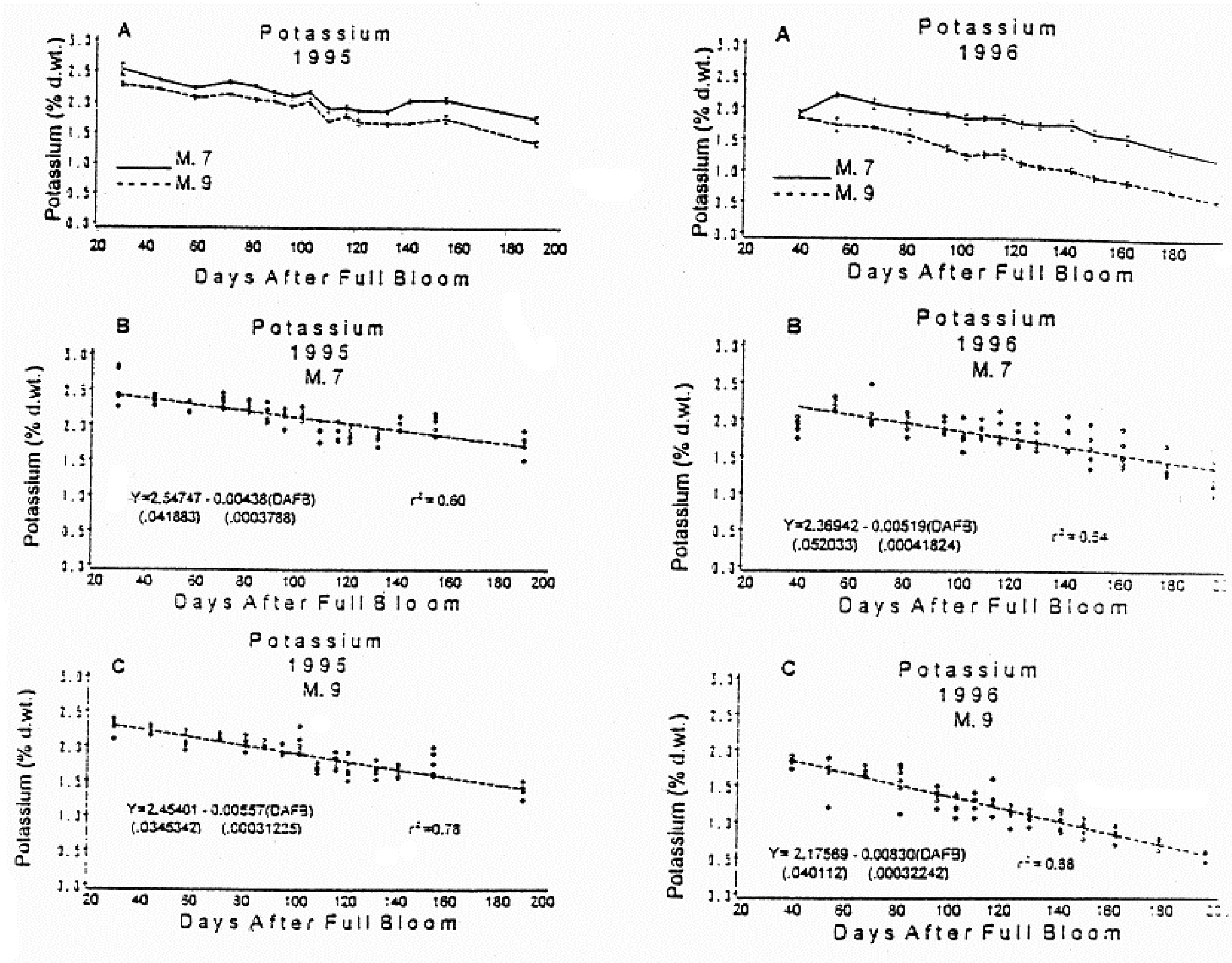

Figure 2. 'Fuji' leaf potassium in 1995 (left) and 1996 (right). Left: 1995 seasonal trends (A), and linear regression equations for M.7 EMLA (B) and for M.9 337 (C). Right: 1996 seasonal trends (A), and linear regression equations for M.7 EMLA (B) and for M.9 336 (C). Bars represent ± 1 standard deviation form sample means. Numbers in parentheses represent the standard errors of the estimates. August 1, 1995 = 95 DAFB; August 1, 1996 = 100 DAFB.

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