FINAL REPORT

UREA COMBINED WITH 6-BENZYLADENINE TO REDUCE ALTERNATE BEARING IN PISTACHIO AND TO INCREASE CUMULATIVE YIELD

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SUMMARY

Alternate bearing results from the excessive abscission of floral buds for next year's crop during the on (heavy crop) year. We successfully increased bud retention in pistachio (Pistacia vera L., cv. Kerman) approximately three-fold and two-fold for two successive years, respectively, on branches bearing >70 nuts per cluster basal to the shoot bearing the buds for next year's crop by use of foliar applications of 0.25% N as urea combined with 25 mg/L 6-benzyladenine (a cytokinin; Accel®, Valent BioScience) applied in early June and again in early July. Based on the results of the two successive branch studies, we established a field experiment at S&J Ranch to test the efficacy of applying nitrogen combined with a cytokinin to the foliage of pistachio trees during the on-year to increase yield the following off-year. The best treatment thus far is two foliar applications of 6.28 lbs. N as low-biuret urea combined with 28 g 6-benzyladenine (Accel®, Valent BioScience) made in early June and again in early July. This treatment has been used for five consecutive years beginning with an on-year. The first crop was harvested the following year. The untreated control trees produced the anticipated off-year crop – 7.0 kg fruit (fresh weight)/tree – which yielded 2.7 kg split nuts (dry weight) per tree. Trees treated with 0.25% N as urea combined with 25 mg/L 6-benzlyadenine June 1 and July 1 yielded 16.9 kg fruit/tree, yielding 5.9 kg split nuts (dry weight) per tree. The yield increase in kg fruit (fresh weight)/tree was significant at *P*=0.04 and in kg split nuts (dry weight)/tree at *P*=0.10. The following year was an on-year again. Foliar application of low-biuret urea combined with the 6-benzyladenine significantly increased yield to 52.5 kg fruit (fresh weight)/tree compared to 37.5 for the untreated control trees (*P*=0.02). This treatment also significantly increased kg split nuts (dry weight)/tree to 21.8 compared to 16.9 for the control (*P*=0.003). The foliar application of urea combined with 6-benzyladenine did not significantly increase yield the following year but was the best treatment numerically, yielding 6.8 kg fruit (fresh weight)/tree and 2.9 kg split nuts (dry weight)/tree compared to 2.7 kg fruit (fresh weight)/tree and 1.1 kg split nuts (dry weight)/tree for the control trees. The final year of the study was an on-year. The foliar application of urea combined with 6-benzyladenine did not significantly increase yield. Treated trees yielded 70.9 kg fruit (fresh wt)/tree and 30.6 kg split nuts (dry wt)/tree compared to control trees at 68.7 kg fruit (fresh wt)/tree and 28.7 kg split nuts (dry wt)/tree. For all years of the study, the split nuts from treated trees had higher nut fresh and dry weight than the control (nonsignificant). There was no significant effect on the number of stained, nonsplit, aborted, or blank nuts. Foliar application of low-biuret urea combined with 6-benzyladenine in early June and again in early July significantly increased cumulative yield for the five years of the study by 2.4 additional US tons split nuts (dry weight)/acre (based on 128 trees per acre) than the untreated control.

During the course of this study, we initiated additional research: (1) to reduce the gallons per acre from 300 to 100; and (2) to test the efficacy of biostimulant cytokinins or other treatments to increase bud retention in the on-year to increase yield in the off-year since 6-benzyladenine is not yet registered for use on pistachio. In a separate project, we are collecting data essential for registration of 6-benzyladenine for use on pistachio.

We determined that 12.5 lbs. N as urea/100 gallons water/acre or 23.4 lbs. N as urea per 200 or 300 gallons water/acre when combined with 27 g 6-benzyladenine is phytotoxic and ineffective in increasing yield of split nuts (dry wt). However, 24.84 lbs. N as urea combined with 2 qts. Binary CQ/200 gallons water/acre resulted in minimal leaf damage. This treatment replaced Accel®, which was used in 1998 (an on-year), in 1999 and has been applied every year through 2001 at our experiment in Kettleman. The treatment has tended to increase yield each year. In 1999, we harvested the first off-year crop. Control trees yielded 4.9 kg split nuts (dry wt)/tree. Treated trees yielded 12.1 kg split nuts (dry wt)/tree. This was a 2.5-fold increase in yield. However, it was not significant at $P \leq 0.05$ and we have not been able to achieve this level of increase in subsequent off-years with Binary CQ. There is no significant difference in the 4-year cumulative yield between treated and control trees. The results suggested that the treatment should be made only in the on-year. Thus, in the subsequent research with this product that is the case.

In separate orchards belonging to Brian Blackwell in Bakersfield and Paramount Farming in Lost Hills, respectively, we have been testing a total of 15 strategies involving five different biostimulant cytokinins in order to develop a cost-effective strategy that growers can use in place of Accel® or until Accel® becomes registered. We are also testing the use of slow-release nitrogen compounds and other fertilizers as foliar sprays to see if we can provide N without phytotoxicity. Treatments were initiated in the on-year and applied only in the on-year. For both sites the anticipated off-year had a yield equal to or greater than the initial on-year. No significant treatment effects were obtained in either year in either orchard.

INTRODUCTION

The production of alternating heavy versus light pistachio (Pistacia vera L., cv. Kerman) crops is a problem of increasing significance in California. The excessive abscission of floral buds beginning in June and intensifying at the time of seed growth (nut fill) in July during the on-year results in the next year's off-year crop. While the unique mechanism leading to alternate bearing in pistachio has been identified, its physiological basis has not. There is convincing evidence that the floral buds fail to compete successfully against the developing nuts for available carbohydrates, and thus abscise (Crane and Nelson, 1971; Crane and Nelson, 1972; Crane et al., 1973; Weinbaum et al., 1994). However, Crane et al. (1976) provided results that were inconsistent with the tenet that carbohydrate is limiting during an on-year (Crane et al., 1973) but left open the possible mechanism of a leaf-produced "anti-abscission" hormone and/or fruit-produced "abscission-promoting" hormone (Crane et al., 1973). Weinbaum et al. (1994a, b) have provided evidence that in on-years there is a strong reproductive demand for nitrogen, significant removal of nitrogen in the fruit at harvest, reduced storage of nitrogen, reduced recovery of January-applied ^{15}N fertilizer, and greater root nitrate concentrations (the latter possibly due to greater uptake or reduced assimilation and transport to other parts of the tree). It is of interest to note that these authors reported the greatest decrease in leaflet nitrogen concentration and total leaflet nitrogen content per tree during the period from preseed fill (early July) to fruit maturation (early Sept.) and that nitrogen removed by the harvest of mature fruit plus the loss of senescent leaflets was 1.0 kg N per tree during an on-year versus only 0.2 kg N per tree in an off-year. Frequently, leaflets at the base of clusters show early senescence in on-years (L. Ferguson, personal communication). Premature senescence, which can be due to nitrogen deficiency, would cause a further loss in photosynthesis, carbohydrate availability, and leaf-produced hormones, as well as essential soluble nitrogen compounds.

During the first year of our research, we tested two possibilities: (i) that the floral buds abscise due to a failure to compete successfully for nitrogen during nut fill (June-July) or (ii) that floral bud abscission is hormonally induced in response to an "abscission-promoting" hormone exported from the nuts and/or the loss of a leaf "anti-abscission" hormone due to early leaf senescence in an on-year. Thus, we attempted to increase floral bud retention with canopy applications of low-biuret urea and/or 6-benzyladenine, a cytokinin, to supply extra nitrogen during the critical period of nut fill, to increase floral bud "sink strength" and their ability to compete, to prevent leaf senescence, to counter the effect of an "abscission-promoting" hormone exported from the nuts, and to compensate for the loss of a leaf "anti-abscission" hormone.

The results of our first year of research provided evidence that excessive abscission of floral buds during early nut development (June–July) in an on-year is hormonally induced: (*i*) during early development nuts exported the "abscission-promoting" hormone abscisic acid (ABA); (*ii*) floral bud ABA concentrations increased approximately 25%; and (*iii*) floral bud concentrations of the cytokinins isopentyladenine and zeatin riboside decreased 40% during the period of intensive floral bud abscission. The lower cytokinin content would likely cause reduced "sink strength" and ability to compete. Consistent with these results, the combination of low-biuret urea and 6-benzyladenine applied to the foliage at the beginning of this period (June 1) and half-way through it (July 1) successfully increased leaf concentrations of isopentyladenine (50%) and the retention of floral buds more than three-fold in year one and more than two-fold in year two on trees bearing a heavy on-crop. Thus, this treatment was tested in a commercial orchard to determine if it might provide a practical field management strategy for increasing yield in the year following an on-year.

PROCEDURES

At S&J Ranch in Madera (Phil Pierre), a second orchard in Kettleman (Paul Coutreau), a third in Bakersfield (Brian Blackwell), and a fourth in Lost Hills (Paramount Farming) the treatments listed below were replicated in a randomized complete block design. The treatments are applied with a commercial sprayer at Kettleman and Bakersfield to a block of 10 data trees, respectively, with a minimum of 14 replications. At S&J and Lost Hills there were 16 and 20 individual tree replicates per treatment, respectively. Treatments were applied with a hand-gun sprayer at 400 psi. Treatments are as follows and started when the trees were carrying the on-crop and are only applied during the on-year, with the exception of the orchard in Bakersfield for which the putative off-year was an on-year. In this orchard we treated both years.

S&J Ranch (Pierre): Treatment 1 was the control; Treatment 2 was 0.25% N as urea (Unocal Plus, <0.1% biuret) in combination with 25 ppm 6-benzyladenine (25 mg BA/L) applied to the foliage June 1 and July 1 in the on-year or applied May 1, June 1 and July 1 in the on-year for

Treatment 3; Treatment 4 was 0.25% N as urea in combination with 50 ppm BA applied to the foliage May 1, June 1 and July 1 in the on-year; Treatment 5 was 0.25% N as urea plus HM9305 at 1 quart/100 trees/acre; and Treatment 6 was HM9305 at 1 quart/100 trees/acre with Bayfolan at 2 quarts/100 trees/acre. All applications were in 11.4 L of water, which was sufficient to provide full canopy coverage to the point of run-off. Starting with the second on-year crop treatment 5, the proprietary material HM9305, was applied at 2 quarts/100 trees/acre without urea and treatment 6, a new proprietary material HM9808, was applied at 1 quart/100 trees/acre without urea or Bayfolan.

Kettleman (Couture): (1) untreated control and (2) 24.84 lbs. N as low-biuret urea combined with Binary CQ (2 qts./100 trees) applied in early June and again in early July in 200 gallons water per acre.

Bakersfield (Blackwell): All treatments were applied in early June and again in early July in 100 gallons of water/acre – (1) Binary CQ, 4 qts./acre plus 6.28 lbs. N/acre as low biuret urea; (2) Binary CQ, 2 qts./acre plus Coron (28-0-0) to supply 6.28 lbs. N/acre; (3) Binary CQ, 4 qts./acre plus Coron (28-0-0) to supply 6.28 lbs. N/acre; (4) Binary 2, 2 qts./acre plus Coron (28-0-0) to supply 6.28 lbs. N/acre; and (5) untreated control.

Lost Hills (Paramount Farming): All treatments were applied in early June and again in early July in 100 gallons of water/acre – (1) Miller Cytokin at 16 oz./acre plus 6.28 lbs. N/acre as low biuret urea; (2) Miller Cytokin at 32 oz./acre plus 6.28 lbs. N/acre as low biuret urea; (3) Miller Cytokin according to manufacturer's instructions; (4) Ohrstrom Maxicrop at 1 lb./acre plus 6.28 lbs. N/acre as low biuret urea; (5) Ohrstrom Kerry at 1 lb./acre plus 6.28 lbs. N/acre as low biuret urea; (6) Ohrstrom Kerry at 32 oz./acre plus 6.28 lbs. N/acre as low biuret urea; (7) Growth Products Nitro-30 (30-0-0) at 3 qts./acre plus Essential at 1 qt./acre; (8) Growth products Nitro+K (22-0-16) at 2 qts./acre plus Essential at 1 qt./acre; (9) untreated control and (10) 6.28 lbs. N/acre as low biuret urea.

Yield was determined at the time of commercial harvest. Commercial shaking and catching equipment was used to harvest the plots. Yield (kg fruit/tree) was determined in the field using portable bin scales. Subsamples (100 nuts/tree) were collected, and nut quality was analyzed for blank nuts (no evidence of embryo growth), aborted nuts (terminated embryo growth), unsplit nuts, split nuts, and fresh and dry weights of nut components (hulls, shells and kernels).

RESULTS AND DISCUSSION

We now have five years of yield data from the research at S&J Ranch testing the effectiveness of treatments to prevent floral bud abscission. The 5-year cumulative yield was significantly higher for trees treated with urea (0.25%) combined with 6-benzyladenine (25 mg/L) in June and July than control trees (Table 1). Thus, foliar application of 6.25 lbs. N (0.25% N) as urea combined with 28 g 6-benzyladenine (Accel®)/300 gallons water/100 trees/acre in early June and again in early July resulted in a net increase 2.4 US tons split nuts (dry weight)/ acre (based on 128 trees/acre) compared to the control trees. There was an increase in cumulative yield for the two off-year crops, despite applying the treatment every year. This makes it clear that the treatment is having an effect. We think we can further increase yield in the off-year by treating only in the on-year. This concluded our research at S&J Ranch, whom we would like to thank immensely for their generous cooperation.

In collaboration with Brian Blackwell, we tested the efficacy of applying the treatment in 100 gallons of water per acre. Thanks to Brain Blackwell, we have been able to determine N concentrations that cause phytotoxicity when applied with 27 g 6-benzyladenine: 12.5 lbs. N as urea/100 gallons water/acre or 23.39 lbs. N as urea/200 or 300 gallons water/acre (Table 2).

Alternatives to Accel®. Since Accel® presently is not registered for use on pistachios, we tested three different biostimulant cytokinins from Helena Chemical that do not require registration. The best one has been released as Binary CQ. The new formulation of this product requires 2qt./100 trees/acre.

Binary CQ (2 qts.) plus 24.84 lbs. N as urea/200 gallons water/acre applied in early June and again in early July is being tested in an orchard belonging to Paul Couture in Kettleman (Table 3). This treatment replaced Accel®, which was used in 1998 (an on-year), in 1999 and was applied in all years through 2001. In 1999, we harvested the first off-year crop. Control trees yielded 4.9 kg spilt nuts (dry weight)/tree. Treated trees yielded 12.1 kg split nuts (dry weight)/tree. This was a 2.5-fold increase in yield. We have not achieved similar yield increases subsequently. Binary CQ tended to increase yield in both on- and off-years but not significantly at this site. The results suggest that Binary CQ should be applied only in the on-year which will be the case starting in 2001.

This year, in separate orchards belonging to Brian Blackwell in Bakersfield and Paramount Farming in Lost Hills, respectively, we initiated additional studies testing a total of 15 strategies involving five different biostimulant cytokinins in order to develop a cost-effective strategy that growers can use in place of Accel® or until Accel® becomes registered. We are also testing the use of slow-release nitrogen compounds and other fertilizers. Treatments were initiated in the on-year and applied only in the on-year. For both sites the anticipated off-year had a yield equal to or greater than the initial on-year. No significant treatment effects were obtained in either year in either orchard (Tables 4 and 5). This research needs to be repeated under conditions of alternate bearing to determine if any treatment can increase yield in an off-year.

CONCLUSION AND PRACTICAL APPLICATION

Foliar application of 6.25 lbs. N as low-biuret urea combined with 28 g 6-benzyladenine (Accel®) (Valent BioScience)/300 gallons water/100 trees/acre in early June and again in early significantly increased cumulative yield for the five years of the study and for the two off-year crops. This treatment remains significantly better than other treatments tested to date for increasing yield in the off-year. However, since 6-benzyladenine (Accel®) is not available for use on pistachios at this time, growers can try 2 qts. Binary CQ plus 6.25 lbs. N/100 gallons/100 trees/acre (pH adjusted to 5.5-6.5) applied in early June and again in early July without any phytotoxicity. We have tested this specific treatment but the orchard had two on-years in a row thus far and no significant results were obtained (Table 4). Based on one two-year bearing cycle at Couture's, it appears that increasing the nitrogen to 24.84 lbs. N as urea in 200 (or 300) gallons of water, which will cause some leaf burn, improves the effectiveness of Binary CQ in increasing yield. However, this treatment has not produced statistically significant increases in yield at this site.

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