USE OF NITROGEN AND CYTOKININ TO REDUCE ALTERNATE BEARING OF PISTACHIO (*Pistacia vera cv. Kerman*) – A Preliminary Report

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ABSTRACT

Alternate bearing in pistachio (*Pistacia vera* L., cv. Kerman) results from the excessive abscission of floral buds for next year's crop during the on (heavy crop) year. We successfully increased pistachio bud retention 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 ppm 6-benzyladenine (a cytokinin) applied in early June and again in early July. Based on the results of the two successive branch studies, we established a field experiment to test the efficacy of applying nitrogen combined with a cytokinin to the foliage of pistachio trees during the on-year increase yield the following off-year. The best treatment thus far is two foliar applications of 0.25% N as low-biuret urea combined with 25 ppm 6-benzlyadenine (Accel, a cytokinin; Abbot Laboratories) made in early June and again in early July. This treatment has been used for three 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 ppm 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 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. 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). Foliar application of low-biuret urea combined with 6-benzyladenine in early June and again in early July significantly increased cumulative yield for the two years of the alternate bearing cycle by 1.5 more tons split nuts (dry weight)/acre (based on 128 trees per acre) than the untreated control.

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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; (*ii*) floral bud ABA concentrations increased approximately 20%; 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.

The objectives of the research were (*i*) to test in a commercial pistachio orchard the efficacy of using foliar applications of urea combined with 6-benzyladenine to increase floral bud retention during the on-year and increase yield the following year; (*ii*) to determine if the results achieved in the first year could be repeated for a second year; (*iii*) to test additional application strategies, doses and cytokinin materials; and (*iv*) to determine if flower buds from treated trees are normal and capable of bearing nuts by harvesting the crop produced by these buds, which we did in year three. The yield results obtained in year three and four are, respectively, the crops produced from buds treated when the trees were carrying an on-year and off-year crop. The overall goal of the research is to reduce alternate bearing in pistachio.

MATERIALS AND METHODS

The treatments were replicated on 16 individual on-year trees. The orchard was entering an on-year and only trees with a heavy crop were used in the experiment: 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 or applied May 1, June 1 and July 1 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; 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 per tree, which was sufficient to provide full canopy coverage to the point of run-off.

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).

Experimental design was a randomized complete block design with 16 individual tree replicates. Means separation was by Duncan's multiple range test at the specified P level indicated in the tables.

RESULTS AND DISCUSSION

We now have three years of field data testing the effectiveness of treatments to prevent floral bud abscission. In year one, treatments were made when trees were producing a heavy on-year crop. The trees were harvested that same year to determine if the treatments had any positive or negative effect on the current crop. There were no statistically significant effects from any treatment on yield or percent split nuts (Table 1). In addition, there was no significant difference between the fresh weight and dry weight of the pistachio embryos or hulls from the control trees versus treated trees.

Table 1. Effect of foliar-applied urea-N and cytokinin as 6-benzyladenine on the current crop in an on-year.

Treatment (rate)[1]	Date of application	Kg fruit/tree Sept. 4	Percent split nuts
Control		59 ± 3.6	56 ± 4
0.25% N as urea[2] + 25 ppm BA[3]	June 12 + July 8	64 ± 3.8	56 ± 4
0.25% N as urea + 25 ppm BA	May 12, June 12 + July 8	55 ± 3.0	50 ± 4
0.25% N as urea + 50 ppm BA	May 12, June 12 + July 8	55 ± 5.0	49 ± 4
0.25% Urea + HM9305 (1 qt/acre)	May 12, June 12 + July 8	63 ± 4.5	63 ± 2
Bayfolan (2 qt/acre) + HM9305 (1 qt/acre)	May 12, June 12 + July 8	63 ± 6.1	57 ± 2
Significance ($P \leq 0.05$)[4]		NS	NS

[1] All treatments were applied to the point of run-off, which required 11.4 L per tree.
[2] Unocal PLUS (<0.1%) biuret); a gift from Unocal Corp.
[3] 6-Benzyladenine; a gift from Abbott Laboratories.
[4] NS = nonsignificant at $P \leq 0.05$ by ANOVA.

In year two, we harvested the crop produced by the previous year's buds to determine if we were successful in preventing bud abscission when the trees were carrying an on-year crop and in increasing yield in the off-year. Foliar application of low-biuret urea (0.25% N) combined with 6-benzyladenine (25 ppm) in early June and again in early July significantly increased yield compared to the untreated control (Table 2).

Table 2. Effect of foliar-applied urea-N and cytokinin as 6-benzyladenine applied to trees on June 1 and July 1 during the on-year on yield the subsequent year.

Treatment (rate)[1]	Date of application	kg fruit (fresh wt.)/tree	kg split nuts (dry wt.)/tree
Control		7.0 b	2.7 b
0.25% N as urea[2] + 25 ppm BA[3]	June 12 + July 8	16.9 a	5.9 a
0.25% N as urea + 25 ppm BA	May 12, June 12 + July 8	12.7 ab	4.8 ab
0.25% N as urea + 50 ppm BA	May 12, June 12 + July 8	12.2 ab	4.7 ab
0.25% Urea + HM9305 (1 qt/acre)	May 12, June 12 + July 8	11.3 ab	4.2 ab
Bayfolan (2 qt/acre) + HM9305 (1 qt/acre)	May 12, June 12 + July 8	10.1 b	3.8 ab
Significance[4]		P=0.04	P=0.10

[1] All treatments were applied to the point of run-off, which required 11.4 L per tree.
[2] Unocal PLUS (<0.1%) biuret); a gift from Unocal Corp.
[3] 6-Benzyladenine; a gift from Abbott Laboratories.
[4] Values in a vertical column followed by different letters are significantly different at the specified P level by ANOVA.

In year three, we harvested the crop produced by the previous year's buds. These were the buds produced when the tree was carrying the off-year crop. Foliar applications of urea (0.25% N) combined with 6-benzyladenine (25 ppm) made in early June and again in early July also significantly increased yield in the on-year. Other treatments which did not significantly increase yield compared to the untreated control trees in the off-year, did significantly increase yield in the on-year (Table 3).

Table 3. Effect of foliar-applied urea-N and cytokinin as 6-benzyladenine applied to trees on June 1 and July 1 during the off-year on yield the subsequent year.

Treatment (rate)[1]	Date of application	kg fruit (fresh wt.)/tree	kg split nuts (dry wt.)/tree
Control		37.5 b	16.9 c
0.25% N as urea[2] + 25 ppm BA[3]	June 12 + July 8	52.5 a	21.8 ab
0.25% N as urea + 25 ppm BA	May 12, June 12 + July 8	43.6 ab	17.9 bc
0.25% N as urea + 50 ppm BA	May 12, June 12 + July 8	49.6 a	21.5 ab
0.25% Urea + HM9305 (1 qt/acre)	May 12, June 12 + July 8	51.6 a	24.0 a
Bayfolan (2 qt/acre) + HM9305 (1 qt/acre)	May 12, June 12 + July 8	50.9 a	23.1 a
Significance[4]		P=0.02	P=0.003

[1] All treatments were applied to the point of run-off, which required 11.4 L per tree.
[2] Unocal PLUS (<0.1%) biuret); a gift from Unocal Corp.
[3] 6-Benzyladenine; a gift from Abbott Laboratories.
[4] Values in a vertical column followed by different letters are significantly different at the specified P level by ANOVA.

The two foliar applications of low-biuret urea (0.25% N) combined with 6-benzyladenine in early June and again in early July significantly increased cumulative yield as both kg fruit (fresh weight)/tree and kg split nuts (dry weight)/tree, whereas urea (0.25% N) plus HM9305 (a cytokinin) applied in early May, June and July increased only cumulative kg split nuts/tree compared to the untreated control trees (Table 4).

Table 4. Effect of foliar-applied urea-N and cytokinin as 6-benzyladenine applied to trees on June 1 and July 1 on cumulative yield.

Treatment (rate)[1]	Date of application	Cumulative kg fruit (fresh wt.)/tree	Cumulative kg split nuts (dry wt.)/tree
Control		40.3 c	17.8 c
0.25% N as urea[2] + 25 ppm BA[3]	June 12 + July 8	70.7 a	28.5 a
0.25% N as urea + 25 ppm BA	May 12, June 12 + July 8	56.4 b	22.5 b
0.25% N as urea + 50 ppm BA	May 12, June 12 + July 8	62.6 ab	26.4 ab
0.25% Urea + HM9305 (1 qt/acre)	May 12, June 12 + July 8	62.6 ab	28.0 a
Bayfolan (2 qt/acre) + HM9305 (1 qt/acre)	May 12, June 12 + July 8	58.1 b	25.7 ab
Significance[4]		P=0.0005	P=0.001

[1] All treatments were applied to the point of run-off, which required 11.4 L per tree.
[2] Unocal PLUS (<0.1%) biuret); a gift from Unocal Corp.
[3] 6-Benzyladenine; a gift from Abbott Laboratories.
[4] Values in a vertical column followed by different letters are significantly different at the specified P level by ANOVA.

CONCLUSION

Foliar applications of low-biuret urea (0.25% N) combined with 6-benzyladenine made in early June and again in early July significantly increased yield for both the off-year and on-year as kg fruit (fresh weight)/tree and kg split nuts (dry weight)/tree compared to the untreated control trees. Three foliar applications of urea (0.25% N) combined with HM9305 (a proprietary cytokinin) in May, June and July did not significantly increase these two yield components in the off-year but did in the on-year. For the first complete cycle of alternate bearing these two treatments resulted in a significant net increase in tons split nuts (dry weight)/acre compared to the untreated control trees. The results are promising but yield data for additional alternate bearing cycles and orchards are required.

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