Exogenous Plant Growth Regulators Show Promise for Management of Alternate Bearing in Pecan

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Introduction

Alternate bearing poses a major challenge for the pecan [*Carya illinoinensis* (Wangenh.) K. Koch.] industry. Alternate bearing (AB) refers to varying crop intensity in which trees tend to produce a heavier crop approximately every other year ("on" year followed by an "off" year). Productivity and yield are directly dependent on the success or failure of the flowering process, whether the season is an on or off alternate bearing year. Flowering control is complex and involves several environmental cues as well as endogenous cues.

Flowers are imperfect with staminate (male) "catkins" consisting of long inflorescences forming in clusters of three on previous season lateral buds (Fig. 1). The pistillate (female) flowers, lacking petals and sepals, are borne on spikes at the terminal end of current season shoot growth (Fig. 1).

Applied plant growth regulators (PGRs) have been studied for the intention of mitigating AB intensity in several alternate bearing species, including apple (*Malus* x *domestica* Borkh.), citrus (*Citrus spp.*), mango (*Mangifera spp.*), walnut (*Juglans spp.*), as well as pecan.

The objectives of these experiments are to determine effects of exogenous applications of ethephon, two concentrations of GA_3, and ReTain on return bloom on fruiting and non-fruiting shoots of mature Western cultivar pecan trees, as well as immature Western and Pawnee trees.

Figure 1. Pecan floral structures. Staminate inflorescences (catkins) hanging in long spikes clustered in three and borne from lateral buds on previous season shoot (left). Cluster of four pistillate flowers borne on terminal end of a current season (new) shoot (right). Both photos taken 28 April 2014 in mature 'Western' pecan tree in Las Cruces, New Mexico.

Materials & Methods

Experimental Design

- 6 mature Western cultivar pecan trees were selected from a commercial orchard in the Mesilla Valley, New Mexico
- 4 Western and 4 Pawnee cultivar trees were selected from immature University orchards nearby (Fig. 2)
- Randomized complete block, each tree was a single block
- Treatments were applied to both fruiting and non-fruiting (vegetative) shoot populations
- In 2014 treatments were
  1) nontreated control (consisting of distilled water)
  2) GA_3 (ProGibb® 4% at 50 mg a.i./L; Valent BioSciences Corporation, Libertyville, IL)
  3) ethephon [(2-chloroethyl)phosphonic acid, Ethrel® at 100 mg a.i./L; Bayer CropScience, Inc., Calgary]
- In 2015 two additional plant growth regulator treatments were
  4) double rate (2x) of GA_3 (ProGibb® 4% at 100 mg a.i./L)
  5) ethylene inhibitor, aminoethoxyvinylglycine, (ReTain®, at 0.88 g/L; Valent BioSciences Corp., Libertyville, IL)
- Each block consisted of 3 experimental units for totals of 18 and 30 sun-exposed lateral shoots tagged for randomly selected treatments per tree in 2014 and 2015, respectively (Fig. 3)
- Applications of treatments were performed using handheld bottle sprayers and plastic funnel-shaped collars to reduce possibility of chemical drift during application of treatments (Fig 4)
- For both years plant growth regulator applications were scheduled at approximately 3-, 6-, and 9- weeks (dependent on irrigation and orchard management schedules and weather) after full bloom in the mature orchard, and at parallel dates in the immature orchards (Table 1)

Data Collection & Statistical Analysis

- Return bloom data was collected from the tagged and treated shoots in springs of 2015 and 2016.
- Data included
  1) total number of new shoots from treated shoots (data presented here, Fig. 5)
  2) flower count per new season shoot (data presented here, Fig. 6)
  3) total number of flowers per treated shoot
  4) percentage of new shoots with flowers
  5) flowers per cluster
- The data analyses for these parameters were generated using PROC MIXED or PROC GLIMMIX from version 9.4 of the SAS System for Microsoft Windows Workstation for x64 (copyright © 2012 SAS Institute Inc. SAS)
- Significance was defined as $P \leq 0.05$ for all analyses. However, differences were acknowledged as "marginally significant" when $P \leq 0.10$
- ANOVA performed with a 2x3 factorial structure in 2015 and 2x5 in 2016
- Subsampling was recognized by including appropriate random effects in the model

Figure 2. Immature pecan orchard.

Figure 3. Shoot selection in mature pecan tree.

Figure 4. Spray application of plant growth regulator.

New Shoots in Mature 'Western' Trees (2016)

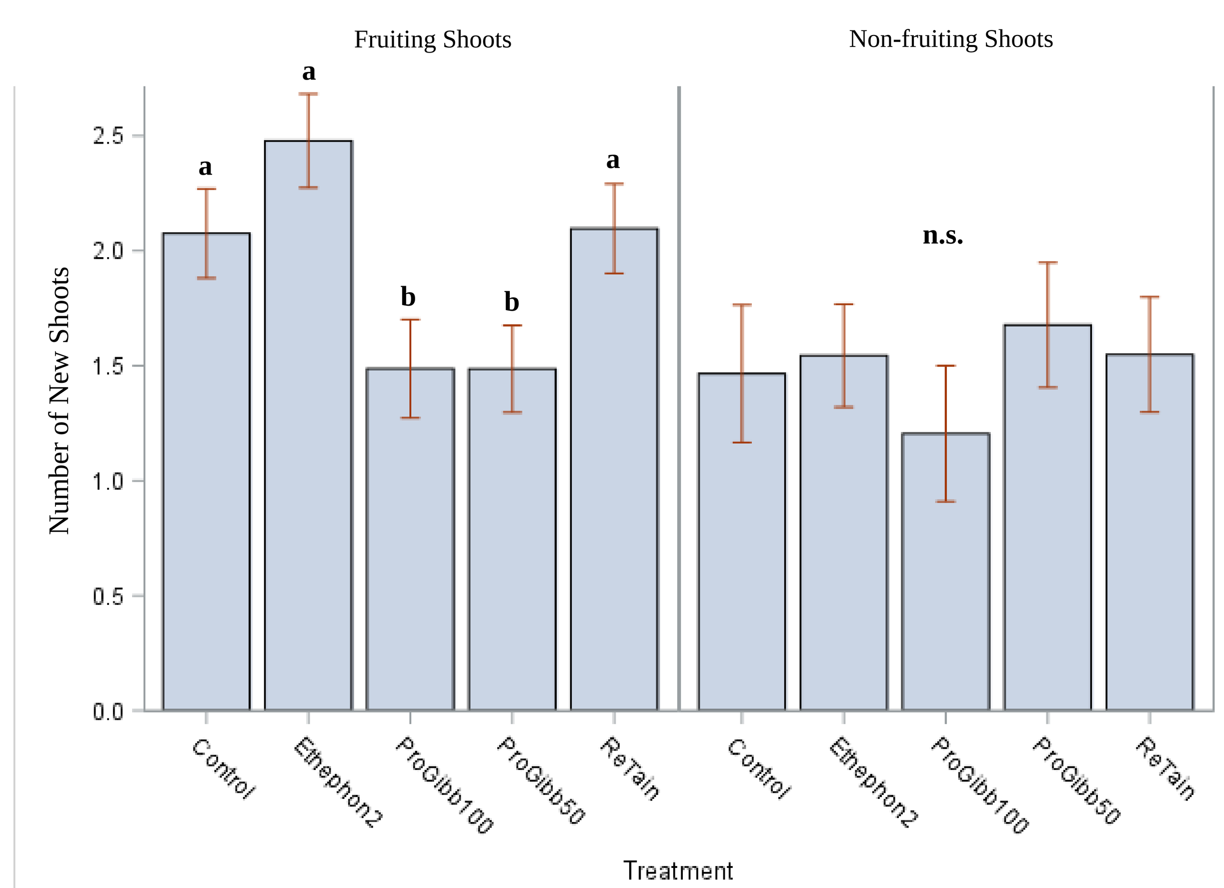

Figure 5. Number of flowers per fruiting (left) and non-fruiting (right) shoots in response to PGR application. LSMEANS and SE are reported. Within fruiting status, LSMEANS accompanied by different letters are significantly different at alpha = 0.10.

Flowers per Shoot in Mature 'Western' Trees (2016)

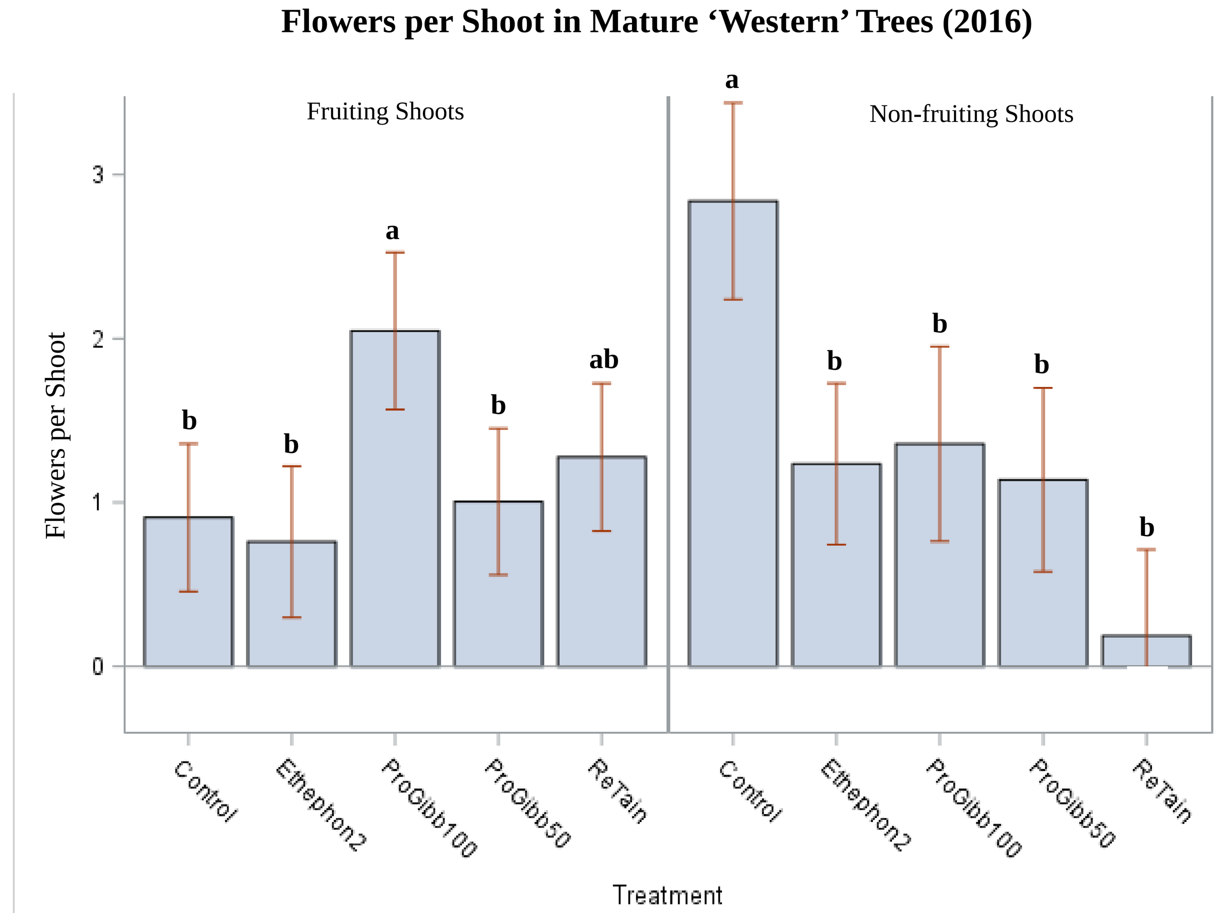

Figure 6. Number of flowers per fruiting (left) and non-fruiting (right) shoots in response to PGR application. LSMEANS and SE are reported. Within fruiting status, LSMEANS accompanied by different letters are significantly different at alpha = 0.05.

Take Home Messages

- We found a significant difference in both fruiting and non-fruiting shoots based on PGR application.
- Both GA applications reduced the number of new shoots born on previously fruiting shoots.
- Our results set the stage for further studies of PGRs as tools for mitigation of alternate bearing in pecan.
- PGR usage has dramatically stabilized production of other fruit crops and, with further research, will help the pecan industry.

Table 1. Dates of plant growth regulator application in mature and immature orchards, 2014-2015.

Mature 'Western'		Immature 'Pawnee' & 'Western'	
2014	2015	2014	2015
6 June	4 June	17 June	12 June
27 June	24 June	8 July	3 July
18 July	16 July	29 July	4 August

Results & Discussion

Number of New Shoots.

Frequently, flowering responses were different for shoots that were fruiting versus non-fruiting at the time of plant growth regulator application. For the return bloom parameter 'number of new shoots', previously fruiting shoots bore more new shoots than previously non-fruiting shoots (Fig. 5). In previously fruiting shoots, both of the GA_3 application rates in the mature 'Western' trees marginally decreased the number of new shoots in year two (Fig. 5).

The result of the fruiting status main effect on the number of new shoots is remarkable. Fruiting shoots yielding higher total number of new shoots in both the mature 'Western' and the immature 'Pawnee' orchards. Fruiting shoots in year of shoot selection and PGR application were more robust than non-fruiting shoots. That is, fruiting shoots were longer, had higher numbers of leaves and buds, as well as larger individual leaf sizes. The GA_3 treatment on non-fruiting shoots resulted in a 73.8% drop compared to the untreated control (Fig 5).

Number of flowers per new shoot

In 2016, the number of flowers per new shoot was 55.6% higher after treatment with 2x GA_3 than control shoots in the previously fruiting mature 'Western' shoots (Fig. 6). This outcome is striking because, as mentioned before, both GA_3 applications reduced the number of new shoots borne on previously fruiting shoots. Understandably, the number of flowers per cluster in these same previously fruiting shoots was higher for shoots treated with 2x GA_3 compared to the control fruiting shoots, although marginally.

The results of PGR application on previously non-fruiting shoots are more extreme (Fig. 6). In the mature 'Western' trees, compared with the non-fruiting control shoots, all treated non-fruiting shoots display a reduction in total number of flowers per new shoot, ranging from a 52.2% - 93.4% reduction (Fig. 6). This effect is also evident as a trend of lower percentage of new shoots with flowers in the mature 'Western' non-fruiting shoots. In year two, both the treatment main effect and the interaction of treatment by fruiting status were significant, the untreated control and ReTain data are the most striking. It appears that ReTain may have switched the alternate bearing tendency in comparison with the control. In previous work, GA_3, as well as GA_{4+7}, decreased both percentage of new shoots with flowers and number of flowers per cluster compared with the untreated control when applied to non-flowering shoots of 25-year 'Pawnee' trees (Wood, 2011). Wood (2011) concluded that GAs inhibited floral induction in the subsequent season. These results are consistent with the conclusion that fruiting status determines production in the subsequent season, and the phytohormone theory of alternate bearing is supported.

Conclusions

Crucial to the interpretation of these findings is the understanding that PGRs do not have single functions in plants. A complex balance of interrelations between PGRs exists, so that application of one PGR may be inhibited or stimulated by presence of another PGR. Endogenous phytohormone levels were not monitored in this study and it is possible that they had a role in determining intensity of these return bloom parameters. It is also possible that the timing or the rates of plant growth regulator applications were incorrect for this region, although every attempt was made to replicate methods used in other experiments which yielded slightly different results (Wood, 2011). Furthermore, few PGRs are currently labeled for control of alternate bearing in pecan. Additional research is needed on the effects of exogenous plant growth regulators in pecans in NM before formal recommendation on plant growth regulator usage is specified.

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Citation

Wood, B.W. 2011. Influence of plant bioregulators on pecan flowering and implications for regulation of pistillate flower initiation. HortScience 46: 870-877.