CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
FERTILIZER RESEARCH AND EDUCATION PROGRAM (FREP)

FINAL REPORT

Project Title: Can a better tool for assessing 'Hass' avocado tree nutritional status be developed? – *A feasibility study*

CDFA Agreement No. 07-002

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STATEMENT OF OBJECTIVE:

California avocado growers must increase yield, including fruit size, and/or reduce production costs to remain competitive in the US market, which now receives fruit from Mexico, Chile, New Zealand, and Dominican Republic, and will soon receive fruit from Peru, Ecuador, South Africa, and Brazil. Optimizing the nutrient status of the 'Hass' avocado (*Persea americana* Mill.) is a cost-effective means to increase yield, fruit size and quality, but the California avocado industry has no reliable diagnostic tool relating tree nutrient status with yield parameters. For the 'Hass' avocado of California, experiments for only N, Zn and Fe have been conducted to determine the optimal leaf concentration for maximum yield (Crowley, 1992; Crowley and Smith, 1996; reviewed in Lovatt and Witney, 2001). Alarmingly, leaf N concentration was not related to yield (Lovatt and Witney, 2001). Optimum ranges for nutrients other than N, Zn and Fe used for interpreting leaf analyses for the 'Hass' avocado are borrowed from citrus and, thus, are not related to any avocado yield parameter. The project's objective is to test the feasibility of using tissues that have frequently proven more sensitive and reliable than leaves to diagnose deficiencies of the 'Hass' avocado sufficiently early that corrective measures would have a positive effect on yield parameters during the current year, not just the following year. Based on results obtained by avocado researchers in Chile (Razeto and Granger, 2001; Razeto et al., 2003; Razeto and Salgado, 2004), it is highly likely that pedicel (the stem of the fruit) and/or inflorescence tissue will meet the criteria essential for an effective diagnostic tool for 'Hass' avocado fertility management in California. However, it must be noted that additional research would be required to develop the broader database required to have confidence in the relationship between nutrient concentrations in pedicel and/or inflorescence tissue and yield or fruit size than would be provided by the two data sets that will be obtained in this proposed 2-year study. Hence, this is a feasibility study designed to determine whether a better tool for assessing 'Hass' avocado tree nutrient status can be developed.

PROJECT OBJECTIVES:

1) Determine the sensitivity of inflorescences and fruit pedicels (stems) to differences in tree nutrient status.

2) Determine if the nutrient concentrations of the tissues above are related to fertilizer rate and to yield parameters.

3) Determine if differences in tissue nutrient concentrations related to yield can be detected sufficiently early to be corrected before they impact yield, fruit size or fruit quality in the current year.

EXECUTIVE SUMMARY:

California avocado growers must increase yield, including fruit size, and/or reduce production costs to remain competitive in the US market, which now receives fruit from Mexico, Chile, New Zealand, and Dominican Republic and soon Peru, Ecuador, South Africa and Brazil. Optimizing the nutrient status of the 'Hass' avocado (*Persea americana* Mill.) is a cost-effective means to increase yield, fruit size and quality, but the California avocado industry has no reliable diagnostic tool relating tree nutrient status with yield parameters. For the 'Hass' avocado of California, experiments for only N, Zn and Fe have been conducted to determine the optimal leaf concentration for maximum yield (Crowley, 1992; Crowley and Smith, 1996; reviewed in Lovatt and Witney, 2001). Alarmingly, leaf N concentration was not related to yield (Lovatt and Witney, 2001). Optimum ranges for nutrients other than N, Zn and Fe used for interpreting leaf analyses for the 'Hass' avocado are borrowed from citrus and, thus, are not related to any avocado yield parameter. Moreover, since optimal ranges for most nutrients are not known, current ranges for N, Zn and Fe are likely inaccurate, since they were determined under conditions where availability of one or more nutrients might have limited yield.

The project's objective is to test the feasibility of using tissues that have frequently proven more sensitive and reliable than leaves to diagnose deficiencies of the 'Hass' avocado sufficiently early that corrective measures would have a positive effect on yield parameters during the current year, not just the following year. Based on results obtained by avocado researchers in Chile (Razeto and Granger, 2001; Razeto et al., 2003; Razeto and Salgado, 2004), it is highly likely that pedicel (stem of the fruit) and/or inflorescence tissue will meet the criteria essential for an effective diagnostic tool for 'Hass' avocado

fertility and fertilizer management in California. However, it must be noted that additional research would be required to develop the broader database required to have confidence in the relationship between nutrient concentrations in pedicel and/or inflorescence tissue and yield or fruit size than would be provided by the two data sets that will be obtained in this proposed 2-year study. Hence, this is a feasibility study designed to determine whether a better tool for assessing 'Hass' avocado tree nutrient status can be developed. The project is a success if one, or more, tissue (a) is sensitive to differences in tree nutrient status, (b) has a nutrient content related to fertilizer rate and yield, fruit size and quality, and (c) reveals nutrient deficiencies sufficiently early that correction will improve yield in the current year.

This project succeeded in determining the sensitivity of inflorescences at two stages of development and fruit pedicels (stems) at six stages of fruit development to differences in tree nutrient status relative to leaves. The results revealed that the nutrient concentrations of the tissues were not responsive to soil fertilizer applications or to differences in fertilizer rate over the short period of two years that we applied the soil fertilizer treatments. The results confirmed that leaf nutrient concentrations were not related to yield or fruit quality parameters, with the exception of a weak, but highly significant relationship between leaf concentrations of Ca, Fe, S and Zn and yield of commercially valuable large size 'Hass' avocado fruit (packing carton sizes 60 + 48 + 40; 178-325 g/fruit) as kilograms per tree ($r^2 = 0.58$; $P = 0.0026$) and as number of fruit per tree ($r^2 = 0.51$; $P = 0.0057$) across all four orchards and the NPK soil fertilizer treatments. The utility of this relationship could be studied further in orchards by using current leaf analyses and collecting yield data. The results of this research identified the several key nutrient concentrations of inflorescence tissue related to total yield, yield of commercially valuable large size fruit (178-325 g/fruit, packing carton sizes 60 + 48 + 40) and fruit quality parameters that were statistically significant and explained in some cases ≥ 60% of the variation in yield or fruit quality. A unique finding was the potential importance of inflorescence tissue concentrations of Cu to yield parameters and Cu and Mn to fruit quality parameters across the orchards in this study. These relationships merit further testing to determine their potential capacity to serve as predictors of the effect of tree nutrient status on yield and fruit quality. Inflorescence tissue has the added advantage that it could be collected and analyzed sufficiently early in the season to mitigate the negative effect of nutrient deficiencies on the current crop and on the fruit quality of the mature crop. However, more research is needed to determine the utility of these relationships on a larger scale, with more years of yield and fruit quality data at more orchards.

WORK DESCRIPTION:

YEAR 1 – TASK 1: Specific objectives are: (1) to determine the sensitivity of the flower, entire inflorescence, and fruit pedicel to differences in tree nutrient status; (2) to determine if the nutrient concentrations of the tissues above are related to fertilizer rate and to yield parameters; and (3) to determine if differences in tissue nutrient concentrations related to yield can be detected sufficiently early to be corrected before they impact yield, fruit size or fruit quality in the current crop year.

Month of initiation: 7/07 Month of completion 6/08

Subtask 1.1: Lay out the experiment, select trees of similar size, crop load and health, and label data trees.

Subtask 1.1 was initiated and completed in July 2007.

Subtask 1.2: Monitor tree phenology and collect tissue samples at appropriate times. Wash, dry, grind samples and send to the UC-DANR Laboratory for analysis.

Subtask 1.2 was initiated in July 2007 and completed in June 2008.

Subtask 1.3: Harvest mature crop and obtain all yield data.

Subtask 1.3 was initiated in July 2007 and was completed in September 2007 for the various orchards.

Subtask 1.4: Collect and process leaves for nutrient analysis. Send leaf samples to the UC-DANR Laboratory for analysis.

Subtask 1.4 was initiated in September 2007 and completed October 2007.

Subtask 1.5: Once yield data and nutrient analyses are obtained, begin statistical analysis of the results. Proceed until all data are obtained and analyzed.

Subtask 1.5 was initiated in August 2007 and completed in June 2008.

Subtask 1.5: Prepare and send annual report to FREP.

Subtask 1.5 was initiated in May 2008 and was completed in June 2008.

YEAR 2 – TASK 2: Specific objectives are: (1) to determine the sensitivity of the flower, entire inflorescence, and fruit peduncle to differences in tree nutrient status; (2) to determine if the nutrient concentrations of the tissues above are related to fertilizer rate and to yield parameters; (3) to determine if differences in tissue nutrient concentrations related to yield can be detected sufficiently early to be corrected before they impact yield, fruit size or fruit quality in the current crop year; and (4) for tissues meeting these criteria, to determine nutrient concentration stability over the 30-days bracketing the sampling time.

Month of initiation: 7/08 Month of completion 6/09

Subtask 2.1: Monitor tree phenology and collect tissue samples at the appropriate times. Wash, dry, grind samples and send to the UC-DANR Laboratory for analysis.

Subtask 2.1 was initiated in July 2008 and completed in June 2009.

Subtask 2.2: Harvest mature crop and obtain all yield data.

Subtask 2.2 was initiated in July 2008 and completed in September 2009 for the various orchards.

Subtask 2.3: Collect and process leaves for nutrient analysis. Send leaf samples to the UC-DANR Laboratory for analysis.

Subtask 2.3 was initiated in September 2008 and completed October 2009.

Subtask 2.4: Once yield data and nutrient analyses are obtained, begin statistical analysis of the results. Proceed until all data are obtained and analyzed.

Subtask 2.4 was initiated in August 2008 and completed in June 2009.

Subtask 2.5: Present the results of the first year at the Annual FREP Conference.

Subtask 2.5 was initiated and completed in November 2008.

Subtask 2.6: Prepare and send final report to FREP (due October 30, 2009 per a no-cost extension).

Subtask 2.6 was initiated Septmeber 2009 and completed by October30, 2009.

RESULTS, DISCUSSION AND CONCLUSIONS:

RESULTS

Sensitivity of tissues to tree nutrient status. The research was initiated with the start of funding in July 2007. Due to the freeze on January 18, 2007, orchards we had planned to use had to be replaced with new ones. This included the trees in year 4 of an experiment comparing rates of N versus NPK soil-applied fertilizers. As a result, we did not have the benefit of using trees that had received fertilizer treatments at different rates of N, P, and K for multiple years. Instead the fertilizer treatments were initiated with the start of the project. In addition, temperatures exceeded 100 °F on June 20, 21, and 22, 2008, causing a significant proportion of the setting fruit to abscise from trees in our research orchards located in San Luis Obispo, Santa Barbara and Santa Paula. Despite these constraints, the results we obtained have proven adequate for meeting the original objectives of the research.

Nutrient concentrations of cauliflower stage (Young inflorescences, March) and full bloom stage (Mature inflorescences, April) collected from 'Hass' avocado trees in Irvine were significantly greater than pedicels (stems) of mature fruit collected in March and April, respectively, (Table 1). Similarly, for 'Hass' avocado trees in Pauma Valley, cauliflower stage inflorescence had significantly greater nutrient concentrations than the pedicels of mature fruit collected from the same trees in March, with the exception of K and Fe (Table 1). For inflorescences collected from these same trees at full bloom (April), only concentrations of K, S, B, Ca, Zn, Mn, and Cu, but not N, P, Mg or Fe, were greater than those of pedicels of mature fruit also collected in April. It is of great interest that for all trees in the fertilizer experiment in Santa Barbara, regardless of NPK treatment, inflorescences collected at the cauliflower stage (Y. inflorescences) and at full bloom (M. inflorescences) had significantly greater nutrient concentrations for all nutrients (except K in a few cases) than the pedicels of mature fruit collected from the same trees at the same time in March and April, respectively (Table 2).

For the five orchards in which we collected inflorescences at both the cauliflower and full bloom stage of inflorescence development, cauliflower stage inflorescences always had significantly greater concentrations of N, P, Zn, and Cu, but significantly lower concentrations of K and Fe than full bloom inflorescences (data not shown). The results in Santa Barbara were similar. For each fertilizer treatment cauliflower stage inflorescences had significantly greater concentrations of N, P, K, Zn and S, and a significantly lower concentration of Fe. Neither tissue showed differences in concentrations of N, P or K related to the soil fertilization treatments. It is also of interest that when averaged across all trees in four orchards, including the trees in the NPK soil fertilizer treatments, Cu and Ca concentrations in cauliflower stage inflorescences were related to yield and fruit size, but the Cu, S, K and Zn concentrations of inflorescences collected at full bloom were stronger predictors of total yield and yield of commercially valuable large size fruit (178-325 g/fruit) both as kilograms and number of fruit per tree (discussed in detail below). The relationship between inflorescence tissue nutrient concentrations and fruit quality was also stronger when inflorescences were collected at full bloom in April. Regardless of whether inflorescences were collected at the cauliflower stage or full bloom, Cu was a major determinant of fruit length, fruit width and the number of days necessary for fruit to ripen after harvest (discussed in detail below).

Mature leaves (M. leaf) on spring flush, non-fruiting terminal shoots collected in September, the standard time for avocado leaf analysis, had significantly greater concentrations of nutrients than pedicels collected from young fruit (Y. fruit stem) that developed contemporaneously on spring flush, fruiting terminal shoots (Table 1). For avocado trees in Irvine, all nutrient concentrations were greater in leaves than pedicels, but for trees at Pauma Valley and trees in the fertilizer experiment in Santa Barbara, P and/or K concentrations were not significantly greater in leaves (Tables 1 and 2). In Santa Barbara, the N, P, and K concentrations of pedicels from young fruit collected in September did not reflect the NPK fertilization rates in year 1 or year 2. Regardless of fertilizer treatment, N, P and K concentrations of the pedicels from young fruit were greater in year 1 of the experiment than in year 2 (data not shown).

The failure of pedicels collected from young fruit in June, September and November or mature fruit in March and April to reflect soil-applied fertilizer treatments can be seen in figure 1. There was a dramatic increase in the P and Mg concentrations of pedicels from young fruit sampled in June in the 0.5x NPK treatment that was not related to a fertilizer application, as trees in this treatment receive NPK fertilizer only in July and August. It was of interest that nutrient concentrations of pedicles increased in most cases over the 6-month period from October 2007 (pedicels from young fruit) to April 2008 (pedicels of mature fruit) and by April were typically greater for each treatment than the nutrient concentrations of pedicels from young fruit collected 2 months later in June (Fig. 1). A notable exception was boron. Pedicel boron concentrations were greatest in mature pedicels collected in March. Surprisingly, these relationships, though less pronounced, were evident in the four other avocado orchards, with the exceptions of pedicel S concentrations at Irvine and Pauma Valley and pedicel Zn at Pauma Valley (Fig. 2). From our data we can not tell whether the differences in nutrient concentrations in pedicels from mature fruit in April and young fruit in June reflect the effect of the heavy 2007-2008 on-crop of mature fruit on the lighter 2008-2009 off-crop of young developing fruit in all orchards or whether most nutrients accumulate in the pedicel of fruit throughout their development from June through April the following year; both are intriguing and potentially useful possibilities.

Relationship between tissue nutrient concentrations and yield parameters. We determined which nutrients in each tissue were significantly related to total yield and yield of commercially valuable large size fruit of packing carton sizes 60 + 48 + 40 (fruit weighing 178 to 325 g). Using stepwise regression analyses, we determined the most important combination of nutrients for each yield parameter across all orchards. ***Inflorescence tissue.*** We found significant relationships between nutrient concentrations of inflorescences at the cauliflower and full bloom stage and yield across all orchards including the trees in the fertilizer experiment in Santa Barbara. In all cases, nutrient concentrations of inflorescences collected at full bloom were more strongly related to yield and yield of commercially valuable large size fruit as both kilograms and number of fruit per tree. Cauliflower stage inflorescence tissue concentrations of Cu and Ca explained ≥ 60% of the variation in total yield (as kg/tree) and yield of fruit > 178 g per fruit (as kg and number of fruit/tree) ($P < 0.05$). Interestingly, the Cu concentration of cauliflower stage inflorescences alone predicted 54% of the variation in yield of commercially valuable large size fruit of packing carton sizes 60 + 48 + 40 (178-325 g/fruit) (as both kilograms and number of fruit per tree) ($P < 0.0001$). Cu, S, K and Zn concentrations of inflorescence tissue collected at full bloom predicted 77% of the variation in total yield, yield of fruit > 178 g per fruit and the yield of fruit in the combined pool of fruit weighing 178 to 325 g per fruit (as both Kg and number of fruit/tree) ($P < 0.01$). ***Pedicel tissue.*** P, S, B, and Ca concentrations of pedicels collected from young developing fruit in September explained 56% of the variation in yield of fruit > 178 g per fruit (packing carton size 60) as kilograms per tree ($P < 0.0009$). These nutrients plus Mg were required to predict the yield of fruit greater than packing carton size 60 as number of fruit per tree ($r^2 = 0.53$; $P = 0.0044$) and the yield of fruit in the combined pool of fruit 178 to 325 g per fruit (packing carton sizes 60 + 48 + 40) as kilograms fruit per tree ($r^2 = 0.55$; $P = 0.0039$). Note that this yield parameter as number of fruit per tree was related to P, S, B, Ca and N, not Mg ($r^2 = 0.52$; $P = 0.0138$). When pedicels of young fruit were collected in November, Zn, S, P and Mg concentrations predicted 60% of the variation in yield of fruit of packing carton sizes ≥ 40 (≥ 270 g/fruit) as both kilograms and number of fruit per tree in both years of the study ($P = 0.0244$), with Zn the most important determinant. ***Leaf tissue.*** Our results confirmed that leaf nutrient concentrations by standard leaf analyses were not related to total yield. Leaf nutrient status was also not responsive to the NPK soil fertilizer treatments. However, there was a weak, but highly significant relationship between leaf concentrations of Ca, Fe, S and Zn and yield of commercially valuable large size 'Hass' avocado fruit (packing carton sizes 60 + 48 + 40; 178-325 g/fruit) as kilograms per tree ($r^2 = 0.58$; $P = 0.0026$) and as number of fruit per tree ($r^2 = 0.51$; $P = 0.0057$) across all four orchards and the NPK soil fertilizer treatments.

Relationship between tissue nutrient concentrations and fruit quality parameters. We determined which combination of nutrients in each tissue had the most important effect on fruit quality across all orchards using stepwise regression analyses. The fruit quality parameters evaluated in each orchard were: number of days for fruit to ripen after harvest, peel color at maturity, fruit length, fruit width, width of the mesocarp (edible portion of the fruit), seed diameter, germination of the seed within the mesocarp, vascularization (presence of vascular tissue in the mesocarp), mesocarp discoloration, mesocarp decay. Fruit quality parameters were visually determined using a scale from 0 (none) to 4 (extensive, present in all four quarters of the fruit). ***Leaf tissue.*** Nutrient concentrations of leaves collected at the standard time were not related to any fruit quality parameter evaluated, with the exception that leaf Ca, Mn and Zn concentrations were significantly related to fruit length ($r^2 = 0.60$; $P = 0.0386$). ***Pedicel tissue.*** For pedicels collected from current year fruit, Zn, Fe, Mg, and Mn (September collection) and Zn and Mn (November collection) were also predictive of fruit length ($r^2 = 0.62$; $P = 0.0159$; $r^2 = 0.58$; $P = 0.0005$, respectively). ***Inflorescence tissue.*** Inflorescence tissues were the best predictors of fruit quality, including fruit length, fruit width, mesocarp width, seed germination within the fruit, and the number of days to ripen after harvest, across all four orchards and the NPK soil fertilizer treatments. All parameters were more strongly related to the nutrient concentrations of inflorescences collected at full bloom than at the cauliflower stage of inflorescence development. For inflorescences collected at full bloom, Cu and Mn predicted 82% of the variation in fruit length ($P =$

0.0048); Cu and K predicted 59% of the variation in fruit width ($P = 0.0055$); K and N predicted 57% of the variation in mesocarp width ($P = 0.0093$); K and Mg predicted 53% of the variation in the occurrence of seed germination within the mesocarp ($P = 0.0433$); and Cu alone predicted 51% of the variation in the number of days for fruit to ripen after harvest ($P < 0.0001$). Whereas all the relationships are statistically significant, fruit length was *strongly* influenced only by Cu and Mn nutrient status of full bloom inflorescences as reflected by the high r^2-value ($r^2 = 0.82$).

DISCUSSION

The California Avocado Commission recommends a leaf N concentration of 2.2% (Lovatt and Witney, 2001). For both years of the study, leaf N concentrations were below this level at all sites (Appendix Table 1). In addition, at all sites, including the trees in the NPK soil fertilization treatments, leaf K concentrations were also at the low end or below the optimal range based on the values used by several commercial laboratories. All other macronutrients were within the optimal ranges used by these laboratories. From this perspective, it is interesting that the N concentration of pedicels and full bloom inflorescences was only weakly related, along with other nutrients, to a single yield and fruit quality parameter, respectively: (1) P, S, B, Ca and N concentrations of pedicels from young fruit (September) predicted the 52% of the variation in yield of fruit in the combined pool of packing carton sizes 60 + 48 + 40 (178 to 325 g per fruit) ($P = 0.0138$); and (2) K and N concentrations of full bloom inflorescences predicted 57% of the variation in mesocarp width ($P = 0.0093$). Other macronutrients were more frequently important predictors of yield (P, S, Ca) and fruit quality (K, Ca, Mg) parameters. These nutrients were not limiting according the standard leaf analyses.

Leaf B concentration was low at all sites, except one orchard in Santa Paula. Copper was below optimum in this Santa Paula orchard. Zinc was below the optimum range in the Santa Barbara orchard for both years of the study. All other micronutrients were present at leaf concentrations considered optimal by the avocado industry. Micronutrients were related to yield (Cu, Zn, B, Fe) and fruit quality (Zn, Fe, Mn, Cu) parameters.

Some nutrients that were predictive of yield and fruit quality parameters were tissue specific: Cu, inflorescence tissue; B and Mg, pedicels; and Fe, leaf tissue. Interestingly, Mn was uniquely related to the fruit quality parameter of fruit length across all tissues.

The nutrient concentrations of inflorescence tissue explained a greater proportion of the variation in yield and fruit quality data than those of other tissues. Cauliflower stage inflorescence tissue concentrations of Cu and Ca explained ≥ 60% of the variation in total yield (as kg/tree) and yield of fruit > 178 g per fruit (as kg and number of fruit/tree) ($P < 0.05$) with Cu concentration alone explaining 54% of the variation in yield of commercially valuable large size fruit of packing carton sizes 60 + 48 + 40 (178-325 g/fruit) (as both kilograms and number of fruit per tree) ($P < 0.0001$). For inflorescence tissue collected at full bloom, Cu, S, K and Zn concentrations predicted 77% of the variation in total yield, yield of fruit > 178 g per fruit and the yield of fruit in the combined pool of fruit weighing 178 to 325 g per fruit (as both Kg and number of fruit/tree) ($P < 0.01$). Fruit quality parameters were more strongly related to the nutrient concentrations of inflorescences collected at full bloom than at the cauliflower stage of inflorescence development. For inflorescences collected at full bloom, Cu and Mn predicted 82% of the variation in fruit length ($P = 0.0048$); Cu and K predicted 59% of the variation in fruit width ($P = 0.0055$); K and N predicted 57% of the variation in mesocarp width ($P = 0.0093$); K and Mg predicted 53% of the variation in the occurrence of seed germination within the mesocarp ($P = 0.0433$); and Cu alone predicted 51% of the variation in the number of days for fruit to ripen after harvest ($P < 0.0001$).

CONCLUSION

The results of this research identified the several key nutrient concentrations of inflorescence tissue related to total yield, yield of commercially valuable large size fruit (178-325 g/fruit, packing carton sizes 60 + 48 + 40) and fruit quality parameters that were statistically significant and explained in some cases ≥ 60% of the variation in yield or fruit quality. A unique finding was the potential importance of inflorescence tissue concentrations of Cu to yield parameters and Cu and Mn to fruit quality parameters across the orchards in this study. These relationships merit further testing to determine their potential capacity to serve as predictors of the effect of tree nutrient status on yield and fruit quality. Inflorescence tissue has the added advantage that it could be collected and analyzed sufficiently early in the season to mitigate the negative effect of nutrient deficiencies on the current crop and on the fruit quality of the mature crop.

The results confirmed that leaf nutrient concentrations were not related to yield or fruit quality parameters, with the exception of a weak, but highly significant relationship between leaf concentrations of Ca, Fe, S and Zn and yield of commercially valuable large size 'Hass' avocado fruit (packing carton sizes 60 + 48 + 40; 178-325 g/fruit) as kilograms per tree ($r^2 = 0.58$; $P = 0.0026$) and as number of fruit per tree ($r^2 = 0.51$; $P = 0.0057$) across all four orchards and the NPK soil fertilizer treatments. The value of this relationship could be studied further in orchards by using current leaf analyses and collecting yield data.

PROJECT EVALUATION:

This project succeeded in determining the sensitivity of inflorescences at two stages of development and fruit pedicels (stems) at six stages of fruit development to differences in tree nutrient status relative to leaves. The results revealed that the nutrient concentrations of the tissues were not responsive to soil fertilizer applications or to differences in fertilizer rate over the short period of two years that we applied the soil fertilizer treatments. The results of this research identified that tissue nutrient concentrations were related to yield and fruit quality parameters. The results with inflorescence tissue, especially when collected at full bloom, were the most promising, especially because this tissue could be collected early enough in the season for the results of tissue analysis to be useful in mitigating deficiencies that would negatively impact the production of the current setting crop and quality of the mature crop. However, more research is needed to determine the utility of these relationships on a larger scale, with more years of yield and fruit quality data at more orchards.

OUTREACH ACTIVITIES SUMMARY:

I presented an overview of this project at the CDFA-FREP Annual Meeting November 27, 2007, in Tulare, CA. I am scheduled to present the final results of this project at the CDFA-FREP Annual Meeting November 18, 2009, in Visalia, CA. I gave a presentation, entitled "Properly Timed Foliar

Fertilization Can and Should Result in a Yield Benefit and Net Increase in Grower Income", at the VI International ISHS Symposium on Mineral Nutrition of Fruit crops on May 21, 2008. In this presentation I emphasized the need to supply foliar fertilizers at key stages of tree phenology having high nutrient demand. I used the results from this project, along with earlier work using foliar sprays on the 'Hass' avocado, to reinforce the idea of targeting foliar fertilizers to inflorescences at key stages of development. I was an invited speaker, and I also provide posters (4) about my avocado fertilization and plant growth regulator research, which included our results on avocado phenology, physiology and the results of my previous three CDFA-FREP projects and an overview of the objectives of this project and an example from the limited results we had obtained at that time, to avocado growers of California through a series of seminars hosted by the California Avocado Commission, California Avocado Society and the University California Cooperative Extension. In my talk, entitled "Fine-tuning Orchard Performance", and in my poster, entitled "Fertilization Strategies to Increase Yield and Fruit Size of the 'Hass' Avocado", I discussed CDFA-FREP project 07-002 as part of my on-going research on optimizing fertilization of the 'Hass' avocado. I also presented my talk to the members of the California Association of Pest Control Advisors (CAPCA). These presentations were given as follows: San Luis Obispo, Tuesday, June 10, 2008; Santa Paula, Wednesday morning, June 11, 2008; Temecula, Thursday, June 12, 2008; and CAPCA in Santa Paula, Wednesday afternoon, June 11, 2008. Now that the project is completed, B. Faber, R. Rosecrance and I will each be able to present the results at additional venues in the future, especially avocado grower meetings.

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Table 1. Nutrient concentrations of 'Hass' avocado tissues collected in Irvine and Pauma Valley, Calif.

Tissue[z]	N %	P %	K %	S %	B ppm	Ca %	Mg %	Zn ppm	Mn ppm	Fe ppm	Cu ppm
						Irvine					
Y. inflorescence	3.35 a[y]	0.52 a	2.17 a	0.35 a	54.00 a	0.60 a	0.24 a	56.30 a	38.30 a	37.60 a	19.24 a
M. fruit stem 1	0.97 b	0.19 b	1.85 b	0.06 b	30.10 b	0.22 b	0.12 b	8.10 b	4.30 b	110.40 a	4.43 b
P-value	<0.0001	<0.0001	0.0158	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0845	<0.0001
M. inflorescence	2.89 a	0.38 a	2.36 a	0.37 a	57.50 a	0.59 a	0.27 a	48.90 a	31.30 a	58.90 b	15.03 a
M. fruit stem 2	1.57 b	0.29 b	1.75 b	0.07 b	19.00 b	0.20 b	0.20 b	8.50 b	5.40 b	69.20 a	3.01 b
P-value	<0.0001	0.0123	0.0039	<0.0001	<0.0001	<0.0001	0.0016	<0.0001	<0.0001	0.0426	<0.0001
M. leaf	1.85 a	0.10 a	0.88 b	0.46 a	32.80 a	1.71 a	0.82 a	37.60 a	83.60 a	69.90 a	5.96 a
Y. fruit stem	0.57 b	0.08 b	1.43 a	0.04 b	19.00 b	0.18 b	0.07 b	6.50 b	3.50 b	21.50 b	2.86 b
P-value	<0.0001	0.0461	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
						Pauma Valley					
Y. inflorescence	3.11 a	0.49 a	1.81	0.29 a	45.30 a	0.55 a	0.23 a	48.90 a	38.50 a	67.00	10.08 a
M. fruit stem 1	1.71 b	0.33 b	1.81	0.07 b	20.20 b	0.20 b	0.11 b	9.50 b	3.60 b	62.40	1.81 b
P-value	<0.0001	0.0007	0.9824	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.3547	<0.0001
M. inflorescence	2.60	0.42	2.04 a	0.30 a	56.80 a	0.52 a	0.26	47.00 a	30.90 a	90.70	9.94 a
M. fruit stem 2	2.88	0.49	1.55 b	0.09 b	16.30 b	0.17 b	0.23	13.80 b	5.70 b	89.60	3.66 b
P-value	0.4232	0.1618	0.0094	<0.0001	<0.0001	<0.0001	0.1784	<0.0001	<0.0001	0.917	<0.0001
M. leaf	1.86 a	0.12 b	0.69 b	0.42 a	26.60 a	2.97 a	1.03 a	41.50 a	153.10 a	128.90 a	5.04 a
Y. fruit stem	1.23 b	0.19 a	2.04 a	0.06 b	10.90 b	0.19 b	0.08 b	9.50 b	3.20 b	22.90 b	2.20 b
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z] Y. inflorescence-cauliflower stage of inflorescence development (March); M. fruit stem 1-pedicel of mature fruit (March); M. inflorescence-inflorescence at full bloom (April); M. fruit stem 2-pedicel of mature fruit (April); M. leaf-mature leaf on a spring flush, non-fruiting terminal shoot (September), the standard time for leaf analysis; Y. fruit stem-pedicel of young fruit (September).

[y] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD Test.

Table 2. Effect of N vs. NPK fertilizer rate on tissue nutrient concentrations of 'Hass' avocado trees in Santa Barbara, Calif.

Tissue[z]	N %	P %	K %	S %	B ppm	Ca %	Mg %	Zn ppm	Mn ppm	Fe ppm	Cu ppm
	BMP N July, August, November and April[y]										
Y. inflorescence	3.77 a[x]	0.60 a	2.13	0.35 a	44.25 a	0.55 a	0.33 a	62.75 a	161.13 a	63.00 a	27.69 a
M. fruit stem 1	1.37 b	0.22 b	1.83	0.07 b	18.75 b	0.22 b	0.14 b	7.38 b	20.50 b	51.88 b	2.41 b
P-value	<0.0001	<0.0001	0.2368	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0014	0.0307	<0.0001
M. inflorescence	3.01 a	0.46 a	1.84	0.31 a	43.13 a	0.51 a	0.32 a	43.13 a	140.25 a	105.75 a	19.40 a
M. fruit stem 2	1.60 b	0.28 b	1.87	0.08 b	18.75 b	0.22 b	0.16 b	8.50 b	29.75 b	58.75 b	3.23 b
P-value	<0.0001	<0.0001	0.8978	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.0093	<0.0001	<0.0001
M. leaf	1.91 a	0.12 a	0.73	0.31 a	17.38 a	1.38 a	0.71 a	18.13 a	240.25 a	70.50 a	5.70 a
Y. fruit stem	0.59 b	0.08 b	1.04	0.04 b	13.00 a	0.18 b	0.08 b	5.20 b	11.60 b	29.40 b	2.48 b
P-value	<0.0001	<0.0001	0.176	<0.0001	0.0663	<0.0001	<0.0001	0.0012	0.0106	0.0007	<0.0001
	BMP NPK July, August, November and April										
Y. inflorescence	3.65 a	0.58 a	2.16 a	0.34 a	49.38 a	0.56 a	0.29 a	59.25 a	142.88 a	60.25 a	25.46 a
M. fruit stem 1	1.20 b	0.19 b	1.61 b	0.07 b	21.13 b	0.23 b	0.14 b	7.13 b	20.25 b	50.50 b	2.51 b
P-value	<0.0001	<0.0001	0.0305	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0055	0.0257	<0.0001
M. inflorescence	2.87 a	0.45 a	1.95 a	0.30 a	47.13 a	0.48 a	0.28 a	39.63 a	107.00 a	103.38 a	18.14 a
M. fruit stem 2	1.36 b	0.28 b	1.46 b	0.07 b	17.88 b	0.22 b	0.16 b	7.38 b	25.38 b	55.75 b	2.75 b
P-value	<0.0001	0.0017	0.0126	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.0075	<0.0001	<0.0001
M. leaf	1.72 a	0.11	0.62 b	0.32 a	16.75	1.42 a	0.71 a	16.25 a	252.00 a	74.50 a	5.16 a
Y. fruit stem	0.57 b	0.10	1.37 a	0.04 b	15.25	0.17 b	0.07 b	6.00 b	7.00 b	23.50 b	2.93 b
P-value	<0.0001	0.6	<0.0001	<0.0001	0.3959	<0.0001	<0.0001	<0.0001	0.0121	<0.0001	0.0057
	0.5x N July + August										
Y. inflorescence	3.74 a	0.60 a	2.20 a	0.36 a	44.00 a	0.53 a	0.32 a	59.50 a	156.00 a	64.38 a	25.96 a
M. fruit stem 1	1.41 b	0.21 b	1.62 b	0.07 b	20.13 b	0.24 b	0.14 b	7.25 b	27.88 b	51.75 b	2.65 b
P-value	<0.0001	<0.0001	0.0041	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	0.0088	<0.0001

M. inflorescence	2.87 a	0.45 a	1.91	0.30 a	44.00 a	0.49 a	0.29 a	40.00 a	138.50 a	100.50 a	18.04 a
M. fruit stem 2	1.51 b	0.25 b	1.77	0.08 b	16.38 b	0.24 b	0.15 b	8.13 b	25.00 b	55.25 b	3.26 b
P-value	<0.0001	<0.0001	0.5153	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
M. leaf	1.85 a	0.11 a	0.67 b	0.29 a	17.00 a	1.38 a	0.74 a	15.88 a	208.75 a	78.50 a	5.58 a
Y. fruit stem	0.60 b	0.08 b	1.20 a	0.04 b	12.88 b	0.16 b	0.08 b	5.00 b	10.00 b	25.38 b	2.29 b
P-value	<0.0001	<0.0001	0.0025	<0.0001	0.0021	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
0.5x NPK July + August											
Y. inflorescence	3.82 a	0.61 a	2.25 a	0.35 a	52.38 a	0.64 a	0.31 a	61.25 a	194.75 a	62.50 a	27.26 a
M. fruit stem 1	1.23 b	0.22 b	1.72 b	0.07 b	23.75 b	0.24 b	0.13 b	7.00 b	25.13 b	47.25 b	2.46 b
P-value	<0.0001	<0.0001	0.0444	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0033	0.0007	<0.0001
M. inflorescence	2.90 a	0.47 a	1.97	0.31 a	44.63 a	0.51 a	0.29 a	41.63 a	126.88 a	104.50 a	19.08 a
M. fruit stem 2	1.55 b	0.30 b	1.74	0.07 b	21.38 b	0.23 b	0.15 b	7.38 b	27.38 b	54.00 b	2.76 b
P-value	<0.0001	0.0039	0.3576	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0008	<0.0001	<0.0001
M. leaf	1.76 a	0.11 a	0.73 b	0.31 a	18.25	1.48 a	0.66 a	16.50 a	187.50 a	73.88 a	5.73 a
Y. fruit stem	0.58 b	0.09 b	1.28 a	0.04 b	14.00	0.18 b	0.07 b	5.25 b	11.50 b	26.75 b	2.38 b
P-value	<0.0001	0.0002	0.0007	<0.0001	0.155	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001

[z] Y. inflorescence-cauliflower stage of inflorescence development (March); M. fruit stem 1-pedicel of mature fruit (March); M. inflorescence-inflorescence at full bloom (April); M. fruit stem 2-pedicel of mature fruit (April); M. leaf-mature leaf on a spring flush, non-fruiting terminal shoot (September), the standard time for leaf analysis; Y. fruit stem-pedicel of young fruit (September).

[y] BMP N (25 lb N/acre in July, Aug., Nov. and Apr.; 100 lb N/acre/yr), BMP NPK (25 lb N, 3.75 lb P, 22.5 lb K in July, Aug., Nov. and Apr.; 100 lb N, 15 lb P, 90 lb K/acre/yr), 0.5x N (25 lb N/acre in July and Aug.; 50 lb N/acre/yr), 0.5x NPK (25 lb N, 3.75 lb P, 22.5 lb K in July and Aug.; 50 lb N, 7.5 lb P, 45 lb K/acre/yr).

[x] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD Test.

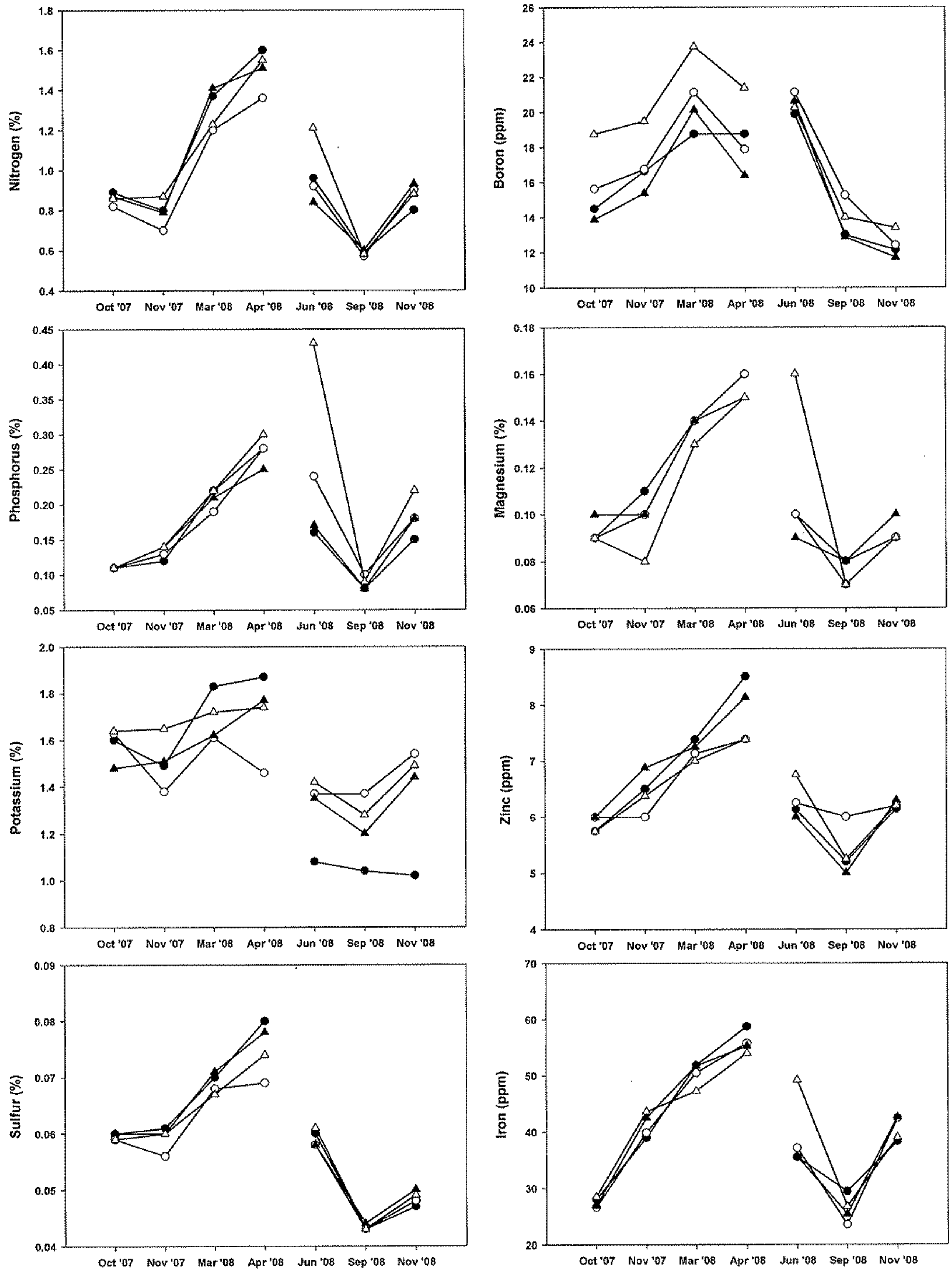

Fig. 1. Nutrient concentrations of pedicels of young fruit (Oct., Nov., June, Sept.) and mature fruit (Mar., Apr.) from 'Hass' avocado trees in Santa Barbara, Calif., receiving soil-applied fertilizer: BMP N (-●-) (25 lb N in July, Aug., Nov. and Apr. /acre/yr); BMP NPK (-○-) (25 lb N, 3.75 lb P, 22.5 lb K in July, Aug., Nov. and Apr./acre/yr); 0.5x N (-▲-) (25 lb N in July and Aug./acre/yr); 0.5x NPK (-Δ-) (25 lb N, 3.75 lb P, 22.5 lb K in July and Aug./acre/yr).

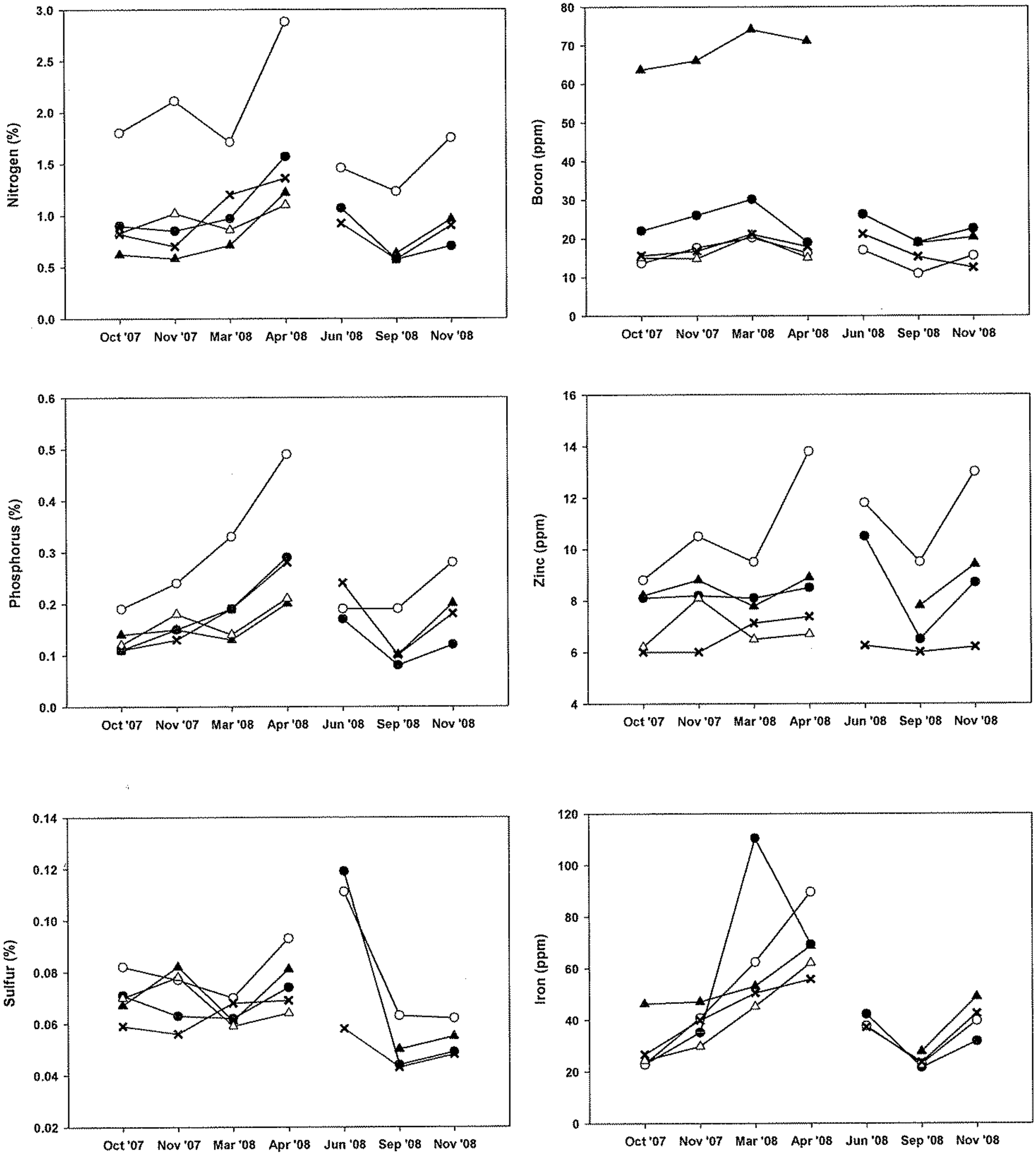

Fig. 2. Nutrient concentrations of pedicels of young fruit (Oct., Nov., June, Sept.) and mature fruit (Mar., Apr.) from 'Hass' avocado trees in Irvine (-●-), Pauma Valley (-○-), Santa Paula (-▲-), San Luis Obispo (-Δ-), and Santa Barbara (-**X**-) in the BMP NPK treatment (25 lb N, 3.75 lb P, 22.5 lb K July, Aug., Nov. and Apr./acre/yr).

APPENDIX I

Table 1. Macronutrient and micronutrient concentrations of 'Hass' avocado leaves collected in September in Irvine, Pauma Valley, Santa Barbara, Santa Paula (2 sites) and San Luis Obispo, Calif.

Site	Sample date	N %	P %	K %	S %	B ppm	Ca %	Mg %	Zn ppm	Mn ppm	Fe ppm	Cu ppm
Irvine	Sep 07	1.73 d[z]	0.10 e	0.84 bcd	0.49 b	31.90 bcd	1.93 c	0.77 bc	30.20 bc	73.50 de	82.40 b	5.31 c
Pauma Valley	Sep 07	2.17 a	0.15 a	0.77 bcd	0.43 b	24.50 de	2.25 b	0.81 b	40.30 a	114.80 cd	88.40 b	6.86 a
Santa Barbara	Sep 07	1.86 cd	0.13 bc	0.69 d	0.32 cd	14.88 f	1.14 e	0.68 cd	16.13 d	191.25 ab	67.13 b	5.60 bc
Santa Paula (1)	Sep 07	1.90 bc	0.13 abc	1.99 a	0.62 a	65.10 a	1.66 cd	0.52 e	44.20 a	40.00 e	88.20 b	6.68 ab
San Luis Obispo	Sep 07	2.04 ab	0.15 a	0.91 b	0.44 b	17.70 ef	1.90 c	0.97 a	22.70 cd	41.50 e	66.80 b	5.32 c
Irvine	Sept 08	1.85 cd	0.10 de	0.88 bc	0.46 b	32.80 bc	1.71 c	0.82 b	37.60 ab	83.60 de	69.90 b	5.96 abc
Pauma Valley	Sept 08	1.86 cd	0.12 bc	0.69 d	0.42 bc	26.60 cd	2.97 a	1.03 a	41.50 a	153.10 bc	128.90 a	5.04 c
Santa Barbara	Sept 08	1.91 bc	0.12 cd	0.73 cd	0.31 d	17.38 ef	1.38 de	0.71 bcd	18.13 d	240.25 a	70.50 b	5.70 bc
Santa Paula (2)	Sept 08	2.07 ab	0.14 ab	0.87 bc	0.51 b	35.50 b	1.76 c	0.64 d	40.90 a	49.70 e	85.10 b	4.81 c
P-value		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.005

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD Test.

Table 2A. Macronutrient concentrations of 'Hass' avocado pedicels collected in Irvine, Pauma Valley, Santa Barbara, Santa Paula (2 sites) and San Luis Obispo, Calif.

Site	Sample date	N %	P %	K %	S %	Ca %	Mg %
Irvine	Sep 07	0.90 hijklm[z]	0.11 mno	1.97 bcde	0.07 cdef	0.22 defg	0.10 jklmno
Pauma Valley	Sep 07	1.80 bc	0.19 efghij	1.97 bcde	0.08 bc	0.21 efgh	0.10 jklmno
Santa Barbara	Sep 07	0.89 hijklm	0.11 mno	1.60 fghij	0.06 fghi	0.18 hij	0.09 klmnop
Santa Paula (1)	Sep 07	0.62 lm	0.14 hijklmno	2.19 abc	0.07 defg	0.22 defg	0.07 pq
San Luis Obispo	Sep 07	0.83 jklm	0.12 lmno	1.60 fghij	0.07 cdef	0.21 efgh	0.13 efg
Irivine	Nov 07	0.85 jklm	0.15 ghijklmn	1.89 bcdefg	0.06 efg	0.23 def	0.10 ijklmn
Pauma Valley	Nov 07	2.11 b	0.24 cde	1.62 efghij	0.08 cd	0.22 defg	0.13 fghi
Santa Barbara	Nov 07	0.80 jklm	0.12 klmno	1.49 hij	0.06 fghi	0.22 defg	0.11 hijklm
San Luis Obispo	Nov 07	1.02 ghijk	0.18 fghijkl	1.71 defghij	0.08 cd	0.23 de	0.18 cd
Santa Paula (1)	Nov 07	0.58 m	0.15 ghijklmno	2.36 a	0.08 bc	0.28 bc	0.09 klmnop
Irvine	Mar 08	0.97 hijkl	0.19 efghijk	1.85 cdefgh	0.06 efgh	0.22 defg	0.12 fghijkl
Pauma Valley	Mar 08	1.71 cd	0.33 b	1.81 defghi	0.07 cdef	0.20 fghij	0.11 ghijklm
Santa Barbara	Mar 08	1.37 defg	0.22 def	1.83 defghi	0.07 cdef	0.22 efg	0.14 ef
San Luis Obispo	Mar 08	0.86 ijklm	0.14 ijklmno	1.56 ghij	0.06 fghij	0.25 cd	0.17 cd
Santa Paula (1)	Mar 08	0.71 klm	0.13 jklmno	2.06 abcd	0.06 fghi	0.31 ab	0.07 nopq
Irvine	Apr 08	1.57 cde	0.29 bc	1.75 defghij	0.07 cde	0.20 efghi	0.20 bc
Pauma Valley	Apr 08	2.88 a	0.49 a	1.55 ghij	0.09 b	0.17 j	0.23 a
Santa Barbara	Apr 08	1.60 cd	0.28 bcd	1.87 cdefg	0.08 c	0.22 efg	0.16 de
San Luis Obispo	Apr 08	1.10 fghij	0.21 efg	1.90 bcdefg	0.06 efg	0.26 c	0.22 ab
Santa Paula (1)	Apr 08	1.22 efghi	0.20 efgh	2.25 ab	0.08 c	0.34 a	0.12 fghijk
Irvine	Jun 08	1.07 ghijk	0.17 fghijklm	1.91 bcdefg	0.12 a	0.21 efgh	0.13 fgh
Pauma Valley	Jun 08	1.46 cdef	0.19 efghij	1.92 bcdef	0.11 a	0.21 efgh	0.11 ghijklm
Santa Barbara	Jun 08	0.96 hijkl	0.16 fghijklmn	1.08 kl	0.06 fghi	0.20 efghi	0.10 ijklmn
Irvine	Sep 08	0.57 m	0.08 o	1.43 jk	0.04 k	0.18 hij	0.07 opq
Pauma Valley	Sep 08	1.23 efgh	0.19 efghij	2.04 abcd	0.06 efg	0.19 ghij	0.08 mnopq
Santa Barbara	Sep 08	0.59 m	0.08 o	1.04 l	0.04 k	0.18 ij	0.08 mnopq
Santa Paula (2)	Sep 08	0.63 lm	0.10 no	1.07 kl	0.05 hijk	0.21 efghi	0.06 q
Irvine	Nov 08	0.70 klm	0.12 lmno	1.70 defghij	0.05 ijk	0.22 defg	0.09 lmnop
Pauma Valley	Nov 08	1.75 bc	0.28 bcd	1.77 defghij	0.06 efgh	0.23 def	0.12 fghij
Santa Barbara	Nov 08	0.80 jklm	0.15 fghijklmn	1.02 l	0.05 jk	0.18 ij	0.09 klmnop
Santa Paula (2)	Nov 08	0.96 hijkl	0.20 efghi	1.47 ij	0.05 ghijk	0.22 efg	0.08 mnopq
P-value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD Test.

Table 2B. Micronutrient concentrations of 'Hass' avocado pedicels collected in Irvine, Pauma Valley, Santa Barbara, Santa Paula (2 sites) and San Luis Obispo, Calif.

Site	Sample date	Zn ppm	Mn ppm	Fe ppm	Cu ppm	B ppm
Irvine	Sep 07	8.10 efg[z]	5.20 fg	22.70 kl	2.62 efghijk	22.00 def
Pauma Valley	Sep 07	8.80 def	5.00 fg	22.80 kl	1.93 jk	13.60 jkl
Santa Barbara	Sep 07	5.75 ij	12.88 cd	28.00 ijkl	2.41 ghijk	14.50 ijkl
Santa Paula (1)	Sep 07	8.20 efg	4.00 g	46.20 cdefghij	4.35 abc	63.60 b
San Luis Obispo	Sep 07	6.20 hij	4.20 g	24.30 jkl	2.81 efghijk	15.00 ijkl
Irivine	Nov 07	8.20 efg	4.70 fg	35.20 ghijkl	2.97 efghij	26.00 cd
Pauma Valley	Nov 07	10.50 cd	4.60 g	40.70 defghijkl	2.67 efghijk	17.60 fghij
Santa Barbara	Nov 07	6.50 ghij	13.63 cd	39.00 efghijkl	2.64 efghijk	16.63 ghijk
San Luis Obispo	Nov 07	8.10 efg	4.30 g	29.80 hijkl	3.57 cdef	14.80 ijkl
Santa Paula (1)	Nov 07	8.80 def	3.90 g	47.00 cdefghij	5.39 a	66.00 b
Irvine	Mar 08	8.10 efg	4.30 g	110.40 a	4.43 abc	30.10 c
Pauma Valley	Mar 08	9.50 de	3.60 g	62.40 cd	1.81 k	20.20 efgh
Santa Barbara	Mar 08	7.38 fghi	20.50 b	51.88 cdefgh	2.41 ghijk	18.75 efghi
San Luis Obispo	Mar 08	6.50 ghij	3.30 g	45.20 defghijk	4.21 bcd	20.80 efg
Santa Paula (1)	Mar 08	7.78 efgh	3.44 g	53.11 cdefg	3.43 cdefg	74.11 a
Irvine	Apr 08	8.50 ef	5.40 fg	69.20 bc	3.01 efghij	19.00 efghi
Pauma Valley	Apr 08	13.80 a	5.70 fg	89.60 ab	3.66 cde	16.30 ghijk
Santa Barbara	Apr 08	8.50 ef	29.75 a	58.75 cdef	3.23 defghi	18.75 efghi
San Luis Obispo	Apr 08	6.70 ghij	3.70 g	62.10 cde	4.43 abc	15.00 ijkl
Santa Paula (1)	Apr 08	8.90 def	4.10 g	68.70 bc	4.98 ab	71.10 a
Irvine	Jun 08	10.50 cd	7.50 efg	42.20 defghijkl	3.59 cdef	26.20 cd
Pauma Valley	Jun 08	11.80 bc	9.20 def	37.60 fghijkl	2.14 ijk	17.00 ghij
Santa Barbara	Jun 08	6.13 hij	14.38 c	35.50 ghijkl	3.03 efghij	19.88 efgh
Irvine	Sep 08	6.50 ghij	3.50 g	21.50 l	2.86 efghijk	19.00 efghi
Pauma Valley	Sep 08	9.50 de	3.20 g	22.90 kl	2.20 hijk	10.90 l
Santa Barbara	Sep 08	5.20 j	11.60 cde	29.40 hijkl	2.48 fghijk	13.00 jkl
Santa Paula (2)	Sep 08	7.80 efgh	3.10 g	27.70 ijkl	1.75 k	18.80 efghi
Irvine	Nov 08	8.70 ef	4.60 g	31.70 ghijkl	2.85 efghijk	22.50 de
Pauma Valley	Nov 08	13.00 ab	3.60 g	39.60 defghijkl	3.44 cdefg	15.50 hijkl
Santa Barbara	Nov 08	6.14 hij	14.00 c	38.29 fghijkl	3.31 cdefgh	12.14 kl
Santa Paula (2)	Nov 08	9.40 de	3.70 g	48.90 cdefghi	2.74 efghijk	20.30 efg
P-value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD Test.

Table 3. Macronutrient and micronutrient concentrations of 'Hass' avocado inflorescences collected at the cauliflower stage and at full bloom in Irvine, Pauma Valley, Santa Barbara, Santa Paula (1) and San Luis Obispo, Calif. in the months of March and April, respectively.

Site	N %	P %	K %	S %	B ppm	Ca %	Mg %	Zn ppm	Mn ppm	Fe ppm	Cu ppm
					Cauliflower inflorescence						
Irvine	3.35 b[z]	0.52 b	2.17 b	0.35 a	54.00 b	0.60 b	0.24 c	56.30 b	38.30 b	37.60 c	19.24 c
Pauma Valley	3.11 c	0.49 bc	1.81 d	0.29 b	45.30 b	0.55 b	0.23 c	48.90 d	38.50 b	67.00 a	10.08 d
Santa Barbara	3.77 a	0.60 a	2.13 b	0.35 a	44.25 b	0.55 b	0.33 b	62.75 a	161.13 a	63.00 a	27.69 a
Santa Paula (1)	3.32 b	0.50 bc	2.35 a	0.33 a	143.20 a	0.77 a	0.23 c	54.80 bc	27.50 b	53.00 b	25.57 ab
San Luis Obispo	2.78 d	0.47 c	1.96 c	0.33 a	44.40 b	0.79 a	0.37 a	51.40 cd	18.50 b	49.40 b	22.87 b
P-value	<.0001	<.0001	<.0001	0.0006	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
					Full bloom inflorescence						
Irvine	2.89 a	0.38 b	2.36 b	0.37 a	57.50 b	0.59 b	0.27 bc	48.90 a	31.30 b	58.90 c	15.03 b
Pauma Valley	2.60 b	0.42 ab	2.04 c	0.30 b	56.80 b	0.52 c	0.26 cd	47.00 a	30.90 b	90.70 ab	9.94 c
Santa Barbara	3.01 a	0.46 a	1.84 c	0.31 b	43.13 c	0.51 c	0.32 b	43.13 ab	140.25 a	105.75 a	19.40 a
Santa Paula (1)	2.25 c	0.41 b	2.64 a	0.31 b	116.40 a	0.62 b	0.21 d	38.70 bc	17.60 b	82.90 b	16.53 ab
San Luis Obispo	2.14 c	0.41 b	2.01 c	0.30 b	41.30 c	0.71 a	0.38 a	36.80 c	16.10 b	63.30 c	15.38 b
P-value	<.0001	0.0166	<.0001	0.0046	<.0001	<.0001	<.0001	0.0004	<.0001	<.0001	0.0001

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD Test.