

FOLIAR UREA AS A SUBSTITUTE FOR SOIL APPLIED N: EFFECTS ON VEGETATIVE VIGOUR AND FRUIT QUALITY OF KIWIFRUIT (*ACTINIDIA DELICIOSA* CV. HAYWARD)

Allan Morton and David Woolley

*Institute of Natural Resources, Massey University
A.R.Morton@massey.ac.nz*

Abstract

The use of foliar sprays of nitrogen (N) in perennial fruit crops can reduce the risk of nitrate (NO_3^-) leaching and excessive vegetative vigour compared to soil applied N. To compare the effects of foliar N with soil applied N, eleven 1% urea sprays were applied at 10 day intervals, from 20 days before fruit set, to the canopy of six mature kiwifruit vines cv. 'Hayward', supplying N at a rate approximately equivalent to 80 kg N ha^{-1} . Another six vines were not given foliar N. Three of the foliar treated vines and three of the untreated vines were also given calcium nitrate applied to the rootzone at a rate approximately equivalent to 80 kg N ha^{-1} . Vegetative vigour of the vines given soil N was more than doubled compared to vines only given foliar N. Leaf N% in January was not significantly increased by the foliar N treatments but was by the soil applied N ($P < 0.05$). Fruit from vines given foliar N but not soil N was 9% heavier ($P < 0.05$) than that from vines given neither soil nor foliar N. Fruit weight from vines given soil N and soil N plus foliar N was not significantly different from other treatments and there were no significant differences between the treatments in fruit dry matter concentration (DM%). Foliar N may be a useful substitute for soil applied N for kiwifruit orchards allowing fruit quality to be maintained while reducing vegetative vigour and NO_3^- leaching.

Introduction

Careful management of the nitrogen (N) fertilisation of kiwifruit orchards is necessary to maintain vine health and produce regular heavy crops without inducing excessive vegetative vigour or nitrate (NO_3^-) leaching (Mills et al. 2008). Excessive vegetative vigour is associated with poor fruit quality and increased labour costs for canopy management (Patterson & Currie 2011). Nitrate leaching contaminates ground water and, increasingly, must be accounted for by growers who must conform to production standards and local environmental regulations (Mills et al. 2008).

Foliar applications of nutrients can supplement the soil supply and thereby reduce the quantity of fertiliser needing to be applied to the soil (El-Otmani et al. 2004). Foliar N sprays can reduce the risk of NO_3^- leaching and vegetative vigour compared to soil applied N (Dong et al. 2005). Therefore, foliar N might be useful for the N management of kiwifruit orchards.

Fruit size can be increased by foliar N particularly when applied during early fruit development. Foliar N applied as urea during the early season increased the size of apples (Dong et al., 2005), citrus (Lovatt, 1999), and guava (Kundu et al., 2007). Larger sized fruit are individually more valuable and can also lead to increased yields of kiwifruit. Fruit dry matter concentration (DM%) is important for kiwifruit because it correlates positively with the taste and consumer liking for the ripe fruit (Patterson & Currie, 2011). Furthermore,

growers receive an incentive payment for fruit with high DM%. However, the effects of foliar N applied during the early and mid season on fruit size and DM% has not been previously reported for kiwifruit.

When kiwifruit are grown on the pergola training system, the underside of leaves and the fruit hanging below the canopy are well exposed to foliar sprays applied from ground operated spray equipment. Kiwifruit leaves have numerous anomocytic stomata on the underside of leaves and many trichomes, both factors conducive to the uptake of foliar applied N (Ferguson, 1990; Haynes & Goh, 1977). The dense indumentum present on both leaves and fruit probably also assists spray retention. Furthermore, kiwifruit have a thin epidermal layer and high rates of surface conductance, compared to some other fruit such as apple, making efficient absorption of foliar N likely, especially during early fruit development (Smith et al., 1995). Thus kiwifruit appear to be well suited to foliar nutrition.

This experiment compares the effects of soil and foliar applied N in respect to fruit quality and vegetative vigour of 'Hayward' kiwifruit.

Materials and Methods

The experiment was carried out on mature T-bar 'Hayward' kiwifruit vines in the Massey University orchard during the 2009-2010 season. Twelve uniform vines were selected. Previous management history had been according to 'organic' methods and there had been no fertiliser applications for at least five seasons previous. Vines were in pairs (bays), and one of four treatments was randomly allocated to each vine or bay. The treatments were:

LN - no nitrogen fertiliser;

LNF - no nitrogen fertiliser applied to the soil, plus foliar sprays of 1% urea;

MN - a moderate rate of nitrogen fertiliser applied to the soil;

MNF - a moderate rate of nitrogen fertiliser applied to the soil, plus foliar sprays of 1% urea.

For MN and MNF treatments, calcium nitrate fertiliser (Calcinit[®], Yara International Ltd, Norway; 15.5% N) was applied to the root area (25m²) of selected bays on 25 November 2009 at a rate equivalent to 80 kg N ha⁻¹. Foliar urea sprays (Yara Urea Tech, Yara Fertilizers NZ Ltd; 46% N, biuret content: 0.65-0.80%) commenced 10 November and were repeated at 10 day intervals with a total of 11 sprays supplying N at a rate equivalent to 80 kg N ha⁻¹. The final urea spray was on 2 March 2010.

Soil within the bays was sampled and analysed for mineral N on 6/11/09 prior to the start of the experiment. Samples were extracted in 2M KCl (Blakemore et al., 1987). Leaf samples (20 youngest mature leaves on non-fruiting shoots from the leader zone of each vine) were collected on 6 November 2009, 13 January 2010 (8 days after the 7th foliar urea application), and 1 April 2010 (29 days after 11th foliar urea application). Dried leaf was extracted by Keldjahl digestion followed by N analysis on auto analyser (Blakemore et al., 1987). Petiole sap NO₃⁻ was measured on the samples collected 6 November using a nitrate-test strips (Reflectoquant[®], E.Merck, Germany) and a reflectometer (Reflectometer RQflex, E.Merck, Germany). Vines were summer pruned 13 January and 5 March 2010 and the fresh weight of prunings recorded. Fruit was harvested on 18 May 2010, approximately 164 days after anthesis. Fresh weight was recorded and equatorial slices were taken from each fruit (24 fruit/vine) and oven dried at 65°C until constant weight for calculation of fruit dry matter (DM) and water contents. Brix and firmness readings were also taken on a total of six fruit per vine. Runoff from the foliar sprays was estimated after collection in shallow trays placed

under selected vines. Statistical analysis was by ANOVA using SAS statistical software (SAS Institute Inc., 2004).

Results and discussion

Runoff of foliar urea to the soil beneath the vines was just 2% of the volume applied and was estimated as being equivalent to about 1.8 kg N ha⁻¹ and was therefore considered irrelevant as a source of N to the vines.

Soil-applied N (80 kg N ha⁻¹) significantly increased vegetative vigour more than two-fold, as measured in terms of the weight of material removed during summer pruning ($P < 0.05$; Table 1). Stimulation of vine shoot growth by relatively low rates of N fertiliser has also been reported for grape vines, where an application of only 50 kg N ha⁻¹ at budbreak increased shoot biomass by 70% (Conradie, 2001).

Table 1. Effect of soil and foliar applied N on shoot growth measured as weight of prunings (g) at two pruning times (January and March).

Tmt	January	March	Total
LN	1.6 ± 0.6	2.2 ± 0.3	3.8 ± 0.8
LNF	1.1 ± 0.3	2.1 ± 0.4	3.2 ± 0.7
MN	3.3 ± 0.3	6.0 ± 0.6	9.3 ± 0.8
MNF	2.9 ± 0.7	6.1 ± 0.9	9.1 ± 1.5

± standard error of the mean

Foliar urea did not increase vegetative vigour in either LNF or MNF (Table 1). Other authors have also reported foliar-applied N to be less stimulatory to vegetative growth than soil-applied N (Klein, 2002; Dong et al. 2005).

An increase in shoot growth in response to increases in the soil-supply of NO₃⁻ is common among plant species, especially nitrophilous species – a classification to which kiwifruit probably belongs (Fichtner & Schulze, 1992). The growth response has been associated with an increase in fine root proliferation and cytokinin synthesis and translocation to the shoots (Takei et al., 2002). However, foliar urea being rapidly assimilated into phloem mobile amino forms does not have this effect (Tan et al., 1999). Nitrate fertilisation might also increase shoot growth by increasing the uptake of nutrient cations such as potassium (Okajima, 1977; Guo, 2007).

The nitrogen content (N%) of leaves sampled on 13 January (eight days after the seventh foliar urea application) was significantly greater ($P < 0.05$) for bays receiving soil-applied N fertiliser than for unfertilised bays (Table 2). At this sampling time foliar urea had significantly increased leaf N% in MN bays ($P < 0.05$) but not in LN bays. This could be due to a greater translocation of N to other sinks within the vine in response to the lower N status of the LN vines (Klein & Weinbaum, 1984). However, Bondada et al. (2001) reported increased uptake of urea by leaves of N-sufficient citrus trees (2.60% N) compared to N-deficient trees (1.80% N). Leaves of the low-N citrus trees had thicker cuticles and more epicuticular wax, which may have reduced the cuticular absorption of the urea.

By the 1st April (29 days after the last foliar urea application) leaf N% in MN and MNF bays had fallen to levels similar to the LN bays, which had remained almost constant (Table 2). The only significant difference between the treatments in leaf N% remaining by April was that between LN and MNF. Leaf N% in LN (2.10%) and LNF (2.06%) in January vines was

slightly below the reported optimum level for January of between 2.2 and 3.0% (Hill, 2010). LNF (1.96%) was also below the optimum level for April of between 2.0 and 2.7%. (Hill, 2010) (Table 2).

Table 2. Effect of soil applied and foliar applied N on leaf N% at mid and late season.

Tmt	January	April
LN	2.10c	2.10ab
LNF	2.06c	1.96b
MN	2.66b	2.11ab
MNF	2.87a	2.22a

Values with different letters within the same column are significant different at $P<0.05$.

Soil-applied N had little effect on fruit FW or DM% (Table 3). However, foliar urea significantly increased fruit FW ($P<0.05$) in the LN vines. Although DM accumulation was increased by foliar urea in both LN and MN vines, the differences lacked statistical significance (Table 3).

Table 3. Effect of soil and foliar urea on fruit FW (g), DM concentration (%), DM accumulation (g), and water accumulation (g).

Tmt	FW (g)	DM (%)	DM (g)	Water (g)
LN	101.8b	16.3a	16.6a	85.3b
LNF	111.0a	15.7a	17.5a	93.6a
MN	105.9ab	15.6a	16.5a	89.4ab
MNF	108.9ab	15.6a	17.0a	91.9ab

Values with different letters within the same column are significantly different at $P<0.05$.

Both foliar and soil applied N tended to reduce fruit Brix at harvest, although the differences lacked statistical significance (Table 3). Firmness was also reduced by N but the effect was significant only in the case of MNF (Table 3).

Table 3. Effect of soil and foliar applied N on fruit Brix and Firmness at harvest.

Tmt	Brix	Firmness
LN	7.35a	8.70a
LNF	7.14a	8.30a
MN	7.14a	8.27a
MNF	7.02a	7.63b

Values with different letters within the same column are significantly different at $P<0.05$.

Although moderate rates of soil-applied N had little effect on the FW or DM% of the fruit, vegetative vigour was more than doubled. However, foliar urea was able to increase fruit FW without any stimulation of vegetative vigour. This supports the idea that foliar applications of urea can be an effective alternative to soil applications of N. Furthermore, foliar application of N is associated with reduced NO_3^- leaching compared to soil-applied N fertiliser (Dong et al., 2005). Any increase in costs associated with the urea foliar sprays would be more than offset by the savings in pruning labour costs.

References

- Blakemore, L.C., Searle, P.L. & Daly, B.K. 1987. Methods for chemical analysis of soils. NZ Soil Bureau Scientific Report 80. DSIR: Lower Hutt.
- Bondada, B.R., Syvertsen, J.P. & Albrigo, L.G. 2001. Urea nitrogen uptake by citrus leaves. *HortScience*, 36(6): 1061-1065.
- Conradie, W.J. 2001. Timing of nitrogen fertilisation and the effect of poultry manure on the performance of grapevines on sandy soil. 1. Soil analysis, grape yield and vegetative growth. *South African Journal of Enology and Viticulture*, 22(2): 53-59.
- Dong, S., Neilsen, D., Neilsen, G.H. & Fuchigami, L.H. (2005). Foliar N application reduces soil NO₃⁻-N leaching loss in apple orchards. *Plant and Soil*, 268: 357-366.
- El-Otmani, M., Taibi, F. Lmoufid, B., Ait-Oubahou, A. & Lovatt, C.J. 2002. Improved use of foliar urea on Clementine mandarin to manipulate cropping in a sustainable production system. *Acta Horticulturae*, 632: 167-175.
- Ferguson, A.R. 1990. Stem, branches, leaves and roots of the kiwifruit vine. In I.J.Warrington and G.C.Weston (eds.), *Kiwifruit: Science and Management* (pp 58-70). NZSHS: Auckland.
- Fichtner, K. & Schulze, E.-D. 1992. The effect of nitrogen nutrition on growth and biomass partitioning of annual plants originating from habitats of different nitrogen availability. *Oecologia*, 92: 236-241.
- Guo, S., Zhou, Y., Shen, Q. & Zhang, F. 2007. Effect of ammonium and nitrate nutrition on some physiological processes in higher plants – growth, photosynthesis, photorespiration, and water relations. *Plant Biology*, 9: 21-29.
- Haynes, R.J. & Goh, K.M. 1977. Review on physiological pathways of foliar absorption. *Scientia Horticulturae*, 7: 291-302.
- Hill Laboratories, 2010. Crop guide: kiwifruit/green. R.J.Hill Laboratories Ltd. 22 November, 2010.<<http://www.hill-laboratories.com/file/fileid/21680>>.
- Klein, I. 2002. Nitrogen pool enrichment in fruit trees for specific target requirement. *Acta Horticulturae*, 594: 131-137.
- Klein, I. & Weinbaum, S.A. 1984. Foliar application of urea to olive: translocation of urea nitrogen as influenced by sink demand and nitrogen deficiency. *Journal of the American Society for Horticultural Science*, 109(3): 356-360.
- Kundu, S., Ghosh, B., Mitra, S.K. & Mazumdar, D. 2007. Effect of foliar spraying of nitrogen, phosphorus and potassium on yield and fruit quality of guava (*Psidium guajava* L.). *Acta Horticulturae*, 735: 433-440.
- Lovatt, C.J. 1999. Timing citrus and avocado foliar nutrient applications to increase fruit set and size. *HortTechnology*, 9(4): 607-612.
- Mills, T., Boldingh, H., Blattman, P., Green, S. & Meekings, J. 2008. Nitrogen application rate and the concentration of other macronutrients in the fruit and leaves of Gold kiwifruit. *Journal of Plant Nutrition*, 31: 1656-1675.
- Okajima, H. 1977. The significance of the nitrate ion in soil solution for the regulation of soil-plant interaction. In *Proceedings of the International Seminar on Soil Environment and Fertility Management in Intensive Agriculture*. Society of the Science of Soil and Manure, Tokyo, pp 797-802.

- Patterson, K.J. & Currie, M.B. 2011. Optimising kiwifruit vine performance for high productivity and superior fruit taste. *Acta Horticulturae*,
- SAS Institute Inc. 2004. SAS 9.1.2. Cary, NC, USA.
- Smith, G.S., Klages, K.U., Green, T.G.A. & Walton, E.F. 1995. Changes in abscisic acid concentration, surface conductance, and water content of developing kiwifruit. *Scientia Horticulturae*, 61: 13-27.
- Takei, K., Takahashi, T. Sugiyama, T., Yamaya, T. & Sakakibara, H. 2002. Multiple routes communicating nitrogen availability from roots to shoots: a signal transduction pathway mediated by cytokinin. *Journal of Experimental Botany*, 53(370): 971-977.
- Tan, X.W., Ikeda, H. & Oda, M. 1999. Absorption, translocation, and assimilation of foliar-applied urea compared with nitrate and ammonium in tomato plants. *Soil Science and Plant Nutrition*, 45 (3): 609-616.