FINAL REPORT
WTFRC Project#: AH-03-310

Project Title:

Nutrient application strategies in apple trees:

a. Nutrient availability and root growth under deficit irrigation conditions
b. Bark nutrient uptake for 'Fuji' trees

PIs:

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Objectives

1. Determine soil water status and nutrient availability, root growth and nutrient uptake under normal and deficit irrigation/partial root-zone drying conditions.
2. Determine the bark nutrient uptake ability during the dormant season and its effects on following season growth in Fuji apple trees.

Significant Findings:

1-1.Deficit irrigation and partial root-zone drying treatments:

- Reduced soil moisture, and subsequently resulted in a decrease of leaf water potential of apple trees.
- Reduced total root and shoot growth.
- When performing partial root-zone drying, root growth in the well-watered part was stimulated.

1-2. Deficit irrigation and partial root-zone drying treatments:

- Reduced root ^{15}N uptake and N use efficiency.
- Root N uptake rate was higher when ^{15}N applied in the partial root zone, but total N uptake was higher when ^{15}N applied in the whole root system.

2-1. 10% ^{15}N-urea painted to the bark of young Fuji/M9 apple trees (greenhouse study) in January and March:

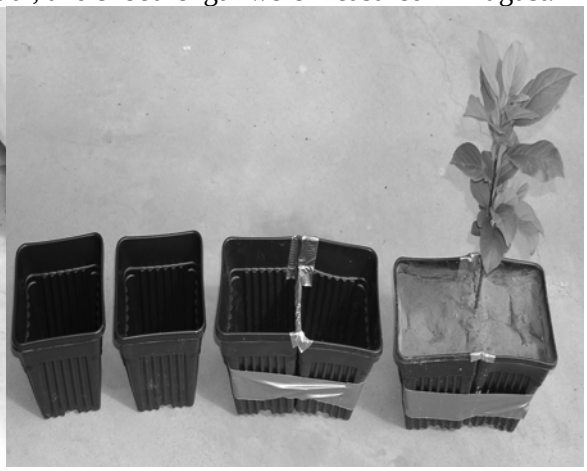
- Increased the new shoot growth in the spring.
- Improved the leaf color (SPAD readings) and leaf N concentration.
- Bark ^{15}N uptake efficiency was 30%.
- No significant difference between January and March treatments.

2-1. Commercial orchard study with 6-year-old Fuji/M9 apple trees (with high N status) sprayed with 0, 10% and 20% urea in March shown:

- There was a trend to increase leaf color (SPAD readings) and leaf N concentration, but not as significant as in the greenhouse study.
- There was no effect on fruit set and yield.
- There was no significant difference between 10% and 20% urea treatments.

Experimental procedures

1-1. Effects of deficit irrigation and partial root-zone drying on root and shoot growth.
Open-top split-root boxes were constructed from 2-cm-thick plywood with one transparent side-wall of 3-mm-thick acrylic sheet (see blow-left picture). The transparent side-wall was covered with a plywood door, which, when closed between measurements, prevented the entry of light into the boxes. One-year-old Granny Smith/M9 apple tree was planted in each box containing a sandy loam soil with the root system evenly divided into two parts by an acrylic sheet in the middle of the box. The boxes were placed on the floor of a greenhouse, and trees were grown under normal greenhouse conditions with the following treatments: 1) Both sides of the root system were well watered (the soil moisture >80%, wet-wet or WW); 2) Both sides of the root system were kept dry (the soil moisture <60%, dry-dry or DD); 3) One side of the root system was kept wet as in 1) and the other side kept dry as in 2) continuously (wet-dry continuously or WDC); 4) One side of the root system was kept wet as in 1) and the other side kept dry as in 2) but alternately every two weeks (wet-dry alternately or WDA); 5) Both sides of the root system received half amount of water as in 1) (half-half or HH). Soil moisture in both sides of the root system was monitored with a time-domain-reflectometry (TDR) system placed in the center of each compartment. Root growth against the transparent side wall was recorded with a scanner-based root image acquisition technique (Dong et al., 2003). Leaf color, leaf N concentration, leaf water potential, and shoot length were measured in August.



1-2. Effects of deficit irrigation and partial root-zone drying on nutrient uptake (split root study).
The split-root boxes constructed from two 1-litre square plastic pots were used in this study (see above-right picture). One small tissue-culture propagated Ottawa 3 apple rootstock liner was planted in each box with the root system evenly divided into two parts. The treatments included 1) Both sides of the root system were well watered (soil moisture >80%, wet-wet or WW); 2) Both sides of the root system were kept dry (soil moisture <60%, dry-dry or DD); 3) One side was kept wet as in 1) and the other kept dry as in 2) constantly (wet-dry or WD). The plants were grown in a greenhouse for two months, and then the following fertilizer treatments were applied with no ^{15}N application as control:

Irrigation treatment		Fertilizer $Ca(^{15}NO_3)_2$ treatment
Dry	Dry	1). ^{15}N applied on one side 2). ^{15}N applied on both sides
Dry	Wet	1). ^{15}N applied on dry side 2). ^{15}N applied on wet side 3). ^{15}N applied on both sides
Wet	Wet	1). ^{15}N applied on one side 2). ^{15}N applied on both sides

Soil moisture was monitored after treatment. Four weeks later, plants were harvested and ^{15}N uptake was determined.

2-1. Bark nutrient uptake in relation to application timing in young Fuji/M9 trees.
One-year-old Fuji/M9 apple trees were grown in pots containing a sandy loam soil for one season in a greenhouse. At the end of the season, trees intact in the pot were moved to a cold room for over winter. 10% ^{15}N-labelled urea was carefully painted to the bark on January 10 and March 21, respectively with trees painted with water as control. On March 24, trees were moved from the cold room to a greenhouse, and grown under normal greenhouse conditions for two months. After leaf SPAD measurements were taken, trees were harvested and separated into new shoots (new stems and leaves), old stem and shank, and roots. ^{15}N in each tissue was analyzed, and N use efficiency was calculated as the percentage of ^{15}N absorbed by the bark to the total ^{15}N applied.

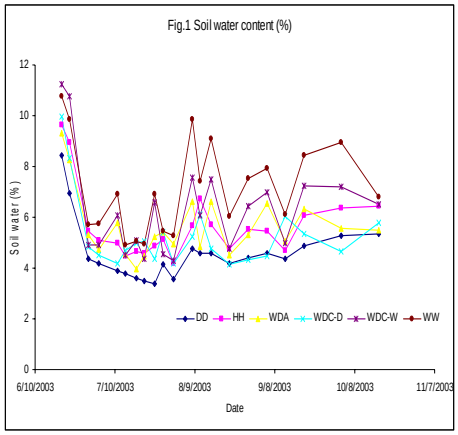
2-2. Field trial

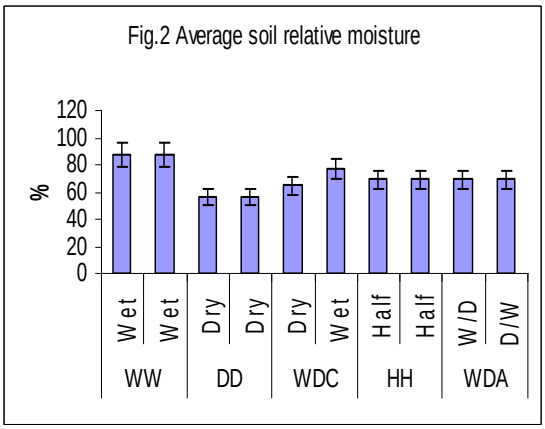
A typical 6-year-old well-managed commercial ‘Fuji/M9’ apple orchard in Trout Creek, Summerland was selected, and uniform trees were used for the bark spray.10% and 20% urea spray treatments were applied on March 24 with trees receiving water spray as control. New shoot growth, flowering and fruit set, and leaf color (SPAD reading) were monitored. Leaf samples were taken in July and leaf N concentration was determined.

Results and discussion

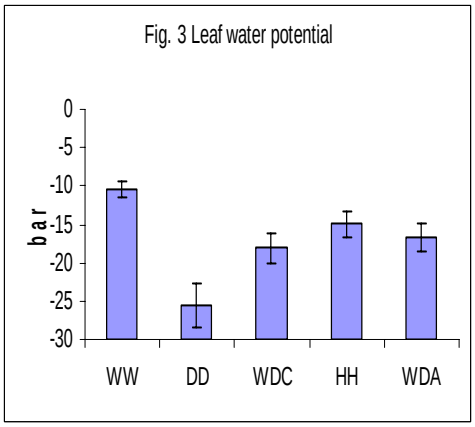
Study 1-1

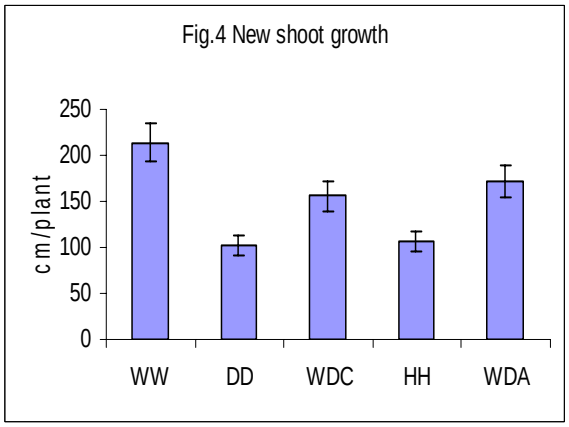
Deficit irrigation and partial root-zone drying changed the soil water contents (Fig.1). The normal irrigation treatment (WW) kept average relative soil moisture above 80%, the relative soil moisture in deficit irrigation treatment was below 60%, while other treatments (HH, WDC and WDA) had relative soil moisture between 60% and 80% (Fig.2). The leaf water potential of the trees showed the similar trend (Fig.3). As a result, shoot growth was reduced (Fig. 4), and the reduction of root growth was more significant (Fig.5). However, Under the partial root-zone drying conditions, the root growth in the well-watered part was stimulated (Fig.5).



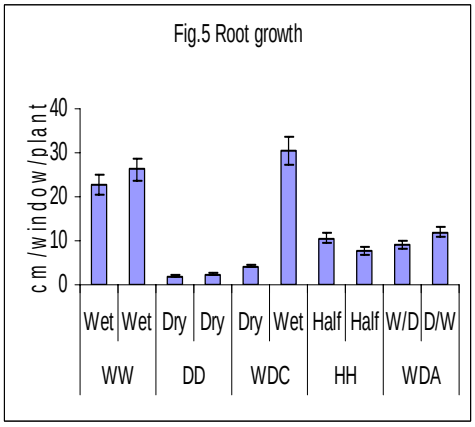


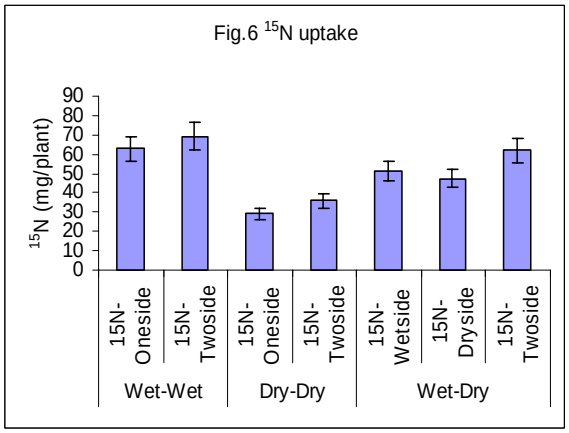
Study1-1 Study1-1





Study 1-1 Study 1-1

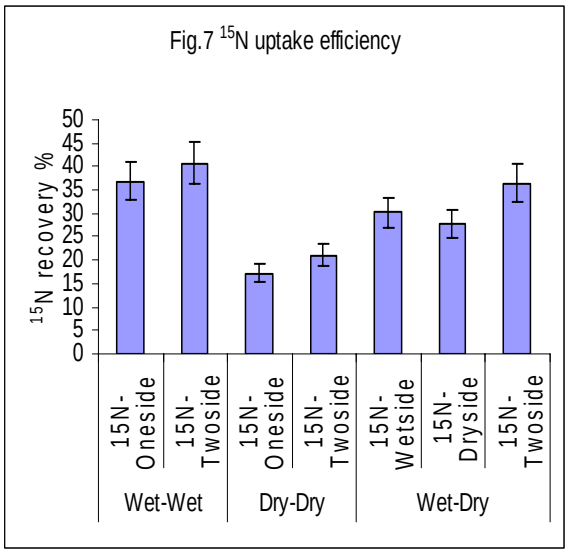


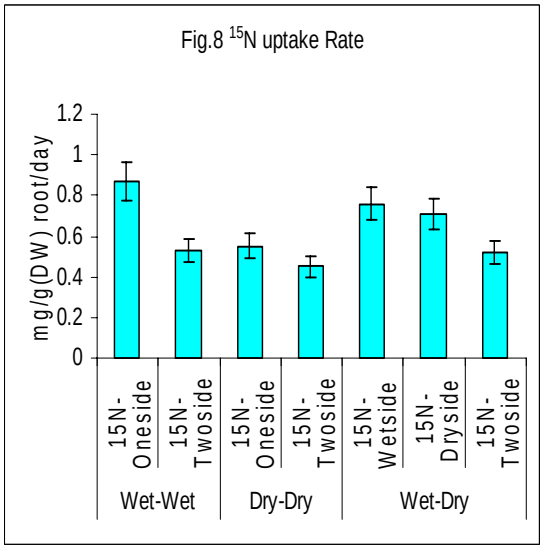


Study 1-1 Study 1-2

Study 1-2

Total ^{15}N uptake was reduced by deficit irrigation (DD) treatment (Fig.6), and the recovery of applied ^{15}N in plants showed a similar trend (Fig.7). uniform application of ^{15}N to the whole root system (both sides) tended to absorb and recover more ^{15}N (Fig.6 & Fig.7), but the uptake rate based on the root biomass was higher when ^{15}N was applied to the part of the root zone (one side) (Fig.8).

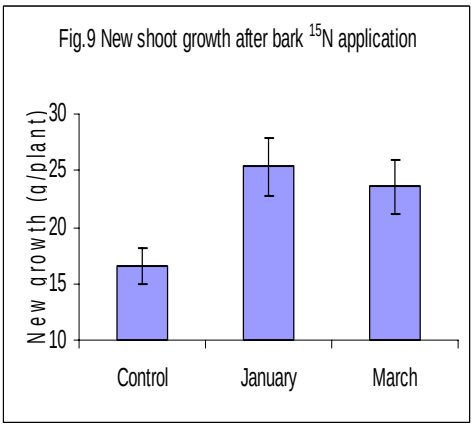


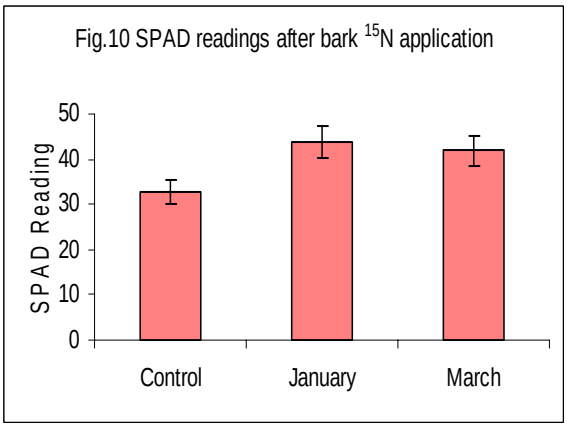


Study 1-2 Study 1-2

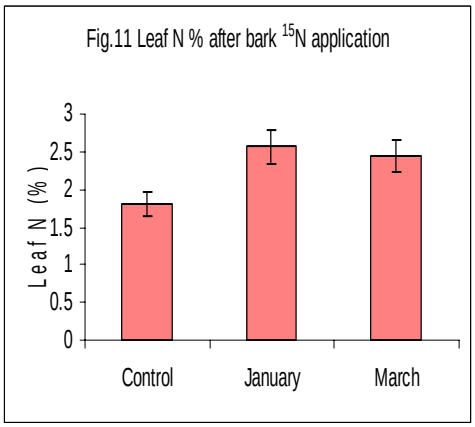
Study 2-1

Bark painting with 10% ^{15}N-labelled urea in January (deep dormant stage) and March (before bud break) increased new shoot growth of young Fuji/M9 apple trees (Fig.9), and the leaf color (SPAD reading) and leaf N concentration were also increased (Fig.10 & Fig.11). Bark absorbed similar amount of ^{15}N at both application dates (Fig.12), and the N use efficiency of bark spray was about 30% (Fig.13). There was no difference between January and March applications. Most ^{15}N absorbed by the bark was distributed in the new shoots, and about 20% remained in the old wood and 10% moved to the roots (Fig.14).

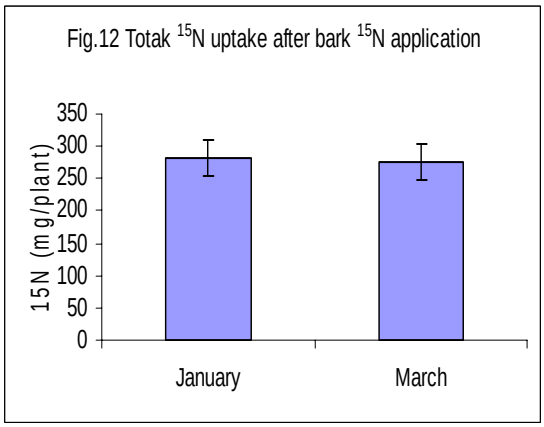




Study 2-1 Study 2-1



Study 2-1



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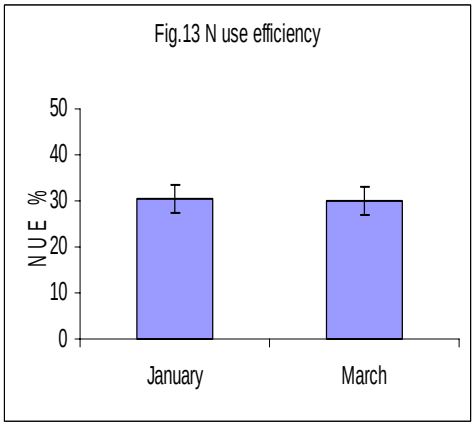

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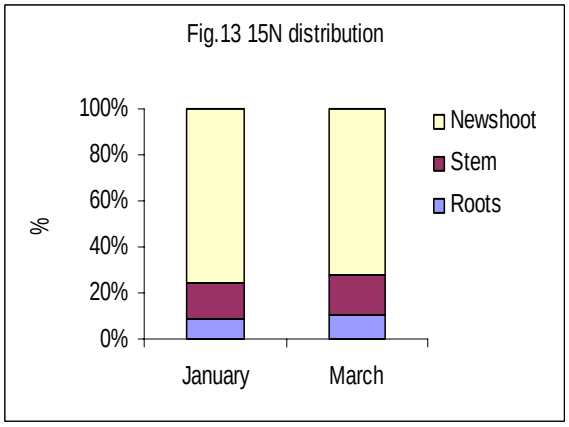
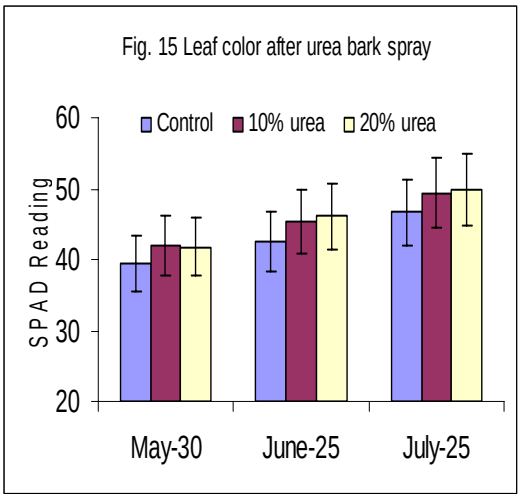
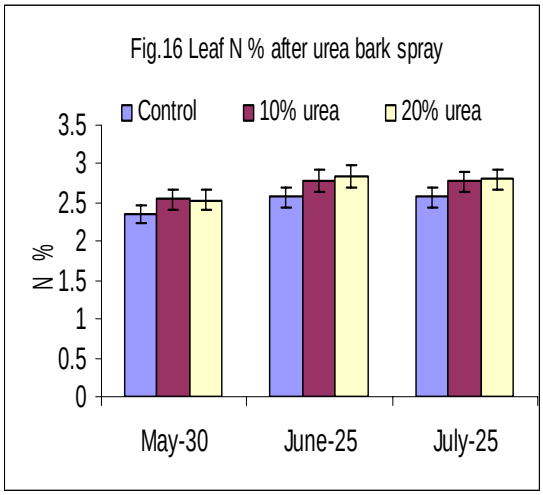


Study 2-1

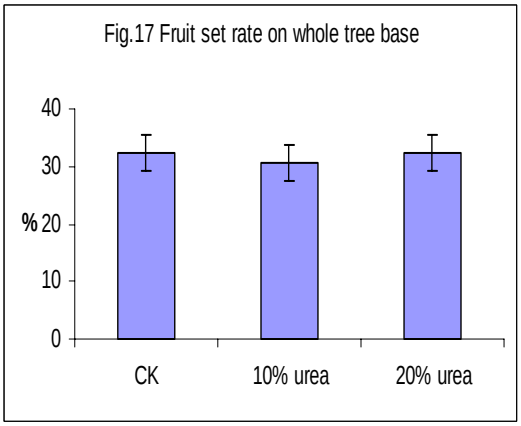
Study 2-2

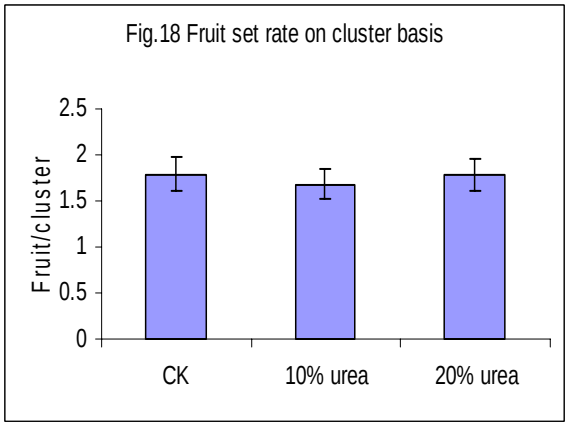
Bark spray with 10% and 20% urea before bud break (March) tended to increase leaf color (SPAD reading) and leaf N concentration (Fig.15 & Fig.16) in a field trial at a commercial Fuji/M9 apple orchard in Trout Creek, Summerland, British Columbia, but the results were not as dramatic as in the young potted trees (Study 2-1). This may reflect the high N status of trees used in this experiment which received regular N fertilization by the grower. The leaf N concentration (about 2.5%) of the trees was reached upper range for optimum fruiting of Fuji trees. Growers may expect benefit effects from the bark spray if orchards show N limitation. No differences were found among the treatments in fruit set rates on either whole tree basis (Fig.17) or the cluster basis (Fig.18) in this experiment.





Study 2-2 Study 2-2





Study 2-2 Study 2-2

Budget

Project Title: Nutrient application strategies in apple trees.
PI: Denise Neilsen
Project duration: 1 year

Year	2003
Salary	$20,000
Supplies and services	$8,000
Total	28,000

Publications:

1. Shufu Dong, Denise Neilsen, Gerry H. Neilsen and Michael Weis. 2003. A scanner-based root image acquisition technique for measuring roots on a rhizotron window. *HortScience*. Vol.38 (7), December, 2003.
2. Shufu Dong, Lailiang Cheng, Carolyn F. Scagel and Leslie H. Fuchigami. 2003. Root damage affects nitrogen uptake and growth of young Fuji/M.26 apple trees. *Journal of Horticultural Science & Biotechnology*. 78(3): 410-415.
3. Shufu Dong, Denise Neilsen, Gerry H. Neilsen and Leslie H. Fuchigami. Extension and feeder root growth and nutrient uptake of young apple trees. *HortScience* (in review).

Acknowledgement: We gratefully thank Washington Tree Fruit Research Commission and Agriculture and Agri-Food Canada MII program for providing research funds.