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Research Article

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Foliar Ethephon Fruit Thinning Improves Nut Quality and Could Manage Alternate Bearing in Pecan

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Abstract Pecan [*Carya illinoensis* (Wangenh.) C. Koch] faces serious problem of alternate bearing producing large number of fruits of low quality in one year, followed by small number of fruits in next year with low total fruit production. As a consequence, the farmers get low income over years. Ethephon application in the form of foliar is considered as an alternative method for fruit thinning, however, limited published information is available on pecan. Effect of different levels of ethephon as source of ethylene on pecan fruit thinning, yield and quality was evaluated in this research. Foliar ethephon; 200, 400, 600 ppm, water spray and control (No spray) were sprayed on 27 year old pecan cultivar 'Wichita' at New Mexico State University, Las Cruces, USA. The ethephon was used as a source of ethylene. The increase in leaf defoliation, chlorosis, and kernel quality with decrease in total kernel weight were significant. However, total number of nuts at harvest remained the same. Foliar ethephon applied at 600 ppm performed better compared with other treatments. In conclusion, the ethephon at the rate of 600 ppm as foliar spray produced good quality by reducing number of nuts in the excessive fruit loading year, which had resulted in greater fruit set in the following year. This may increase profit of the pecan growers on a regular basis.

Keywords Ethephon, ethylene, fruit thinning, yield, quality, pecan

Introduction

Alternate bearing is one of the most important problems for the pecan [*Carya illinoensis* (Wangenh.) C. Koch] producers, which mean excessive low quality fruit load in a year, followed by low fruit load in the following year. Thus, the farmers income get lowered over years [1]. During the year of excessive fruit load the crop produce more flowers and fruits resulting in nuts of smaller size, poorly filled kernels, low quality and reduced flowering next year [2]. Excessive fruit loads also cause physiological disorders, such as nut germination [3] and reduced cold hardiness, making the plant vulnerable to insects/pest attack and may result in the death of the tree [4]. During the year of low load trees may not produce enough nuts even to meet the cost of production [5].

To produce high yield and good quality nuts technology is needed that can reduce excessive fruit load in the 'on' year and increase fruit set in the following or 'off' year. Alternate bearing in pecan could be managed by adopting several strategies including fruit thinning and pruning [6]. Mechanical fruit thinning increases nut size, kernel percentage and kernel grade and return bloom of pecan [1, 5]. Furthermore, mechanical fruit thinning increased profitability of commercial orchards primarily due to increasing the production and price, which offset the yield losses and crop value in response to fruit thinning [7]. However, mechanical thinning may damage pecan trees making them vulnerable to the attack of insects and diseases and thus reduce the life of pecan trees [8].

Chemicals have been used successfully as an alternative method for fruit thinning in other fruit trees. Phytoregulators such as ethephon have been used to promote fruit thinning, most notably in apples [9]. Ethephon releases ethylene upon contact with the plant tissue, promoting abscission, and has been considered more efficient in comparison to other phytoregulators [10]. Ethephon promoted the abscission of young apple fruit, increased ethylene of leaf, with induction of leaf abscission [11]. This fruit abscission is more closely related with increased level of ethylene application at the rate of 500 mgL^{-1} in the form of ethephon [12]. Ethephon application at 200 and 600 $mg.l^{-1}$ increased fruit size of apple with slight reduction in total yield [13].

Ethephon increased defoliation in citrus fruits [14] and at 800 mg L^{-1} caused 28.5% fruit thinning of citrus [15]. Ethephon has increased fruit abscission, reduced competition between sinks and improved fruit size of citrus species [15]. However, others reported that response to ethephon application at 150 to 600 mg L^{-1} varied according to the time of application and the development stage of the fruit [16-18]. Ethephon application delay bloom and reduced crop load in peach [19]. Abscission of peach fruit set was reduced by 70 to 100 % at 100-200 mg L^{-1} ethephon [20]. Ethephon consistently reduced initial fruit set in avocado by 40% at 42 mlL^{-1} when 20% to 80% of the flowers had opened [13]. Application of ethephon at 250-500 ppm in spring before full leaf expansion reduced fig crop load by 92% whereas fall application of 500 ppm reduced crop load by 30% [21]. Ethephon application of 0.1, 1.0, or 10 $\mu L \cdot L^{-1}$ to 17 commonly traded potted foliage plant genotypes enhanced leaf and bract abscission or senescence [22]. No systematic research on the use of foliar ethephon for the management of Alternate bearing in pecan is done before. Therefore, the current research was initiated to quantify the effects of various levels of foliar ethephon on pecan production, nuts quality, and thinning in New Mexico.

Materials and Methods

Site description

A field experiment was conducted at Leyendecker Plant Science Center, College of Agricultural, Consumer and Environmental Sciences, New Mexico State University, Las Cruces, USA during 2004. Leyendecker Plant Science Center is located at elevation of 1183 m, latitude of 32^o 16 4 N, longitude of 106^o 46 18 W. The study was conducted in a 27 year old pecan orchard (cultivar 'Wichita'), planted in 9 meter rows with plant to plant distance of 5.7 meters. The orchard was basin irrigated by Rio Grande water.

Youngest fully expanded leaves were collected on August 3, 2004 from each tree before foliar ethylene spray and transported to laboratory been placed on ice cubes. Leaves were surface washed for removal of surface contamination with a mild 2% detergent solution. After washing, the leaves dried and 1 g grounded leaves were ashed for 3 h at 500 ^oC, then it was dissolved in 2N hydrochloric acid, diluted to 50 mL with distilled water and heated to re-dissolve all nutrients. Solutions were analyzed for B [23], total nitrogen (N) in leaves by Kjeldhal method as described in Bremner and Mulvaney [24] at the Soil Water and Air Testing Laboratory, New Mexico State University, Las Cruces. Plant total N, nitrate N and B in the plant digest was 1.92 to 2.38 % total N, 15 to 18 mg nitrate N kg^{-1} and 236 to 288 mg B kg^{-1}.

Experiment

Ethylene was applied in the form of ethephon. Five ethephon treatments [200, 400, 600 mg ethephon L^{-1}, water spray, control (no spray)] were applied in a randomized complete block (RCB) design with 8 replications. Each tree was considered a separate replication. The trees were sprayed twice to coat foliage completely. Half of the ethephon was applied with small hand sprayer on August 3, 2004, while remaining half of ethephon was sprayed on August 21, 2004. All the 5 treatments were applied to a single tree. Ten branches were selected in each tree, properly tagged and number of fruits was counted before ethephon foliar application. Each treatment consisted of two branches. Uniform cultural practices including irrigation water and fertilizer application were used for the entire experiment. Data were recorded on number of nuts before ethephon spray, nuts at harvest, number of leaves, leaf health status and nut yield and kernel quality. Number of nuts in each treatment was counted separately for each branch before ethephon foliar spray. Number of leaves was counted in each branch after the second application of ethephon. The leaf status was evaluated 5 weeks after application of second half of ethephon using the following scale. 1= healthy leaves showing no sign of chlorosis, 2= moderate marginal chlorosis, 3= marginal chlorosis, 4= chlorosis observed on tip of the leaves only, 5= complete loss of leaves. Kernel grading was done using the following UDSA grading system. 1= kernel brightly colored, full bodied and solid, 2= kernel brightly colored, but light weight, 3= kernel amber colored, light weight with adhering material and 4= kernel poorly developed, shriveled kernel that would be discarded. Nut yield was recorded by weighing the kernel of each branch separately after drying with electronic balance.

Statistical analysis

SAS the PROC GLM procedure in SAS [25] appropriate for a randomized complete block design was used for statistical analysis and mean were separated using LSD test at 0.05 level of probability. Single degree of freedom contrasts for control vs. rest, control vs. ethylene (E), water vs. E were also estimated. Mean values of nut yield and quality were regressed against E levels.

Results and Discussion

Number of Nuts before Spray

Since none of the treatments were applied at this stage of the experiment, therefore non-significant effect of ethylene (ethephon) was observed (Table 1).

Table 1: Analysis of variance of number of nuts before spray, leaf chlorosis, number of leaves, kernel weight, grading and weight kernel^{-1} of pecan as affected by foliar ethylene.

S.V	D.F	Nuts before spray	Leaf chlorosis	Number of leaves	Number of nuts at harvest	Kernel weight (g)	Kernel grading
Replication	7	3.8	0.5	2.9	4.6	186.1	1.2
Ethylene	4	0.7	48.2 **	155 **	0.7	220**	11.2 **
E vs. Water	1	0.3	94.9 **	190 **	0.1	170**	15.2 **
Control vs. E & W	1	1.2	56.9 **	79 **	0.7	3.3	7.8 **
E_L	1	1.1	40.5 **	344 **	2	708**	19.5 **
E_Q	1	0.2	0.4	6.5 **	0	0.1	2.3 **
Branches (Br)	1	2.1	0.1	0.1	1.3	43.2	0.3
E x Br	4	1.0	0.4	0.5	0.8	22.1	0.3
Error	63	0.8	0.5	2	0.9	31.3	0.3

E = Ethylene, E_L = linear, * = significant at 5% P level, Br = branches, E_Q = quadratic,

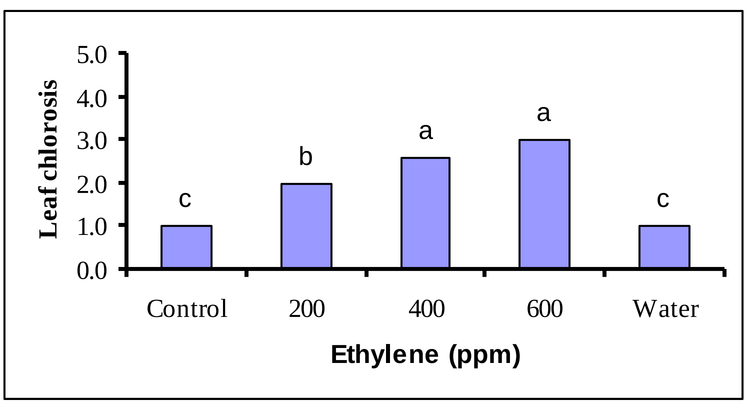

Figure 1: Leaf chlorosis of pecan as affected by foliar ethylene. Bars sharing similar letters are non-significant at 0.05% probability using LSD test.

Leaf Chlorosis

Ethephon (E), E vs. water (W), control (C) vs. E & W and ethephon linear (E_L) significantly affected leaf chlorosis, whereas ethylene quadratic (E_Q), branches (Br) and E x Br effects were not significant (Table 1). Planned mean comparison of control vs ethephon showed that lowest leaf chlorosis (1.0) was noted for the control compared with ethephone treated branches (Table 2). Leaf chlorosis increased with each increment of ethephon with the highest chlorosis (5.0) recorded at 600 ppm ethephon (Figure 1). There was a negative correlation between leaf chlorosis and kernel weight and number of leaves, but a positive correlation with nut grade and nuts harvested (Table 3). Increased chlorosis at higher levels of ethylene may be due to exogenous ethylene accelerating endogenous ethylene production leading to enhanced leaf senescence which results in earlier leaf abscission [22, 26-27].

Table 2: Planned mean comparison for various parameters of pecan.

	Nuts before spray		**Leaf chlorosis**		**Number of leaves**		**Number of nuts at harvest**		**Kernel weight (g)**		**Kernel grading**	
C vs. E & W	3.69	4.00	1.00	3.11	6.50	4.02	3.69	3.92	18.29	17.78	1.56	2.34
C vs. E	3.69	4.04	1.00	3.81	6.50	3.02	3.69	3.94	18.29	16.84	1.56	2.63

E = Ethylene, C = Control, W = Water

Table 3: Correlation among various parameters of pecan as affected by foliar ethylene.

	Nuts before spray	**Leaf chlorosis**	**Number of leaves**	**Number of nuts at harvest**	**Total kernel weight**
Kernel grading	-0.81	0.91	-0.94	-0.28	0.87
Total kernel weight	0.99	-0.7	0.82	0.68	-
Nuts at harvest	0.75	0.05	0.15	-	-
Number of leaves	0.74	-0.98	-	-	-
Leaf chlorosis	-0.62	-	-	-	-

Number of Leaves

Ethephon, E vs. W, C vs. E & W, E_L and E_Q significantly affected leaf number (Table 1). The control, foliar water and 200 ppm foliar ethephon retained the highest number of leaves (Figure 2). Higher foliar ethephon concentration (400, 600 ppm) decreased leaf number. There was a positive correlation between leaf number and weight kernel^{-1}, kernel weight and nuts harvested, and a negative correlation with nut grade (Table 3). The reduction in the number of leaves at higher ethephon rates likely is caused by ethylene-induced abscission of leaves [28].

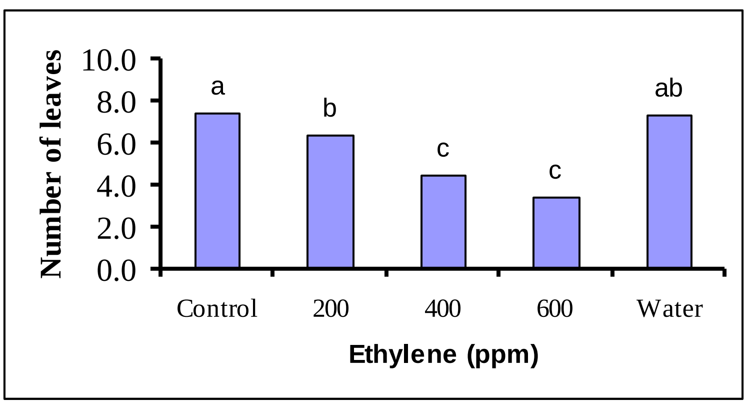

Figure 2: Number of leaves of pecan as affected by foliar ethylene. Bars sharing similar letters are non-significant at 0.05% probability using LSD test.

Nuts at Harvest

None of the treatments significantly affected the number of nuts at harvest (Table 1). All ethephon levels and control resulted in an equal number of nuts (Figure 3), but there was a positive correlation between nut nuts at harvest and weight kernel^{-1} and kernel weight, and a negative correlation with nut grade (Table 3). Ethephon was applied relatively late in the growing season, which might explain the lack of thinning response. Fruit might be removed more effectively if ethephon is applied at an earlier stage of fruit development particularly ovule expansion [5].

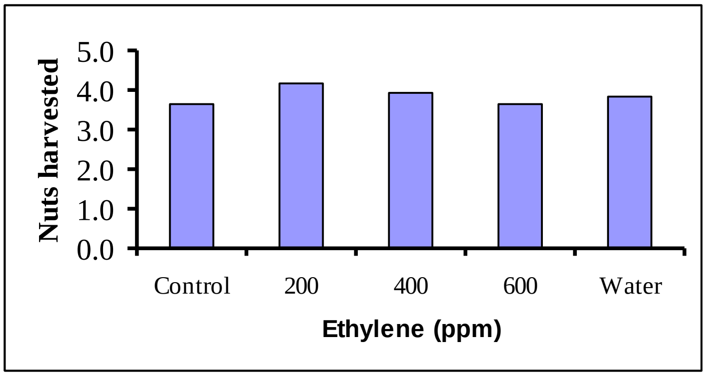

Figure 3: Number of nuts at harvest of pecan as affected by foliar ethylene.

Total Kernel Weight (g)

Ethephon, E vs. W and E_L significantly affected total kernel weight, while C vs. E & W, E_Q, but branches (Br) and E x Br interaction had no significant effect on kernel weight (Table 1). Higher total kernel weight was recorded from water, control and low ethephon application (200 ppm) whereas higher foliar ethephon (600 ppm) drastically reduced total kernel weight (Figure 4). Total kernel weight was negatively correlated with the kernel grading (Table 3). The reduction in total kernel weight at the highest ethephon level may be because the highest level of ethephon caused leaf defoliation and nut removal which resulted in fewer nuts of heavier weight [28].

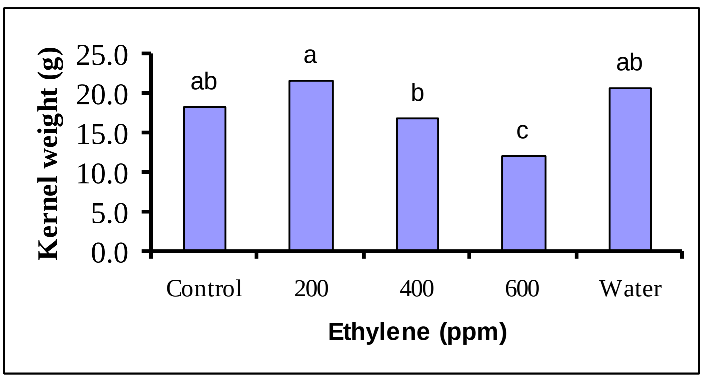

Figure 4: Total kernel weight (g) of pecan as affected by foliar ethylene. Bars sharing similar letters are non-significant at 0.05% probability using LSD test.

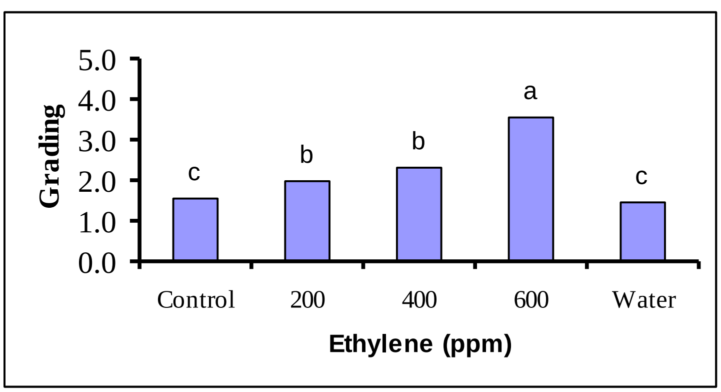

Figure 5: Kernel grading of pecan as affected by foliar ethylene. Bars sharing similar letters are non-significant at 0.05% probability using LSD test.

Kernel Grading

Foliar ethephon, E vs. W, C vs. E & W, E_L, and E_Q significantly affected kernel grading, while branches (Br) and interaction of E x Br were not significant (Table 1). The lowest grade nuts occurred in the control (Figure 5). Increasing ethephon concentration improved kernel quality and the highest grade nuts (3.56) occurred at 600 ppm. Higher ethephon levels reduced the number of fruits. The photosynthates produced at adjacent branches and stored in the same branch might have translocated to the developing nuts which resulted in good grade nuts due to fewer number of nuts. Good quality kernel in pecan due to fruit thinning was also reported [1].

Conclusion

Foliar ethephon could be effectively used for pecan fruit thinning to control/reduce excessive fruiting in the year of heavy production that will result in good grade pecan kernels and will increase fruit set the following year. This will help the pecan growers to maximize their profit from pecan orchid.

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