DEVELOPMENT OF NUTRIENT MANAGEMENT TOOLS FOR DRIED PLUMS (Year 3)

Project No:

Project Leader: Patrick H. Brown, Department of Plant Sciences, UC Davis. MS#2, One Shields Avenue, Davis CA (530) 752-0929, Fax (530) 752-8502, phbrown@ucdavis.edu

Project Cooperators: Franz J.A. Niederholzer. University of California Cooperative Extension, Sutter-Yuba Counties, 142A Garden Highway, Yuba City, CA 95991-5512, (530) 822-7515, fjniederholzer@ucanr.edu

Amber Bullard, MS Student, Department of Plant Sciences, UC Davis. MS#2, One Shields Avenue, Davis, CA 95616, anbullard@ucdavis.edu

Objectives:

- To investigate the influence of yield, plant nitrogen status and fruit size on nitrogen removal by prune fruits.
- To investigate the seasonal pattern of nitrogen accumulation in prune fruit.
- To develop early-season leaf sampling protocols and interpretation methods.

Interpretive Summary

In California, there are 58,000 acres bearing orchards of dried plums. This makes up a significant area of land, which requires annual addition of nitrogen fertilizers to maintain high yields and produce quality. Currently, N management in prune is based on leaf sampling and analysis in summer, which is to late for N adjustment during the season. Further no guidelines are available to inform growers of the time and rate of fertilizer application. Due to the lack of N management support tools, there is potential for overuse of N fertilizer that could leach below root zone to ground water. There is increasing concern for ground water quality and the California Water Board is working o which demands environmental stewardship from the farmers. To provide better N management and monitoring tools to growers to guide the rate and time of fertilizer application and in season monitoring of tree N status, this experiment was continued during 2015. Influence of yield, tree nitrogen status and fruit size on nitrogen removal by prune fruits was monitored in the organic orchard by taking fruit samples at harvest, categorizing the fruits by size and determining N

concentration. Seasonal accumulation of N in fruits was developed by monitoring N concentration and biomass accumulation in fruits. N removal from the orchard was calculated by monitoring trees for yield and nutrient concentration. Leaf samples were collected to relate N status with N export in fruit. Leaf samples from orchards at different sites were collected in July to understand the spatial and temporal variability of tree N status. Perennial trees store a large quantity of N in the perennial biomass it takes 1-2 years for the treatment effect to establish. The information from this project will be used to develop N management protocol for prune, based on N budget and in-season monitoring of leaf N.

Materials and Methods

Fruit load and N status influence on N removal (Objective 1)

There was significant variation between trees in the same orchard studied in 2014. In 2015 a more uniform organic orchard was selected to carry out this experiment. Thirty trees in the orchard were randomly selected and labeled in April. Trunk cross-sectional area (TCSA) measured at one foot above the soil surface. Three nitrogen fertilization treatments were applied in order to generate a range of leaf nitrogen status. N – treatments were applied in 2015 and 2016 as follows: 1) Low Nitrogen (LN): 0 kg N $tree^{-1}$, 2) Medium Nitrogen (MN): 0.23 kg N $tree^{-1}$ equivalent to 104 kg N ha^{-1} and 3) High Nitrogen (HN): 0.45 kg N $tree^{-1}$ equivalent to 204 kg N ha^{-1}. Nitrogen fertilizer was manually applied as organic nitrogen fertilizer. Each treatment was replicated on 10 trees.

A composite leaf sample was collected in April and individual leaf samples were collected in 2015 and 2016 from every tree at the end of July. Samples consisted of one hundred non–fruiting spur leaves taken from exposed mid-canopy positions. Leaves were washed with deionized water and dried at 60°C and then ground to pass a 30-mesh screen using Wiley Mill. The samples were analyzed for N, P and K in UC ANR Lab.

At harvest (August), yield of individual trees were determined. In 2015 a subsample of 300 fruits was fresh weighted and sized (small fruits (<17 g $fruit^{-1}$), medium (between 17 and 25 g $fruit^{-1}$), and large (> 25 g $fruit^{-1}$)). 4 lbs. samples were dried in a commercial drying facility to ~18 % moisture content to obtain the fruit hydration ratio. One sub-sample of 20 fruits by size range was selected on each tree (90 samples), weighted and carried to the laboratory to be

processed. These samples were separated and weighed as mesocarp, endocarp, and seed, and then ground for analysis. Nitrogen concentration was determined both in the mesocarp and in the endocarp & seed. The methodology changed slightly fro 2016 due o the poor yield. A subsample of fruits was collected and of this, 40 fruits were used to determine the size distribution on each tree. Fruits were not separated into small medium and large sized fruits for processing. If there was not enough fruit for both the 4 lbs. sample and the 40 fruit subsample, the 4 lbs. sample was not taken.

Seasonal accumulation of nitrogen in fruit (Objective 2)

In the same orchard used on the Objective 1, eight independent trees were sampled nine times during the 2015 season (approximately 14 day intervals). The experiment was designed with four subsamples (two trees per subsample). During the first two sampling dates we harvested 50 fruits, as fruits were small and 20 fruits on the subsequent sampling dates. In 2016, fruit samples were taken from the RAI orchard, a conventionally managed orchard with higher N inputs. Due to poor yield, 42 trees were sampled ten times at approximately 14-day intervals. These trees included 6 subsamples of 8 individual trees and 20 fruit were collected for each subsample. For analysis at UC ANR, 2 subsamples were combined for a total of 3 samples per sampling date for budgetary reasons. For example, at each sampling date subsamples 1 and 2, 3 and 4, and 5 and 6 were combined for N concentration analysis. Fruit samples were weighed in the field and dried in the laboratory. Biomass of the dried fruits was determined after drying in oven at 60°C. N concentration in fruits in each sample dates were determined in the UC ANR Lab.

Prediction of July leaf N from early spring leaf N (Objective 3)

Leaf samples were collected from 6 orchards from different sites selected to represent a range of typical prune production practices in April and July 2014, 2015, and 2016. These orchards were located in the Yuba City area and are as follows: Everest East, Everest West, Filter Young, Hops, Organic, and RAI. In 2014 and 2015, orchard leaf samples were taken from 30 individual trees in 6 orchards. During April a composite sample of the 30 trees was taken for analysis and in July individual trees were analyzed. In 2016, 30 individual trees were sampled for a composite sample in both April and July. Leaf samples consisted of taking 8 non-fruiting spurs from each

individual tree for the composite sample. If an individual tree was analyzed then 25 individual non-fruiting spurs were collected. Leaves were washed with deionized water to remove contaminants and dried at 60ºC and then ground to pass a 30-mesh screen using a Wiley Mill. Samples collected were analyzed for N, P and K in the UC ANR Lab. N was determined by DUMAS combustion (Bremner & Mulvaney, 1982) and all remaining nutrients were determined through nitric acid digestion (Zarcinas et al., 1987).

Results

Fruit load and N status influence on N removal (Objective 1)

In 2015, the average N removal from the orchard in harvested fruits ranged from 5.48 to 5.80 kg per ton dry yield, with no significant difference in N export between treatments (LN, MN, or HN). Nitrogen concentration by the fruit size (S, M, or L) was only significantly different in the high N treatment where small fruits removed significantly more N compared to large and medium fruits as a percentage of dry weight (Figure 1). Since there was very low yield in 2016, we could not confirm these results the second year.

N concentration in the various parts of the fruit varied with fruit size. At harvest, the N concentration was significantly higher within small sized fruits compared to medium and large (p value of 0.00044 and 0.00067). The highest total amount of N was accumulated occurred in medium sized fruits; there was not a significant difference among N treatments with a p value of 0.30564. This is also due to the fact that medium sized fruits constituted 53% of tree yield in 2015.

Further analysis of the N treatments, effects on the fruit revealed that the medium sized fruit endocarp and seed N concentrations were higher under low N treatment than under High N treatment. In small sized fruit endocarp and seed N concentrations were lower under High N treatment than under low N treatment. After accounting for fruit size distribution and tree yield, there was however no significant difference in the total amount of N accumulated within each fruit size in the seed plus endocarp.

There were significantly higher concentrations of N in the prune mesocarp in small sized fruit compared to medium and large. However there was no significant difference between LN and HN treatments in mesocarp N concentrations. Within the LN treatment, there was a

significantly higher concentration of N within the small sized fruit mesocarp relative to medium and large sized fruits. There were no significant differences in mesocarp N % between medium and large sized fruits in addition to between LN and HN treatments.

There were no statistical differences in N removal depending on N application rates during 2015 or 2016 at a significance level of 0.05 (Figure 1). The average N removals for 2015 and 2016 were 5.03 and 5.35, 5.44 and 5.30, and 4.80 and 5.39 kg of N per dry ton for LN, MN, and HN, respectively. In the same orchard, there were no statistical differences between April or July leaf N percentage among N fertilizer application rates during 2016 (Figure 3).

The relationship between leaf and fruit %N is shown in Figure 4; the trend line accounted for 20% (R squared value) of the variability within all treatments. Within all N treatments, the July leaf %N varied from 1.61 (Low N) to 1.95% N (High N). Fruit %N varied from 0.39 (Low N) to 0.59% N (Low N).

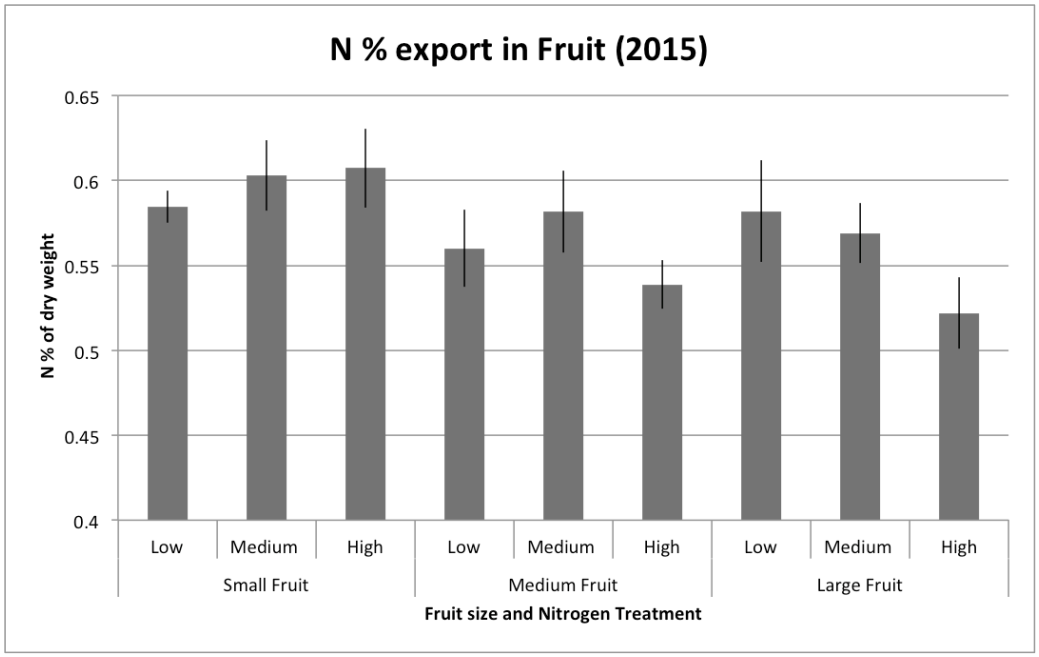

Figure 1: N % concentration in 2015 for fruit size classes and N fertilizer treatments.

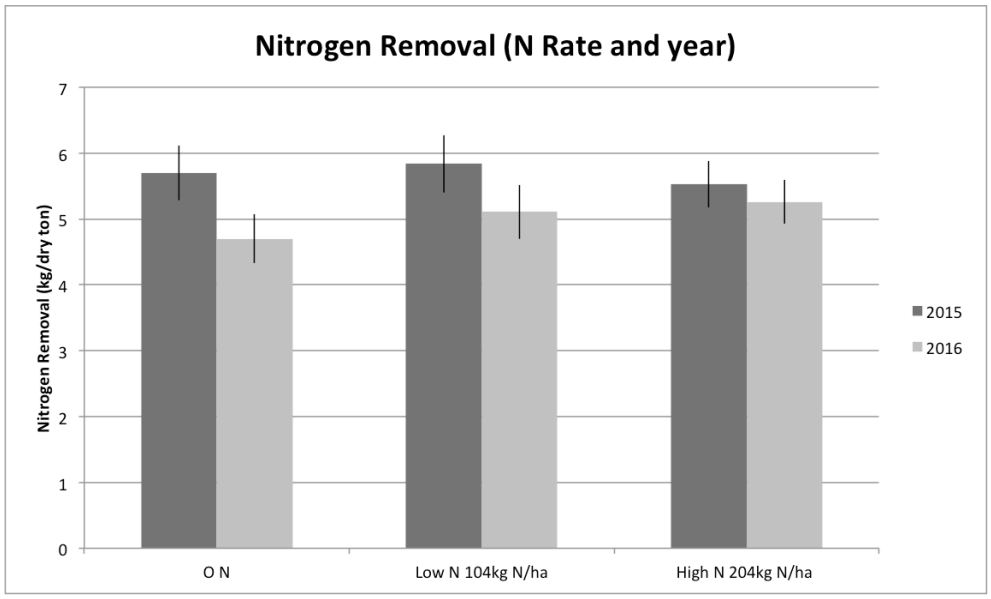

Figure 2: N removal for each of the N applications during 2015 and 2016. There were no statistically significant differences among the treatments at a level of 0.05.

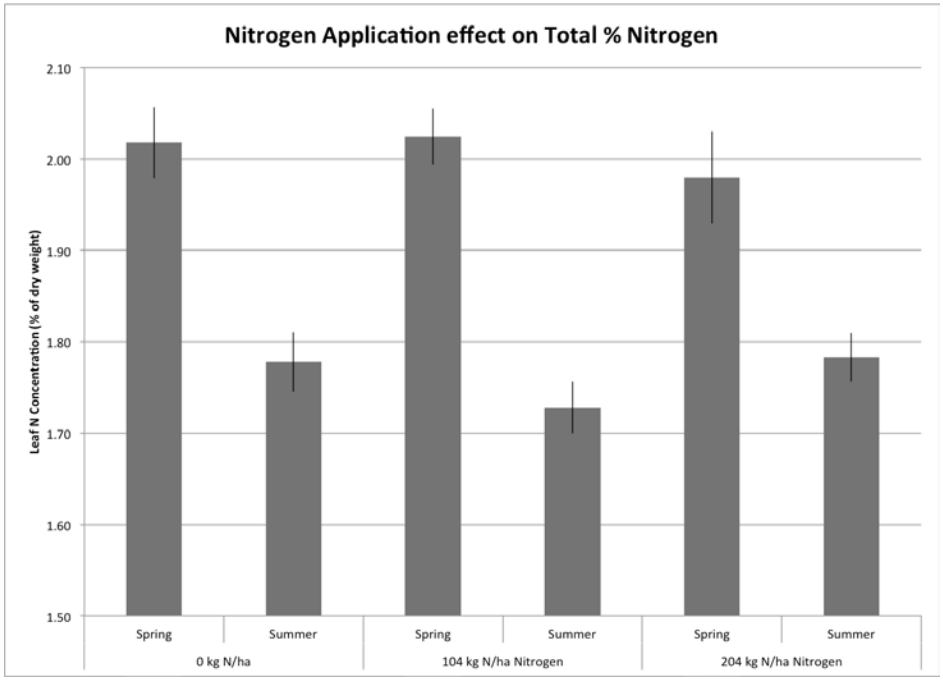

Figure 3: There was no statistical differences among April or July leaf N concentrations in 2016 among N fertilizer rates at significance of 0.05.

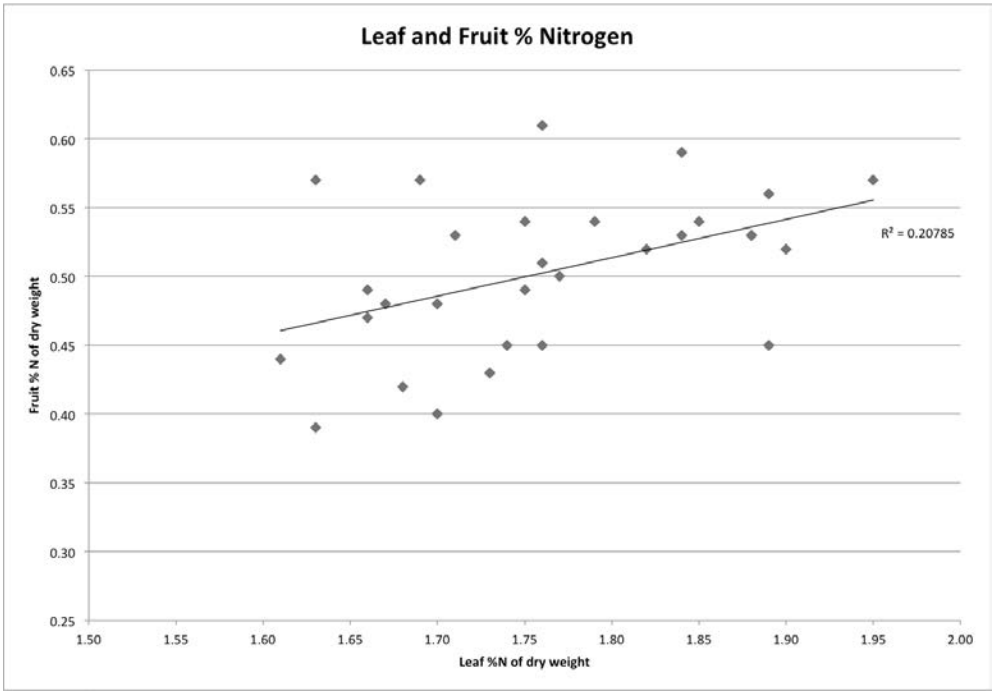

Figure 4: Data from 2016 illustrating the relationship between leaf %N and fruit %N.

Seasonal accumulation of N in fruit (Objective 2)

N accumulation in fruit was measured throughout the season. Fruit N accumulation in both 2015 and 2016 (two different orchards) followed a nearly linear accumulation rate with about 65% and 50% of total seasonal N accumulation accumulated in fruit by the first week of June (Figure 5 and Table 1). In 2015, an organic low N input orchard was sampled, while in 2016 a higher N input orchard was sampled. Differences in the pattern of fruit N accumulation may be a consequence of the orchards or may have arisen due to the poor yield in 2016. Despite variation between years and orchards, the N accumulation in the fruit was not significantly different with 5.78 and 5.37 kg N per dry ton of fruit exported from 2015 and 2016, respectively.

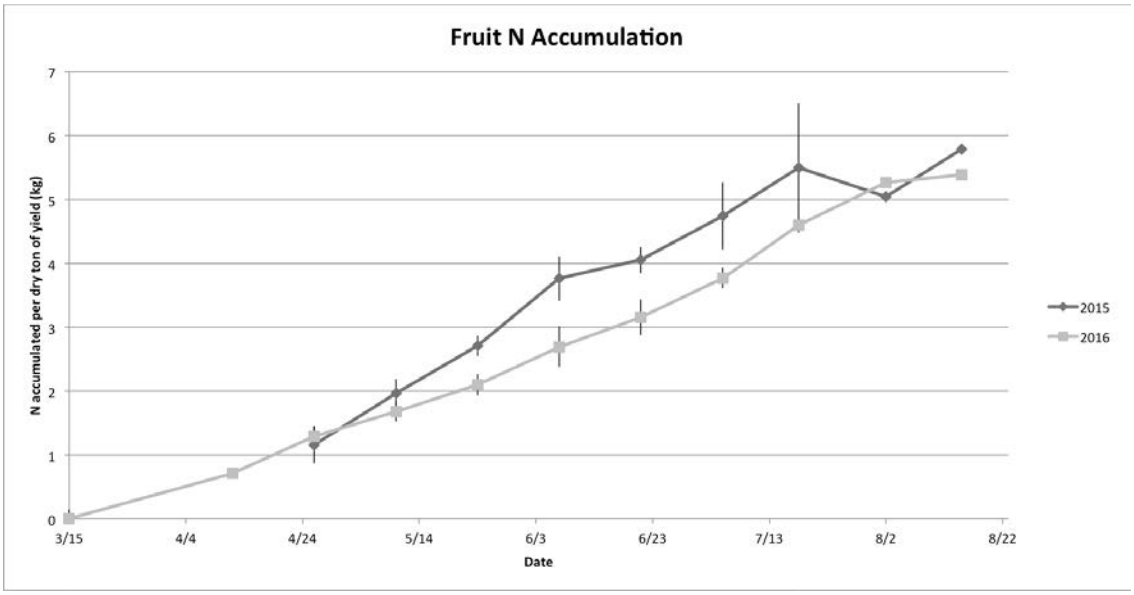

Figure 5: N accumulation in the fruit until harvest for both 2015 (organic orchard) and 2016 (conventional orchard).

	Percent of N Accumulation		
	2015	**2016**	**Average**
4/12		13	
4/26	20	24	22
5/10	34	31	33
5/24	47	39	43
6/7	65	50	58
6/21	70	59	64
7/5	82	70	76
7/18	95	85	90
8/2	87	98	92
8/15	**100**	**100**	**100**

Table 1: Percent N accumulation throughout the season. Percent is based upon total N accumulation at harvest.

Prediction of July leaf N from early spring leaf N (Objective 3)

The project to develop an early leaf sampling model and prediction protocol is still underway and will be completed in 2017. Here I discuss only the preliminary data from 2014, 2015, and 2016. This data is not adequate to develop the prediction model.

N concentrations significantly varied among the orchards sampled. This was due to a number of reasons including N fertilization, grower management, seasonal variation, and yield differences. In combination with subsequent sampling, these data will be used to develop

protocols to predict July leaf N status from early season leaf sampling. Figure 6 illustrates the relationship between April and July leaf % for both 2015 and 2016.

Figure 7 shows the variation of July leaf %N between years and within orchards. Leaf N% varied from a low of 2.15 to a high of 2.86 % N in the Organic orchard. In this graph, the variation among years and orchards is visible.

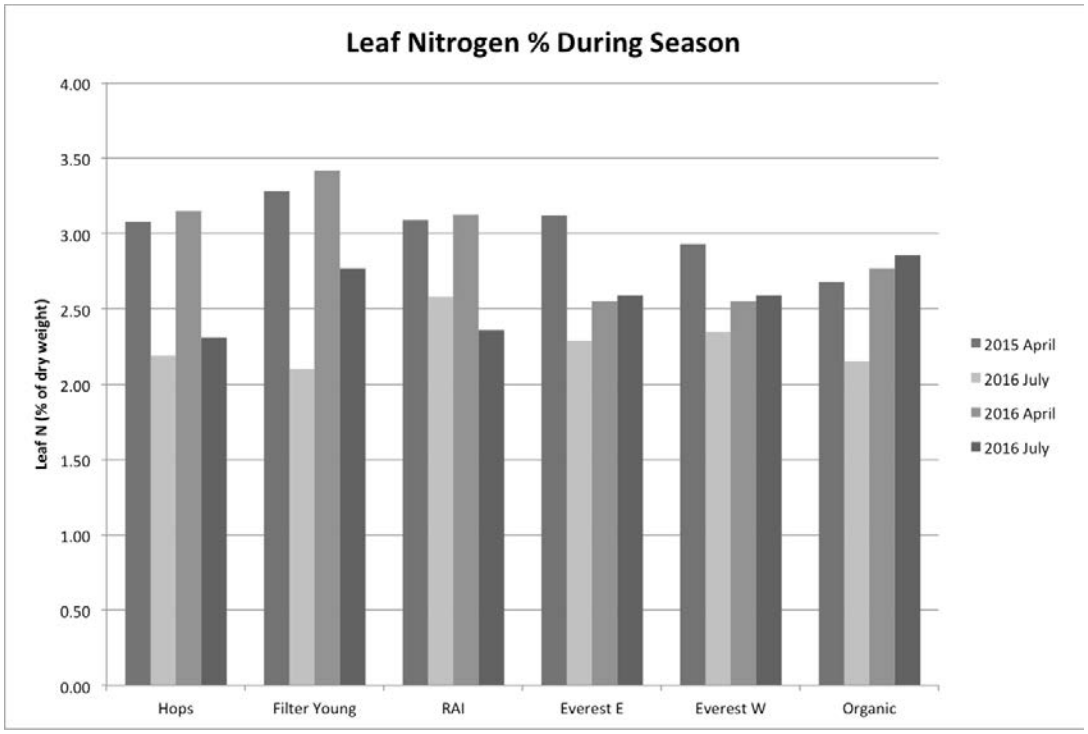

Figure 6: The relationship between April and July leaf samples varies due to various influences including orchard, season, and N management.

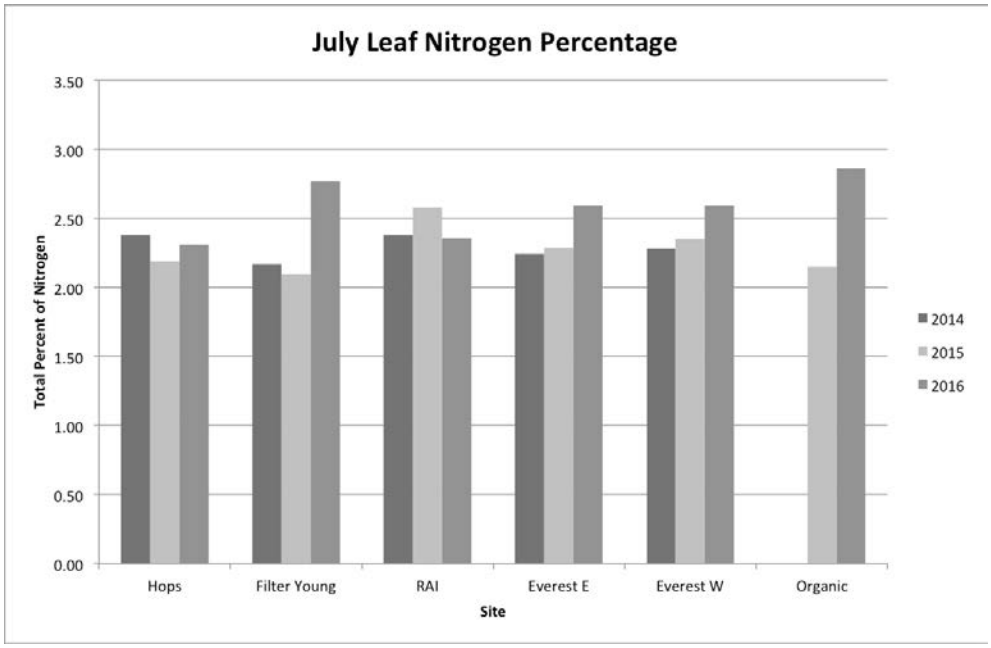

Figure 7: The July leaf N percentage across year and orchards.

Discussion

Frit load and N status influence on N removal (Objective 1)

For 2015, the only significant difference in prune fruit % N accumulation was in the high N treatment (204 kg N ha^{-1}) where small fruits accumulated significantly more N than the medium or large fruit classes (Figure 1). This may be a consequence of an effect of N on seed and endocarp N concentrations when N is abundant. This increased concentration of N was evident in small sized fruits both in the endocarp plus seed in addition to the mesocarp. However, this may not indicate that more N was exported from the tree since that would be highly dependent on the size distribution of the fruit in the orchard. Since 53% of the fruit was medium sized, the majority of N exported came from the high numbers of medium sized fruit. Despite the differences in fruit size distribution, there were no significant differences in the amount of N exported per dry ton for each of the N treatments (Figure 2). This may be a consequence of the abundant residual N and tree N that delayed the occurrence of N deficiency and that the lack of an N response on yield, leaf, or fruit suggests even the organically managed orchard with minimal N applications still had sufficient N. These results differ from previous experiments when it was calculated that 102 kg N ha^{-1} was exported in a heavy fruited crop, however this was calculated based on yields (~17 dry tons ha^{-1}) that were approximately 3 times higher than

average California prune yields (Weinbaum et al., 1994).

Due to the poor yield in 2016, there was less competition among fruits for nutrients and resources; therefore the size distribution of fruits was skewed toward larger fruits. Because of the high percentage of large fruits, the effects of N treatment on fruit size and N% could not be determined in 2016.

To understand how N applications affects the leaf N in both spring and summer sampling, leaf samples were collected. Despite annually receiving no N fertilization, there was no significant difference in leaf %N in either April or July. The lack of a response may be a result of inadequate N fertilization or inadequate time to establish treatments. This may have occurred because tree foliar N absorption and high amino acid concentrations in the plant down regulated N uptake (Youssefi et al., 2000). Additional years of results may be necessary to establish differential N responses in prunes as was seen in almond (Muhammad et al., 2015). The relationship between the April and July leaf samples will be subsequently described in Chapter 3.

Seasonal accumulation of nitrogen in fruit (Objective 2)

Knowledge of the seasonal N accumulation in the fruit can be used to guide N applications and increase NUE. By the end of May, 43% of the total N content of the fruit had been accumulated, and by the first week of July, 76% of all N had been accumulated (Table 3). The prune fruit followed the seasonal N accumulation patterns that were previously described in pear and peach, but N accumulation appeared to slow closer to harvest (Buwalda & Meekings, 1990; Rufat & DeJong, 2001). This may be due to prune fruit remaining on the tree longer than peach or pear, which are harvested at physiological maturity. The average N exported in 2015 and 2016 was 5.78 kg of N per dry ton of fruit. Between 2015 and 2016 the N accumulation varied; this may be due to differences in orchard and N management. Despite variation between years and orchards, N export was not significantly different between 2015 and 2016. 2015 data was collected from an organic orchard with minimal N applications, while 2016 data was collected from a conventional orchard with traditionally higher N inputs. The small variations in N content, yield, and fruit size between years may also be due to yield differences between the two years. Compared to data collected by Weinbaum et al. (1994), defruited trees accumulated significantly less N than cropped prune trees with 121 and 250 grams of N, respectively. This may be due to poor management and yield of the organic

orchard or the unusually high yielding prune orchard utilized by Weinbaum. Additional studies may be beneficial if conducted on conventionally managed orchards. Nutrient accumulation in the fruit is vital to determine nutrient export especially for nitrogen.

Prediction of July leaf N from early spring leaf N (Objective 3)

Overall, leaf sampling results were not as expected which may be due to a number of reasons including yearly environmental differences, various orchard management practices, and poor sampling technique. In comparison to previous leaf sampling results on prunes with cropped and defruited trees, N concentrations did not follow the expected trends. In prior work, there was a significant difference between leaf N concentrations with 2.4% in cropped trees and 2.23% in defruited trees (Weinbaum et al., 1994); similar results were expected between 2015 and 2016, but this was not the case. These results confirm that despite efforts to standardize leaf samples, variation still remains suggesting the need for additional research or other methods to determine plant nutrient status (Burns, 1992). Due to inconsistent results, the development of a model specifically for prunes may be more complicated than previously anticipated.

The results from 2014, 2015, and 2016 will be used as preliminary data for the model development of a specific early leaf-sampling model for prunes. The current results confirm that a similar sampling methodology may be used in prunes as in almonds, but more work is needed on its development. Future leaf sampling will focus on using a pooled sample from each orchard. These data will also give the model data points from multiple years which will be useful in determining if tree-to-tree orchard variation will also account for variation that may occur yearly. In conclusion, this preliminary data will be useful in the development of a model for early leaf sampling in prunes with hopes of being available in 2017.

Works Cited

2016 California Dried Plum (Prune) Forecast. (2016). Sacramento, CA Retrieved from https://www.nass.usda.gov/Statistics_by_State/California/Publications/Fruits_and_Nuts/2016/201606prunf.pdf.

Bremner, J. M., & Mulvaney, C. (1982). Nitrogen—total. *Methods of soil analysis. Part 2. Chemical and microbiological properties*(methodsofsoilan2), 595-624.

Burns, I. (1992). Influence of plant nutrient concentration on growth rate: Use of a nutrient interruption technique to determine critical concentrations of N, P and K in young plants. *Plant and Soil, 142*(2), 221-233.

Buwalda, J. G., & Meekings, J. S. (1990). Seasonal Accumulation of Mineral Nutrients in Leaves and Fruit of Japanese Pear Pyrus-Serotina Rehd *Scientia Horticulturae (Amsterdam), 41*(3), 209-222. doi:10.1016/0304-4238(90)90004-x

Muhammad, S., Sanden, B. L., Lampinen, B. D., Saa, S., Siddiqui, M. I., Smart, D. R., Olivos, A., Shackel, K. A., DeJong, T., & Brown, P. H. (2015). Seasonal changes in nutrient content and concentrations in a mature deciduous tree species: Studies in almond (Prunus dulcis (Mill.) D. A. Webb). *European Journal of Agronomy, 65*, 52-68. doi:10.1016/j.eja.2015.01.004

Rufat, J., & DeJong, T. M. (2001). Estimating seasonal nitrogen dynamics in peach trees in response to nitrogen availability. *Tree Physiology, 21*(15), 1133-1140.

Saa, S., Brown, P. H., Muhammad, S., Olivos-Del Rio, A., Sanden, B. L., & Laca, E. A. (2014). Prediction of leaf nitrogen from early season samples and development of field sampling protocols for nitrogen management in Almond (Prunus dulcis Mill. DA Webb). *Plant and Soil, 380*(1-2), 153-163. doi:10.1007/s11104-014-2062-4

Weinbaum, Niederholzer, F. J. A., Ponchner, S., Rosecrance, R. C., Carlson, R. M., Whittlesey, A. C., & Muraoka, T. T. (1994). Nutrient uptake by cropping and defruited field-grown 'French' prune trees. *Journal of the American Society for Horticultural Science, 119*(5), 925-930.

Youssefi, F., Weinbaum, S. A., & Brown, P. H. (2000). Regulation of nitrogen partitioning in field-grown almond trees: Effects of fruit load and foliar nitrogen applications. *Plant and Soil, 227*(1-2), 273-281. doi:10.1023/a:1026572615441

Zarcinas, B., Cartwright, B., & Spouncer, L. (1987). Nitric acid digestion and multi-element analysis of plant material by inductively coupled plasma spectrometry. *Communications in Soil Science & Plant Analysis, 18*(1), 131-146.