Efficient Nitrogen Fertilization for Control of Vegetative Growth and Optimum Cropping

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Abstract

This project addresses two of the main concerns in nitrogen Best Management Practices (BMP): efficiency of nitrogen use to optimize cropping and control of vigor through nitrogen management. Current cropping of pear in California tends to be much higher than when N recommendations were first developed and while it is logical that more crop 'removes' more N, higher N also tends to decrease storage life of pome fruits and much more of the current pear crop is produced for fresh market than in the past. Improved knowledge of optimum timing, form, and amount of N to produce pears to today's standards is warranted.

Because pear trees may respond gradually to changes in applied nutrients (Raese, 1996); Ingels, 2005), a practical approach toward comparing N levels is to identify and use orchards with existing 'low' and 'high' N practices. We began evaluating N partitioning to vegetative and reproductive tissues in March, 2009 in 'High N' and 'Low N' orchards. These orchards have similar yields (25-30 t/A/yr), tree age, density, soil and growing conditions.

- The 'Low N' orchard has not had 'full N' (120 $\#N_{act}$/A/yr) applied since 2007 as a cost-saving measure, whereas the 'High N' orchard receives 120 $\#N_{act}$/A/yr.
- We sampled tissues during bud swell (March 9), preharvest (July 7), and postharvest/preleaf fall (October 1).
- We have found that in March and July there are no differences between 'low' and 'high' N orchards, but only between tissue types.
- Spur buds have significantly higher N than shoot buds and while bearing spur leaf N declines up to July, shoot leaf N rises. Non-bearing spur leaf N is intermediate to these.
- Current recommendations for N analysis vary, depending on the information source
    - o Pear in Calif (DANR Bulletin #1879, 1978) – spur leaves in June-July; deficient in N is < 2.3%N, with 2.3-2.8% adequate
    - o Shear and Faust, 1980 -- non-bearing spur leaves or shoot leaves from mid-portion of terminal shoots sampled at cessation of terminal growth (July-August) deficient is <1.8% and adequate is 1.8-2.6%
- October N values will be added for shoot buds, spur buds, shoot leaves and spur leaves when analyses are completed.

This project is exploratory in nature and has afforded the opportunity to apply for, and receive a 3-year grant from CDFA's Fertilizer Research and Education Program to continue and expand this work, for a total of $150,000.

Introduction

N fertilization recommendations for California European pear trees have been modified from 1991 (moderate amount = 75 to 125 lb actual N applied to the soil per acre 'Integrated Pest Management for Apples & Pears) to 2007 (2 lb actual N/ton of crop/acre; Pear Production and Handling Manual). The 2007 recommendation establishes two physiological premises for N management. The first is based on cropping, so that a 30 ton/acre orchard should receive 60 lb actual N per acre per year. The second premise, based on controlling vegetative vigor is to apply no nitrogen if the average shoot length is greater than 12 inches. These criteria address two of the main concerns in nitrogen Best Management Practices (BMP): efficiency of nitrogen use based on cropload and control of vigor through nitrogen management. Reproductive and vegetative growth tend to be competitive processes, i.e., as one increases, the other declines. Both are highly subject to nitrogen (N) level, with high N tending to favor vegetative growth, yet good cropping depends on a certain level of N as well. Excessive canopy production shades the inner and lower canopy, reducing flower production and fruitfulness with permanent consequences to cropping.

BMP should reflect N partitioning spatially in tissues and temporally during the growth and rest cycles, with emphasis on application of N in forms and at timings that minimize over-usage, increased vigor, and ground water leaching. Yet, growers tend to perceive reduction in N use as an unacceptable risk for reduced cropload and smaller fruit size and that critical leaf N values are outdated as they were established when tonnage was lower, tree density per acre was lower and most fruit went to processing (thus fruit size was less important), or fresh fruit were not stored (often stored 2+ months at present). Knowledge of BMP for California's Delta orchards may be inadequate, where most trees are 30 to 100+ years old, are often inter-planted to increase tree density, may retain tissue nitrogen for years without applied N and crop well (1997-2000 unpublished study, Ingels), and are intensively farmed; alternatively, BMP may already be well-understood by many growers, based on their experience, but are not reflected in the current recommendations.

Because pear trees may respond gradually to changes in applied nutrients (Raese, 1996; Ingels, 2005), a practical approach toward comparing N levels is to identify and use orchards with existing 'low' and 'high' N practices. Similar gradual change in K status has been reported in apple (Moulton et al. 1998). Thus, we have begun monitoring nitrogen levels in two orchards in which 'low' and 'high' N use (the extremes found in the recent survey conducted in the 'Delta' (Ingels, 2008), preparatory to more intensive studies.

Objectives:

1. Develop baseline data on seasonal N tissue levels and N demand in European pear.
2. Compare 'low' and 'high' N orchards to test assumptions about N critical levels.

Plans and Procedures:

Orchard information and fertilizer levels

Two orchards were identified as 'high' and 'low' N application orchards from the survey results (Ingels, 2008). Both orchards are 'Bartlett', on the immediate west side of the Sacramento River and within approximately 5 miles of each other. The 'High N' orchard was originally planted at 20' x 20', more than 100 years ago; interplants are more than 30 years old at 10' spacing in the row. The rootstock is unknown. Yields are typically about 30 tons/acre. Total actual N applied is 120 lb/acre/year,

The 'Low N' orchard was planted about 100 years ago, probably on 'Winter Nelis' rootstock at an original spacing of 16'x 17'and interplants have been continually added for approximately 30 years, as trees are removed, and to decrease the in-row spacing. Yields are typically about 25-30 tons/acre. This orchard has had 120 lb actual N/acre until 2007, and has since had 60 lb/acre.

Both orchards received KNO_3 in spring; in the 'High N' orchard, KNO_3 is routinely applied in spring; its use this year was 'typical', at the grower's discretion and orchard-wide. KNO_3 was applied to the 'Low N' orchard this year at first cover spray, at 5 lb/acre. Different forms of nitrogen are used by California pear growers: CAN17, $CaNO_3$, KNO_3, NH_4NO_3, UN-32, and urea (2008 survey). KNO_3 is often added to blight sprays (3-6 lb/A) until oil sprays after petal fall and may be added to codling moth sprays until leaves harden off in spring (B. Zoller, personal communication). KNO_3 may suppress hatching European red mite nymphs when applied at this timing (B. Zoller) and has been reported to inhibit pear psylla in Europe (personal communication, S. Carruthers). Thus there is interest in incorporating KNO_3 applications into an experimental design for N applications testing rate, form and timing of N fertilization. KNO_3 in spring will be a treatment incorporated into the new CDFA FREP project next year.

Tissue sampling

Samples were obtained from the oldest trees in each orchard, from 20 trees selected at random and spaced well-apart throughout the orchard, avoiding 'problem' areas. Spur buds and spur leaves were sampled from spurs no more than 4" in length, at approximately 3-6' above ground level, on all sides of the canopy and at the canopy periphery for maximum light exposure. Terminal shoot buds were selected at the tips of 1-year old wood, in similar locations as the spur samples.

Sampling terminal vegetative shoot buds and spur buds prior to bloom provides an early picture of N status; sampling the same buds in fall prior to leaf drop will show both N status due to cropping and N status due to longer-term postharvest N uptake than mid-summer sampling of leaves would. Thus, our sampling schedule included three collection timings and five tissue sample types:

1. Timing 1 = 'budswell'; shoot and spur (mixed floral and vegetative) buds – approximately 15-20 buds per sample collected March 9
2. Timing 2 = preharvest (late June, early July); shoot, non-bearing and bearing spur leaves – 10 leaves per replicate tree of each type collected July 7
3. Timing 3 = pre-leaf fall (late September, early October); shoot and spur (mixed floral and vegetative) buds and leaves from shoots and spurs collected October 1

Leaves were washed in a mild soap solution, rinsed and dried in an oven at ~55 °C, and ground. Percentage of tissue nitrogen has been determined from a subsample on a dry weight basis.

Data analysis and statistics

Treatment effects for the two-site comparison were evaluated using Proc GLM in SAS (SAS Institute Inc., Cary, NC) in which the experimental design was a CRD (completely random design, replicated by 'site' with 20 replicate trees sampled randomly and 'replicate tree' nested within 'orchard'); estimation of fixed effects was based on Least Means Squares (LSM) tests for main effects of 'orchard' and '%N' and interaction of 'replicate' X 'sample type'. Proc Mixed was used to test 'replicate' and 'orchard' as random effects with 'sample type' as a 'fixed' effect. Where significant effects were found, within-orchard N levels were compared by t-tests (SAS Proc Ttest) when only two sample types were collected, and by LSM when more than two were collected, correcting treatment means for 'replicate' effects by the use of Type III Mean Squares and F-test, level of significance P = 5%. Outliers were plotted with distributions in Proc BoxPlot.

Results and Discussion

March buds had tissue levels that differed significantly between shoot and spur buds, but not between orchards (Table 1); average shoot bud level was 1.60-1.62 %N and average spur bud level was 2.42 to 2.60 %N. The range in values for shoot buds in both orchards was much greater than for spur buds (Figure 1). It has been our experience in previous trials for vigor control, using Apogee (BASF) that pear extension shoots are of two types, in that one type continues to grow vigorously for 2-3 months, while the other type grows no more than 1-3" before setting a terminal bud. Perhaps the range in values for the terminal shoot buds reflects this pre-determined growth difference.

When sampled in early July, terminal shoot leaves had much higher N values (2.64 and 2.75%), while bearing spur buds had declined in tissue N to 2.09-2.15%; non-bearing spur buds were intermediate, but much closer to shoot leaf values (2.41-2.48%; Table 2). No significant differences were found for 'orchard', thus, these values were similar for both orchards, despite N application differences for two years that amounted to half-rate N in the 'Low N' orchard. The range for different leaf N values was similar and relatively small for all leaf types (Figure 2). In addition to N values being highly significant among the leaf types, there were also highly significant 'replicate' differences, indicating that the range from tree-to-tree was contributing to differences among tissue N; the two populations of trees (each orchard is a 'population') exhibit large tree-to-tree differences in tissue N level for the same kind of leaf. This is typical in orchards in general, regardless of what response or characteristic is sampled, often obscuring treatment differences due to high replicate variance. We will use harvest blocks as replicates rather than individual trees in subsequent trials to reduce variance, although some sampling may still be tree-by-tree.

Thus, because there are no differences between the orchards, despite different levels of applied N, the values are plotted together to show change in tissue N over time (Figure 3), illustrating the reverse change between shoot tissues and spur tissues. The first increases from budbreak to preharvest while the latter decreases, probably due to higher demand by the growing fruit on the tissues immediately subtending the fruit. October tissue samples should provide additional information about N removal by the crop.

Tissue sampling in mid-summer is too late to make adjustments for current season needs, thus, sampling both early and later in the season may provide more opportunity to make adjustment and anticipate inadequacies in the following year, particularly after a very heavy cropload when reserves may be insufficient to support a high-cropped condition. A clear understanding of which tissues sampled will give the best information of N levels relative to cropping in pear is lacking; the leaves sampled are recommended to be from non-fruiting spurs, although fruiting spurs may have the highest demand for N.

Ingels' 4 year study (1997-2000; CPAB report) of N management included a 0-N treatment (no N applied for 4 years), yet leaf N only slightly declined during the study period, never reaching inadequate levels (2.2-2.4% leaf N is considered adequate; IPM manual). Our recent study that utilized 2% (v/v) foliar urea for defoliation and dormancy-induction found leaf N levels in the excessive range, regardless of leaf type, treatment type or analysis timing (Ingels et al., 2008). Despite recommended guidelines for N application and growers' use of leaf analysis to manage N applications, it is possible that N fertilization is excessive in many Sacramento River Delta orchards, and possibly pear orchards in other districts as well. The harvest of pears removes 1.3 lbs. N/ton (Weinbaum, 1992), thus, a 20-ton crop removes only 26 lbs. N/acre. While additional N is required for vegetative growth, even assuming 50% efficiency of uptake from soil-applied N and equal amount of N required for vegetative and reproductive growth, a typical River Delta orchard may require no more than 100 lb N/A annually if all were applied to the soil (especially if top-dressed). Foliar feeding and/or fertigation may be more effective means to deliver N and other nutrients. Our up-coming FREP trials will attempt to develop more information about N form, application timing and amount that provides the best balance for high cropload and vigor control.

Pertinent references

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Broc Zoller's recommendation to include KNO_3 as an important component of 'choice' and 'multiple benefits' for nitrogen BMP is also very much appreciated.

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Table 1.Tissue N (% nitrogen) in expanding pear buds, March 9, 2009			
Orchards (Low N vs High N)	Shoot terminal bud	Spur bud	Significance [y]
60 units nitrogen/years	1.60 b [x]	2.50 a	***
120 units nitrogen/year	1.62 b	2.42 a	**

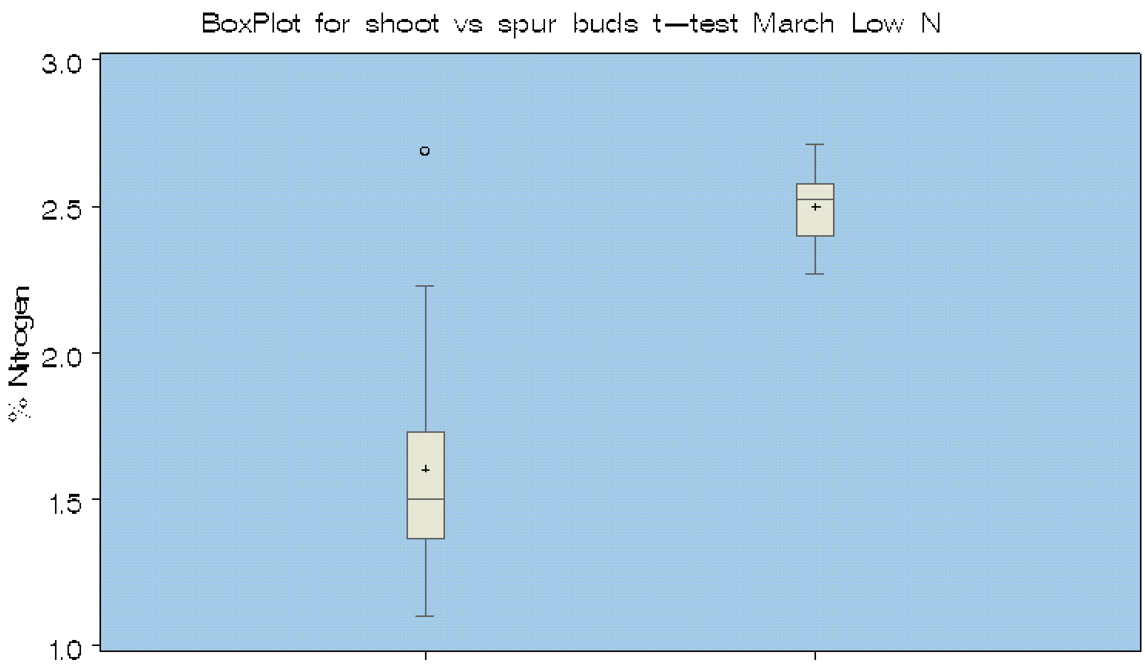
[x] Means separation by Student's ttest, P = 0.05; means with the same letters **within rows (a given orchard)** do not significantly differ.
[y] ***, ** = significance at 0.001 and 0.01, respectively.

Analysis of Variance of Nested Model testing differences between Orchard High N and Orchard Low N; N = orchard rep(orchard) bud rep*bud

Source	df	MS III
Model	59	0.32***
Orchard	1	0.1
Rep(orchard)	38	0.06
Bud type	1	14.5***
Rep*bud type	19	0.07
Error	20	0.04

[X] ANOVA by SAS Proc GLM, P=5%; *** is significant at P = 0.1%.

Figure 1. Box plots for shoot and spur buds, respectively, for Low N and High N orchards, March 9, 2009. The line within each boxplot indicates the mean for the treatment, the upper box edge is the 75% limit and the lower edge is the 25% limit for the treatment means. The 'whiskers' extending above and below each box represent the range of the data. Outliers are identified by open circles above and below the whiskers, where present.



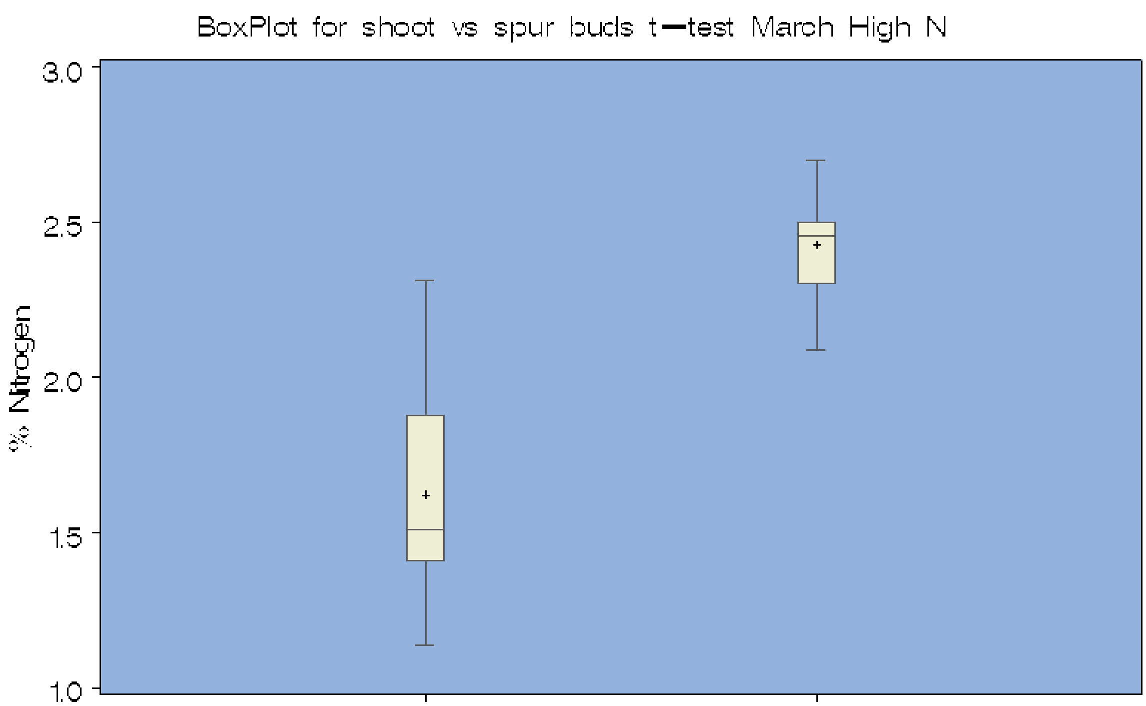


Table 2.Tissue N in pear leaves, July 7 2009. Within and between orchard comparison of %N in shoot leaves (current year extension shoots, mid-shoot sample), bearing, and non-bearing spur leaves.

Within each orchard (Low N or High N)	Shoot leaf	Spur leaf		Significance	
		Nonbearing	Bearing	Replicate (tree)	Leaf type
60 units nitrogen/years	2.64 a	2.41 b	2.15 c	***	***
120 units nitrogen/year	2.75 a	2.48 b	2.09 c	***	***

Means separation by LSMeans, *P* = 0.05. Means with the same letters **within rows (a given orchard)** do not significantly differ. Error term is rep*leaf type.

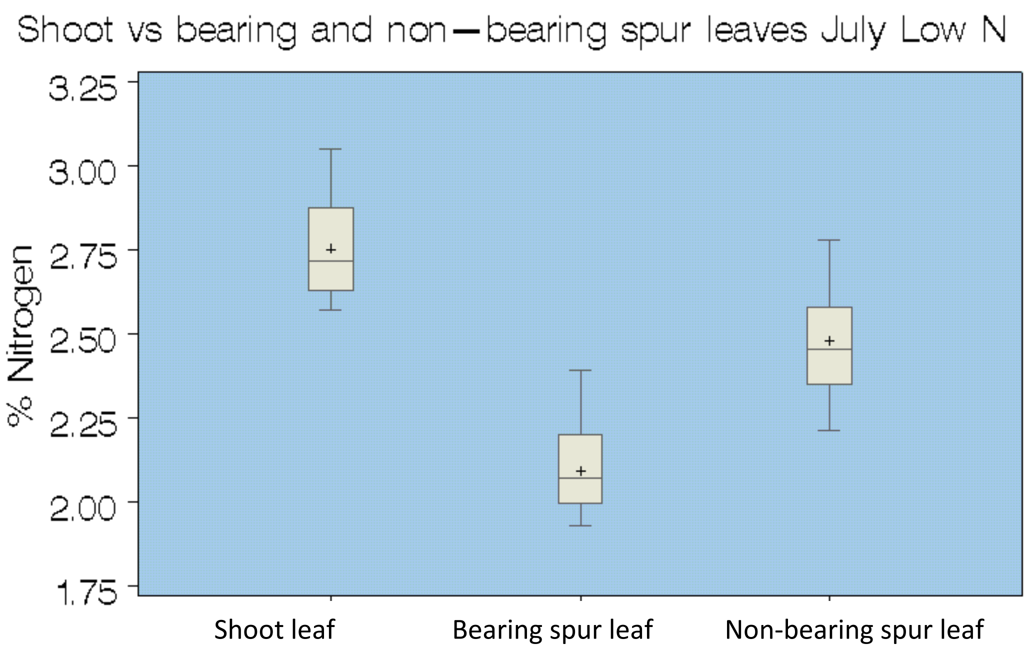
Comparison within both orchards (combined) and between orchards (compared) testing leaf types for significant differences in %N				Significance	
				Orchard	Leaf type
Combined orchards (Low N + High N)	2.70 a	2.44 b	2.12 c		***
Compared orchards (Low N vs Hi N)				NS	

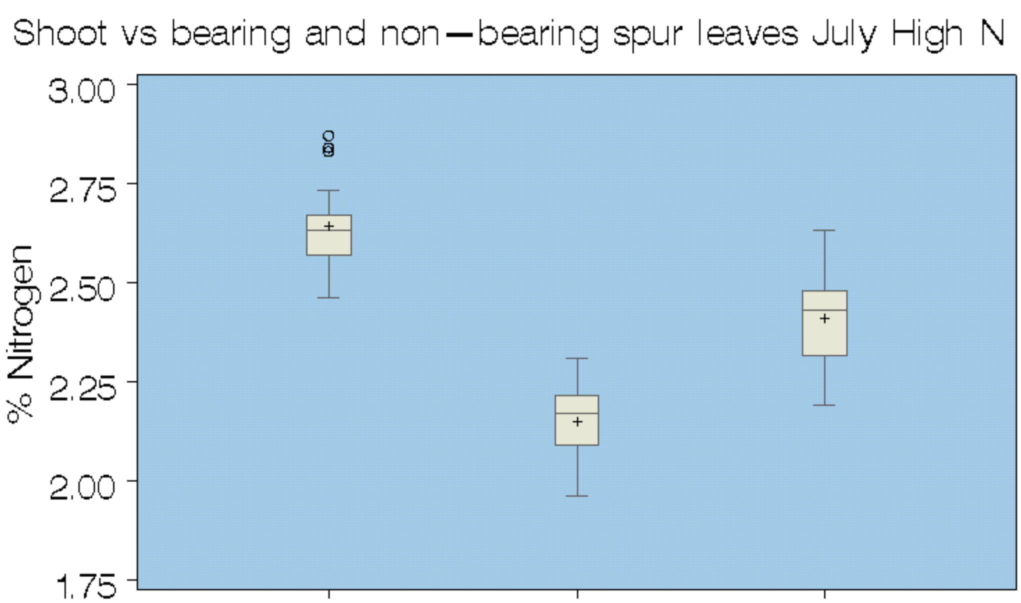
Means separation by Proc Mixed, 'leaf type' as fixed effect, orchard and replicate as random effects. LSMeans, *P* = 0.05; means with the same letters **within row (leaf types combined across orchards) d**o not significantly differ. Error term is rep(orchard); ***, NS = significant at 0.1%, non-significant, respectively.

Analysis of Variance of nested model N = orchard rep(orchard) leaftype rep*leaftype; error term is rep(orchard).

Source	df	MS III
Model	79	0.105***
Orchard	1	0.049
Rep(orchard)	19	0.033***
Leaf type	2	3.322***
Rep*Leaf type	38	0.008
Error	40	0.009

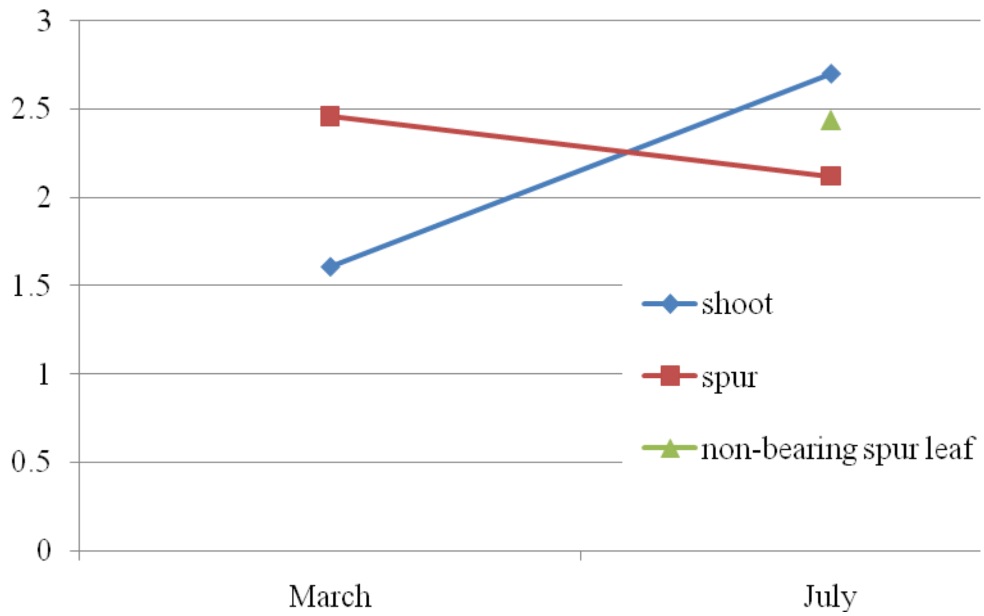
Figure 2. Box plots for leaves for Low N and High N orchards, July 2009. The line within each boxplot indicates the mean for the treatment, the upper box edge is the 75% limit and the lower edge is the 25% limit for the treatment means. The ‘whiskers’ extending above and below each box represent the range of the data. Outliers are identified by open circles above and below the whiskers, where present.





spur leaf

Figure 3. Change in % nitrogen for shoot and spur buds to leaves (shoot, bearing and non-bearing spur) over time, 2009. Sample dates were March 9 (expanding buds) and July 7 (preharvest). 2.2-2.4% leaf N is considered adequate (IPM manual) for pear, measured from shoot leaves midsummer.



Note that the October values will be added as they are made available.