Comparison of Effects Between Foliar and Soil N Applications on Soil N and Growth of Young Gala/M9 Apple Trees

Shufu Dong, Denise Neilsen, Gerry H. Neilsen
Pacific Agri-Food Research Center Agriculture and Agri-Food Canada
4200 Highway 97
Summerland, BC V0H 1Z0
Canada

Lailiang Cheng
Department of Horticulture,
Cornell University,
Ithaca
NY 14583, USA

Leslie H. Fuchigami
Department of Horticulture
Oregon State University
Corvallis,
OR 97331, USA

Keywords: foliar, soil application, N, *Malus domestica*

Abstract

The increasing concern about environmental contamination by nitrate leaching from agricultural land has stimulated a search for more efficient ways to apply N fertilizers. An experiment was carried out to compare the effectiveness of foliar and soil N applications on apple tree growth and soil nitrogen status in order to evaluate N use efficiency. One-year-old, uniform Gala/M9 apple trees were selected and transplanted into 4-litre pots with a typical loamy sand soil. The plants grew in the greenhouse and were randomly divided into five groups of 17 trees. The experiment included a control (no N) and 4 N treatments where the same amount of N as urea was applied once every two weeks started when shoot growth exceeded 5cm. N was applied by 1) foliar only, 2) soil only, 3) soil early and late, foliar mid-summer (combination I), or 4) foliar early and late, soil midsummer (combination II). New shoot number was recorded, and shoot length, plant and soil N nutrients were measured throughout the growing season. Plants were moved from the greenhouse in late October to over-winter outside. Five trees were sampled for total N analysis at the dormant stage. The remainder was put in the screen house for re-growth evaluation in the following season. Shoot number was unaffected by treatments in the first season, but soil N application alone and combination I significantly increased shoot length. All N treatments significantly increased leaf N status and leaf color (as indicated by SPAD-chlorophyll readings) compared to the unfertilized control, but there were no significant differences among different N treatments. Foliar application increased reserve N content at the dormant stage and promoted re-growth, but all N treatments resulted in similar root/shoot ratios, which were lower than that of the control treatment. Both soil NO_3^- and NH_4^+ were significantly increased by soil N application compared with either control or foliar application, an indication that soil N application created a higher potential for leaching loss.

INTRODUCTION

Nitrogen (N) is an essential element for agricultural production, and N fertilizers are the most widely used fertilizers in the world (Mengel and Kirkby 1978). Although the application of N fertilizers has dramatically improved plant production, it has also resulted in a world-wide problem of environmental contamination. Increasing public concern about excessive nitrate leaching from agricultural lands has encouraged a search for a more efficient way to apply N fertilizers (Dinnes et al, 2002).

Soil application is the traditional method of supplying N to sustain plant production in agriculture, but it is often associated with high soil N leaching and low efficiency of use. Foliar N application to fruit trees can have higher use efficiency (Weinbaum, 1988), but it may adversely affect plant vigor and reduce the economic yield if relied upon solely. Combinations of soil and foliar N application might achieve optimum N use and plant production, but there have been no consistent results reported in literature (Johnson et al, 2001). The objective of this study is to compare effects of foliar, soil or their combined N application on the growth of young apple trees.

MATERIALS AND METHODS

One-year-old uniform Gala/M9 apple trees were selected and transplanted into 4-litre pots with loamy sand soils. The plants were grown in the greenhouse under standard growth conditions and randomly divided into five groups with 17 trees in each group. The experiment included a control (no N application, CK) and 4 N treatments where the same amount of N as urea was applied once every two weeks from mid May (when shoots were 5cm-long) to early mid September and about 4g N in total was applied to each tree. N was applied by 1) foliar only (Foliar), 2) soil only (Soil), 3) soil early and late, foliar midsummer (combination I, Com.I), or 4) foliar early and late, soil midsummer (combination II, Com.II). New shoot number was counted, and shoot length, plant and soil N nutrients were measured periodically during the growing season. Leaf greenness readings, measured by a SPAD meter (Minolta Corporation), were also made. Plants were moved from the greenhouse in late October and allowed to over-winter outside. Five trees were sampled for total N analysis in the dormant season. The rest of trees were placed in a screen house for an evaluation of regrowth with no N application in the following season.

Plants were portioned into leaves, stems and roots, dried and weighed. Total N in leaves, stems and roots was determined with a LECO FP-528 N analyzer (LECO CORPORATION, 3000 Lakeview Avenue, St. Joseph, MI 49085-2396, USA). Soil NH_4^+ was analyzed by the Nessler method, and NO_3^- by the nitrophenoldisulfonic-yellow method (Jackson, 1958). All data were subjected an ANOVA analysis with NCSS'97 Statistical System software (NCSS Statistical Analysis Software, Kaysville, UT, USA).

RESULTS

Plant Growth

Neither soil nor foliar N applications nor their combinations affected the number of new shoots produced in the first year (data not showed). Both soil N application alone and soil-foliar combined N applications significantly increased the first-year shoot length, while foliar N application alone did not affect new shoot length (Fig. 1). At the end of the growing season, all N treatments had a similar root/shoot ratio (0.45), while the control treatment had a significant higher root/shoot ratio (0.55) (Fig. 2).

Plant N Status

During the growing season, all N treatments significantly increased leaf SPAD readings (Fig. 3) and leaf N content (Fig. 4) compared with the control treatment, and there was no significant difference between different N treatments. All N treatments significantly increased shoot and root N concentrations at dormancy, but the highest N content was achieved after foliar N application (data not showed).

Soil N

Soil NO_3^- and NH_4^+ were both increased by Soil, Com.I and Com.II treatments (Fig. 5 and Fig. 6), and there was a positive relationship between available soil N and the amount of N applied to the soil. Foliar application also increased the available soil N compared with the control, but the increment was much less than that of soil application (Fig. 5 and Fig. 6).

Regrowth Performance

Foliar and soil N applications and their combinations all promoted an equivalent amount of new shoot growth in the following season (Fig. 7). There was a positive relationship between plant N content at dormancy and new shoot growth (Fig. 8). Foliar N application promoted flower bud initiation, and about 75% of trees treated with foliar N application began flowering and less than 50% for all other treatments (data not showed).

DISCUSSION

Nitrogen is essential for plant development, and N fertilizers usually promote plant growth (Mengel and Kirkby 1978, Marschner 1995). This experiment showed that both soil and foliar N applications and their combinations were able to supply enough nitrogen to young apple trees for growth and development. Soil application resulted in higher soil available N status (both NO_3^- and NH_4^+), which increased the potential risk of N leaching loss. In term of nitrogen usage, foliar application should be more efficient than soil application as reported previously (Hill-Cottingham and Lloyd-Jones 1975, Weinbaum 1988, Khemira 1995).

Soil N application promoted plant vigour and produced more long shoots. As a result, trees receiving soil N applications had delayed flower initiation. Flower bud initiation requires high availability of nutrients and a balance between nutrients such as carbon and nitrogen (Faust 1990). The formation of long shoots likely consumed more carbon than nitrogen, decreasing C/N ratio, which may explain why soil N application retarded the flower bud formation.

Roots are the main organ by which plants absorb nutrients and water from soil (Fallahi 1994). When soil nutrient availability becomes limited, plants usually invest more resources into root production to increase absorbing surface area and counter the decline in supply of soil nutrients (Marschner 1995). As a result, root growth can be promoted at low nutrient supply, resulting in an increase in root/shoot ratio as in the control treatment in this experiment. However, different methods of N application did not affect root/shoot ratio in the experiment, which may indicate the plant had a unique mechanism to sense internal N status. The plant did not expend too much resource for root construction as long as enough N was supplied, no matter how N was supplied whether through soil or via foliar application.

Literature Cited

Dinnes, D.L., Karlen, D.L., Jaynes, D.B., Kaspar, T.C., Hatfield, J.L., Colvin, T.S. and Cambardella, C.A. 2002. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. Agronomy Journal. 94:153-171.

Fallahi, E. 1994. Root physiology, development and mineral uptake. In: A. Brooke Peterson and Robert G. Stevens (eds.) Tree Fruit Nutrition. Good Fruit Grower, Yakima Washington, USA. Pp19-30.

Faust, M. 1989. Physiology of Temperate Zone Fruit Trees. John Wiley & Sons. Pp169-234.

Hill-Cottingham, D.G. and Lloyd-Jones, C.P. 1975. Nitrogen-15 in apple nutrition investigations. J. Sci. Food and Agri. 26: 165-173.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall, INC., Englewood Cliffs, N. J., USA. Pp195-201.

Johnson, R.S., Rosecrance, R., Weinbaum, S., Andris, H. and Wang, J. 2001. Can we approach complete dependence on foliar applied urea nitrogen in early-maturing peach? J. Amer. Soc. Hort. Sci. 126: 364-370.

Khemira, H. 1995. Nitrogen partitioning and remobilization in field-grown apple trees. Ph. D. Dissertation, Oregon State University, Corvallis, OR, USA.

Marschner, H. 1995. Mineral Nutrition of Higher Plants (the second edition). Academic Press. Pp231-255.

Mengel, K. and Kirkby, E.A. 1978. Principles of Plant Nutrition. International Potash Institute, Worblaufen-Bern, Switzerland.

Weinbaum, S.A. 1988. Foliar nutrition of fruit crops. In: Neumann, P. E. (ed.) Plant Growth and Leaf Applied Chemicals. CRC Press, Boca Raton, Florida, USA. Pp81-100.

Figures

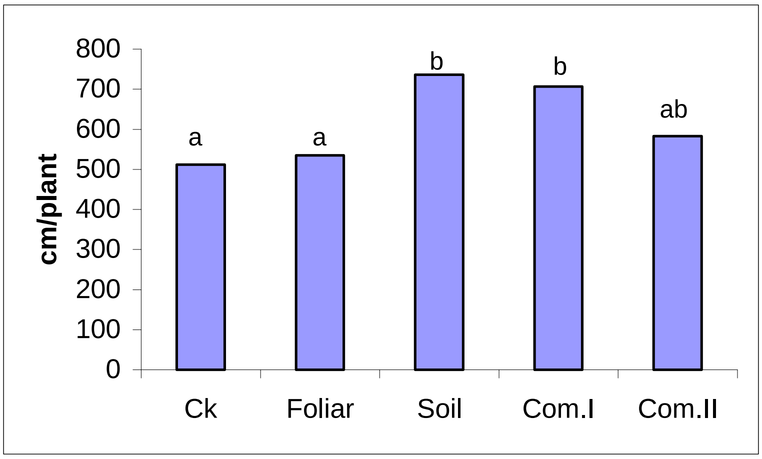

Fig. 1. Total shoot length at the end of the first growing season.

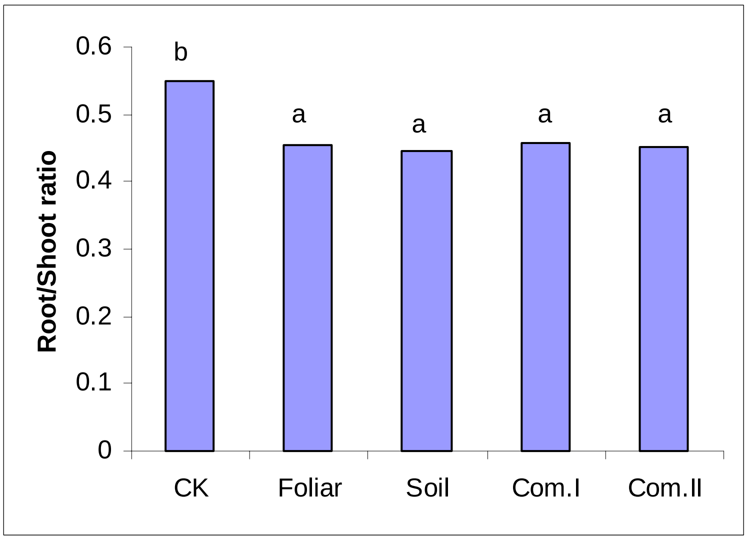

Fig. 2. The root/shoot ratio as affected by N treatments at the end of the first growing season.

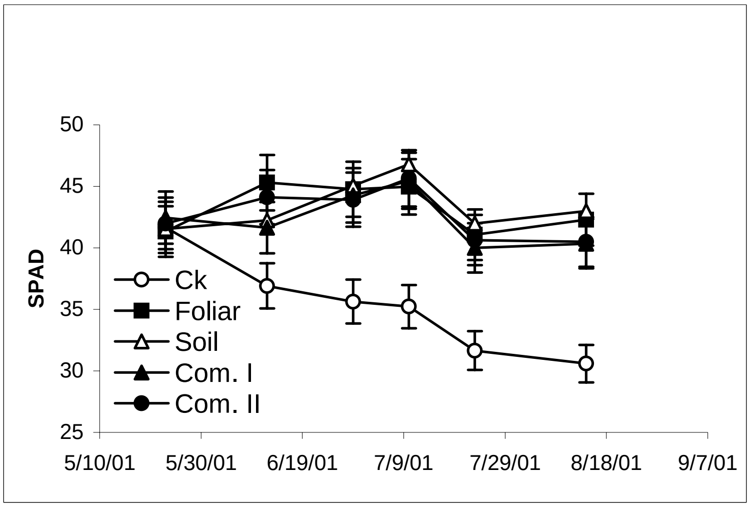

Fig. 3. Changes of SPAD readings during the growing season.

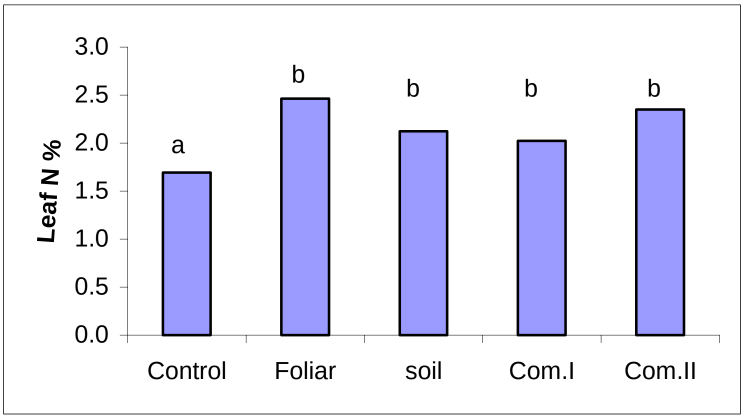

Fig. 4. Leaf nitrogen content in the mid of the first growing season.

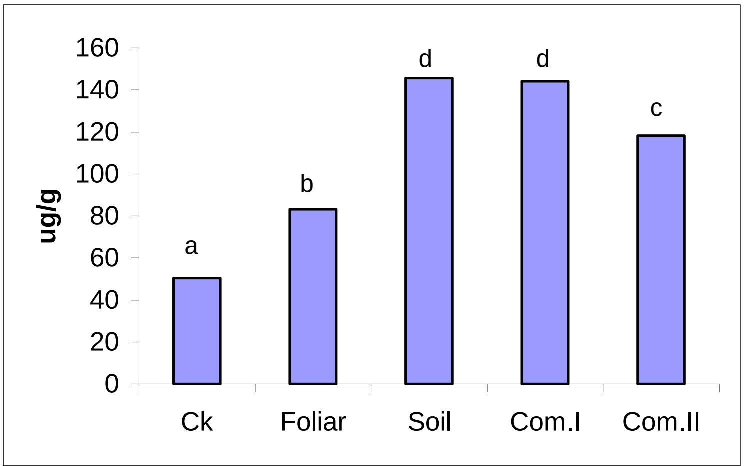

Fig. 5. NO_3^- content in the pot soil.

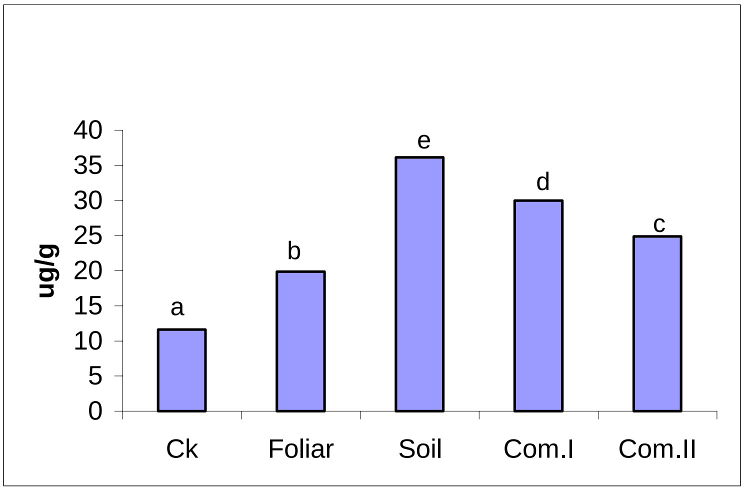

Fig. 6. NH_4^+ content in the pot soil.

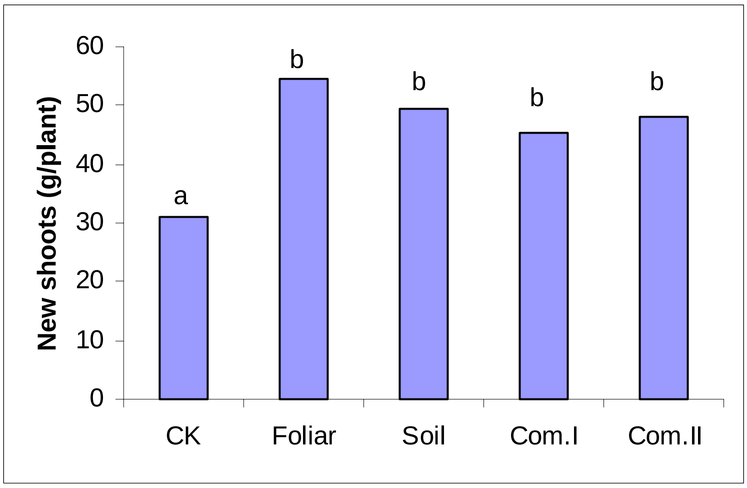

Fig. 7. Regrowth performance in the following season.

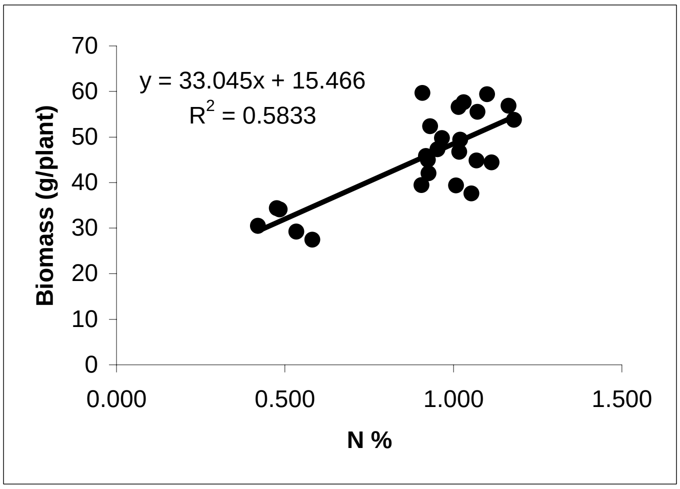

Fig. 8. Relationship between N content at dormancy and shoot regrowth (biomass) in the following season.