DEVELOPMENT OF FRUIT THINNING
GOALS FOR PECAN

By

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DEVELOPMENT OF FRUIT THINNING

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PREFACE

The purpose of this study was the development of fruit thinning goals for pecan in order to improve annual production. Two experiments were performed. One experiment involved thinning fruit within a cluster, while in the other the percent of fruiting shoots was controlled. An additional experiment to determine the best method for estimating pecan leaf area was necessary in order to develop leaf area-to-fruit ratios.

This is the beginning of a five year experiment. Because of frequent flooding, the experiment will be moved to another location in 1987.

I wish to express my greatest appreciation for my thesis adviser, Dr. Mike Smith. His patience, encouragement, and assistance were vital to the successful completion of this work.

An extra special thanks also goes to Brenda Simmons, who spent many long hours in the hot sun and deep mud of Sparks, Oklahoma. Thanks also to Harold Davis and Donnie Quinn at the Oklahoma Pecan Research Station, and to Becky Aufill for helping take data in the rain.

Andy Mauromoustakos deserves credit for a major part of the accomplishment of this work. Without his work on the statistical analysis, which required many late nights and long hours, this thesis would not have been completed on time.

The support network of friends which helped me through the times of high pressure was of utmost importance. I expecially want to thank Dr. Zola Hursey, Dr. Farrell Wise, Dr. Wilfred McMurphy, Teresa James Bates, Bill Evans, Dr. F. Khan Wazir, Robert Bourne, and Monty Howard for listening and offering helpful suggestions.

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CHAPTER I

INTRODUCTION

Alternate bearing is the most severe problem facing pecan growers (7,20). It is characterized by a pattern of a large crop followed by one or more years of very small crops (3,11,20). Several causes have been proposed for alternate bearing. These include production of substances by pecan fruit which inhibit formation of pistillate flowers the next season (2,10,20,24,28), nitrogen deficiency (2,3,6,20), and lack of sufficient carbohydrate reserves following a large crop to support flowering the following year (3,7,17,20,31, 33).

Growth promoters and inhibitors have been found in the liquid endosperm of pecan fruit (10,28), and it is speculated that growth substances produced by fruit may act to reduce flowering of pecans the following year (30, and M.W. Smith, unpublished data). Nitrogen deficiency also depresses fruiting the next season (2,3,6,20). Nitrogen nutrition of the tree is related to the vigor of individual shoots; and therefore to the vigor of the entire tree (2,6). Nitrogenous compounds may be effective as growth regulators, acting directly to inhibit or promote flowering, or indirectly by affecting tree vigor.

The vigor of individual shoots and of entire trees is related to the energy available for growth. Healthy photosynthesizing leaves are the source of this energy, and may produce a flower promoting substance (7,32). Trees must carry a healthy canopy of leaves until the normal time of frost to produce fruit the next season (1,2,13,15,16,20,22,23). It has been found that long vigorous shoots consistently produced more fruit than short weak shoots (2,13,23). This phenomenon is related to the amount of leaf area per fruit.

Leaf area per fruit has been measured for several cultivars (2,12,16,20,23, and M.W. Smith, unpublished data). The optimum shoot length for fruiting is different between cultivars (1,15,16,24, and M.W. Smith, unpublished data), and may be different within cultivars from year to year (21). Optimum leaf:fruit ratios have been estimated, but branch ringing was used to restrict translocation between shoots (16). This gives a biased estimate since ringing restricts photosynthetic rates, and may decrease flowering (9,11). Leaf areas may be estimated by sampling vegetative and fruiting shoots for a particular season and then using linear regression analysis to obtain an appropriate equation (21, and M.W. Smith, unpublished data). In general, as leaf area per fruit increases, the fruit size and kernel percent of the fruit also increases (2,12,13,15,16,20,23).

Another factor which is closely related to leaf area per fruit, fruit size, and kernel percent is the total crop load of the tree. Crop size is inversely related to fruit size and kernel percent (3,12). Reduction in quality is important when the crop is marketed. Hunter's (8) study in 1968 revealed that trees producing a moderate crop (45 kg per tree) had a higher net return at marketing than trees producing a very high yield (103.6 kg per tree). Adequate data are not available to determine optimum leaf to fruit ratios for each cultivar. These ratios may vary with economic conditions and management problems. However, it may be assumed that high yields of fruit may not be as desirable as constant moderate crops due to poor fruit quality and alternate bearing. Furthermore, high yields of fruit year after year may be impossible to achieve.

A year of high fruit yield is typically followed by a year of very poor yield (3,11,20). This problem is more severe in pecans than in any other tree crop (20). Pecan yield for one season is negatively correlated with pecan yield for the previous season (20,33). Large quantities of carbohydrates are required to provide energy for the initiation of growth and flowering in the spring (17). Large crops of fruit reduce available carbohydrates for fruit development and stored reserves for the next season's growth and flowering (17). This results in a weakened tree. Alternate bearing cultivars have decreased winter hardiness following a heavy crop (27). Weakening of trees by large crops also affects initiation of growth and pistillate flower differentiation early the next spring (17,27). Early spring also seems to be a time which is critical to the phenomenon of alternate bearing. Most or all of the pistillate flowers may drop before they become receptive to pollen the spring after a heavy crop (30). This may be due to the inability of the tree to differentiate female flowers early enough for them to be pollinated (30).

Alternate bearing occurs on whole trees and on individual shoots within a tree (12,13). Shoots which did not produce fruit the previous year had more pistillate flowers (13,18) and yielded more nuts at harvest (13) than shoots which fruited the previous year. It may be argued that one can estimate effects of treatment for whole trees by treating individual shoots or limbs, if it is assumed that the influence of the individual shoots or limbs on others is minimal.

Experimental treatments of portions of trees and of individual limbs have shown significant differences between treated and untreated units (5,7,11). Specific studies using autoradiography have traced the incorporation of carbon-14 into carbohydrates, its storage over the winter, and its translocation when growth was initiated the next spring the next season (11). These studies have shown that carbohydrates synthesized in a pecan shoot during one growing season tend to return to the same shoot and to shoots in direct line with that shoot (11). This would seem to indicate that the treatment of individual branches as experimental units would be justified without concern about the influence of branches upon each other.

Thinning of pecan fruit is a logical way to increase leaf area per fruit, which should increase fruit size and degree of filling (3,22). In some cases, thinning has not proved to be effective in improving return bloom and fruit set. These cases include young trees (Mielke, E. A., unpublished data) which may not yet be in full production, and trees on which ethephon has been used as a thinning agent (28). The lack of effect of thinning with ethephon may be due to an overall depression of photosynthesis by the ethephon or by its petroleum based carrier (28). Since these cases do not represent the typical situation, they do not necessarily contradict the effectiveness of thinning in other situations. In more typical situations, thinning has increased return bloom and fruit set, the size and weight of fruits, and the yield of the tree throughout its life (3,22).

The stage of fruit development at which thinning should be done may vary with cultivar due to different rates of fruit growth (24). However, most cultivars exhibit a pattern of filling in which the most important phase, the increase in size of the cotyledons (14), occurs during the last three months of fruit development (4). Up to 85 percent of the final dry weight of the pecan is assimilated during this time (4). Most of the dry weight is carbohydrates and carbohydrate derivatives that were translocated to the fruit during this time (20,25). Thinning prior to the rapid transport of carbohydrates to the fruit would be expected to result in the greatest amount of carbohydrate storage and flower induction.

The research project discussed herein involves thinning of pecan fruit. The objectives of this research were to determine the effects of pecan fruit thinning intensity and time on fruit quality and return bloom the next season. Factors considered include: time of thinning, leaf area to fruit ratio, amount of thinning, and whether thinning should be based on proportion of fruiting shoots (thinning by terminal) or on fruiting intensity (thinning by cluster).

LITERATURE CITED

1. Amling, H.J. 1968. Shoot growth and pecan fruiting. Proc. S.E. Pecan Growers Assn. 52:45-48.

2. Crane, H.L. 1930. Terminal growth in relation to fruiting in the pecan. Nat. Pecan Assn. Bul. 29:24-32.

3. Crane, H.L., M.B. Hardy, N.H. Loomis, and F.N. Dodge. 1934. Effect of nut thinning on size, degree of filling, and annual yields of pecans. Proc. Amer. Soc. Hort. Sci. 32:29-32.

4. Davis, J.T., and D. Sparks. 1974. Assimilation and translocation patterns of Carbon-14 in the shoot of fruiting pecan trees, *Carya illinoensis* Koch. J. Amer. Soc. Hort. Sci. 99:468-480.

5. Davis, L.D. 1957. Flowering and alternate bearing. Proc Amer. Soc. Hort. Sci. 70:545-556.

6. Finch, A.H., and H.L. Crane. 1931. Physiological factors associated with the productiveness of pecan shoots. Nat. Pecan Assn. Bul. 30:98-107.

7. Hinrichs, H.A. 1962. Pecan industry and some research developments in Oklahoma. Northern Nut Growers Assn. Proc. 53:80-85.

8. Hunter, J.H. 1968. The relation of yield and quality in pecans. Proc. S.E. Pecan Growers Assn. 158-159.

9. Isbell, C.L. 1928. Growth studies of the pecan. Ala. Agr. Expt. Sta. Bul. 226:1-63.

10. Lipe, J.A., P.W. Morgan, and J.B. Storey. 1969. Growth substances and fruit shedding in the pecan, *Carya illinoensis*. J. Amer. Soc. Hort. Sci. 94:668-671.

11. Lockwood, D.W., and D. Sparks. 1978. Translocation of ^{14}C in 'Stuart' pecan in the spring following assimilation of $^{14}CO_2$ during the previous growing season. J. Amer. Soc. Hort. Sci. 103:38-45.

12. Malstrom, H.L., and D. Sparks. 1973. Analysis of yield components in mature trees of 'Schley' pecan, Carya illinoensis Koch. J. Amer. Soc. Hort. Sci. 98: 496-500.

13. Malstrom, H.L., and J.L. McMeans. 1982. Shoot length and previous fruiting affect subsequent growth and nut production of 'Moneymaker' pecan. HortScience 17:970-972.

14. McKay, J.W. 1945. Embryology of pecan. J. Agr. Res. 74:263-283.

15. Pelham, J.L. 1926. Terminal growth an indicator of cultural requirements in pecan growing. Nat. Pecan Growers Assn. Bul. 25:42-46.

16. Sitton, B.G. 1931. A preliminary report on the relation of foliage to filling of the pecan. Nat. Pecan Growers Assn. Bul. 25:42-46.

17. Smith, C.L., and J.G. Waugh. 1938. Seasonal variations in the carbohydrate and nitrogen content of roots of bearing pecan trees. J. Agr. Res. 57:449-460.

18. Smith, M.W., R.W. McNew, P.L. Ager, and B.C. Cotten. 1986. Seasonal changes in the carbohydrate concentration in pecan shoots and their relationship to flowering. J. Amer. Soc. Hort. Sci. 111:558-561.

19. Sparks, D. 1967. Effect of potassium gibberellate on fruit characteristics and flowering of the pecan, Carya illinoensis Koch. cv. 'Stuart'. Proc. Amer. Soc. Hort. Sci. 90:61-66.

20. Sparks, D. 1974. The alternate fruit bearing problem in pecans. Northern Nut Growers Assn. Proc. 47:80-85.

21. Sparks, D. 1966. A rapid method for estimating the leaf area of the Stuart pecan, Carya illinoensis Koch. HortScience 1:93-94.

22. Sparks, D., and C.E. Brack. 1972. Return bloom and fruit set of pecan from leaf and fruit removal. HortScience 1:131-132.

23. Sparks, D., and J.L. Heath. 1972. Pistillate flower and fruit drop of pecan as a function of time and shoot length. HortScience 7:402-404.

24. Thompson, T.E. 1983. Genetic variability in pecan fruit development. HortScience 18:955-957.

25. Thor, C.J.B., and C.L. Smith. 1935. A physiological study of seasonal changes in the composition of the pecan during fruit development. J. Agr. Res. 50:97-121.

26. Wood, B., and J. Payne. 1984. Influence of single applications of insecticides on net photosynthesis of pecan. HortScience 19:265-266.

27. Wood, B.W. 1986. Cold injury susceptibility of pecan as influenced by cultivar, carbohydrates, and crop load. HortScience 21:285-286.

28. Wood, B.W. 1983. Fruit thinning of pecan with ethephon. HortScience 18:53-54.

29. Wood, B.W. 1982. Gibberellin-like substances in developing fruits of pecan. HortScience 17:70-71.

30. Woodroof, J.G., N.C. Woodroof, and J.E. Bailey. 1928. Unfruitfulness of the pecan. Ga. Expt. Sta. Bul. 148: 1-40.

31. Worley, R.E. 1979. Fall defoliation date and seasonal carbohydrate concentration of pecan wood tissue. J. Amer. Soc. Hort. Sci. 104:195-199.

32. Worley, R.E. 1979. Pecan yield, quality, nutlet set, and spring growth as a response to time of fall defoliation. J. Amer. Soc. Hort. Sci. 104:192-194.

33. Worley, R.E., W.A. Harmon, and R.L. Carter. 1972. Correlation among growth, yield, and nutritional factors for pecan (*Carya illinoensis* W. cv. Stuart): Correlations with yield, quality, and terminal shoot growth. J. Amer. Soc. Hort. Sci. 97:511-514.

CHAPTER II

A NON-DESTRUCTIVE METHOD FOR ESTIMATION OF LEAF AREA IN PECAN

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Key Words: _Carya illinoensis_, leaf area

Abstract. The object of this study was to determine whether counting leaves provides a better estimate of leaf area of pecan (_Carya illinoensis_ (Wangenh.) C. Koch) than measuring shoot length. Samples were taken separately for vegetative and fruiting shoots of 'Mohawk' and 'Western' cultivar pecan trees. Regression analysis showed that counting leaves provided the better estimate of leaf area. The relationships for 'Mohawk' were different from those for 'Western', but the relationships between leaf area and shoot length were linear for fruiting shoots and quadratic for vegetative shoots in both cases.

Non-destructive estimation of leaf area of pecan (_Carya illinoensis_ (Wangenh.) C. Koch) has traditionally been done by obtaining a relationship between shoot length and leaf area, then measuring the length of the shoots in question (4, and M.W. Smith, unpublished data). However, in other crops leaf length (1) or number of leaves (3) have been used as estimators of leaf area. Measuring individual leaves is

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more time consuming and requires more data storage than does measuring shoot length, but counting leaves does not have these drawbacks. In fact, estimation of leaf area by counting leaves could require less time and data storage space than shoot length measurement.

The purpose of this study was to determine if number of leaves is a better estimator of leaf area in pecan than is shoot length measurement.

Materials and Methods

Fifty fruiting and 50 vegetative shoots were removed randomly from one tree each of 'Mohawk' and 'Western' cultivars from the Oklahoma Pecan Research Station near Sparks, Oklahoma, in August, 1985. The fruit and pedicel were removed from fruiting shoots. All shoots were measured to the nearest 5 mm, and the number of leaves on each shoot was recorded (Table 1). Leaf areas were measured using a Li-Cor 3100 leaf area meter. Regression analyses were used to determine the relationships between shoot length and leaf area and between number of leaves and leaf area for each cultivar and shoot type.

Results and Discussion

In each case, number of leaves per shoot proved a better estimator of leaf area than did shoot length (Table 2). Each shoot type and cultivar was different from the others in its relationships between shoot length and leaf area and between number of leaves and leaf area (Table 3). Regression analysis showed both relationships for fruiting shoots to be linear, while relationships chosen for vegetative shoots were quadratic. Quadratic relationships for vegetative shoots are the result of the longest, most vigorous shoots producing the largest leaves (Fig. 1 and Fig. 2). A similar relationship has been observed in apple (2).

These results suggest that counting leaves may provide a better estimate of leaf area in pecan than measuring shoot length. Since the relationships for fruiting shoots are linear, it may be possible to sum all leaves of fruiting shoots within an experimental unit, thus decreasing the data storage required to get leaf area estimates. However, this does not seem feasible for vegetative shoots because of the quadratic relationships; therefore, the number of leaves on each vegetative shoot would have to be counted separately. In addition, counting leaves is also a more convenient method of leaf area estimation than measuring shoots because it does not require a measuring scale. All these advantages make counting leaves the preferred method of leaf area estimation for pecan.

LITERATURE CITED

1. Ackley, W.B., P.C. Crandall, and T.S. Russell. 1958. The use of linear measurements in estimating leaf areas. Am Soc. Hort. Sci. Proc. 72:326-30.

2. Barlow, H.W.B. 1980. The relationship between leaf size and shoot length in apple. J. Hort. Sci. 55:269-283.

3. Chacko, E.K., Y.T.N. Reddy, and T.V. Ananthanarayanan. 1982. Studies on the relationship between leaf number and area and fruit development in mango (<u>Mangifera indica</u> L.) J. Hort. Sci. 57:483-492.

4. Sparks, D. 1966. A rapid method for estimating the leaf area of the Stuart pecan, <u>Carya illinoensis</u> Koch. HortScience 1:93-94.

Table 1. Shoot lengths used for development of leaf area estimation equations.

Shoot Type	Length (cm) Range	Length (cm) Mean	Number of leaves Range	Number of leaves Mean
'Mohawk' fruiting	3.0 to 17.5	8.5	4 to 10	6.0
'Mohawk' vegetative	0.5 to 35.0	5.8	1 to 15	4.4
'Western' fruiting	4.5 to 25.0	10.8	3 to 11	6.8
'Western' vegetative	0.5 to 46.5	7.3	1 to 22	5.1

Table 2. R-Square values and mean squares for error for relationships of leaf area with shoot length and and with leaf number.[z]

Shoot Type		Shoot Length		Leaf Number	
		R^2	MSE[y]	R^2	MSE[y]
'Mohawk'	Fruiting	.538	125434	.733	72498
'Mohawk'	Vegetative	.888	12058	.930	75161
'Western'	Fruiting	.388	74099	.501	60364
'Western'	Vegetative	.948	19295	.966	12704

[z]Relationships are linear for fruiting shoots and quadratic for vegetative shoots in all cases.

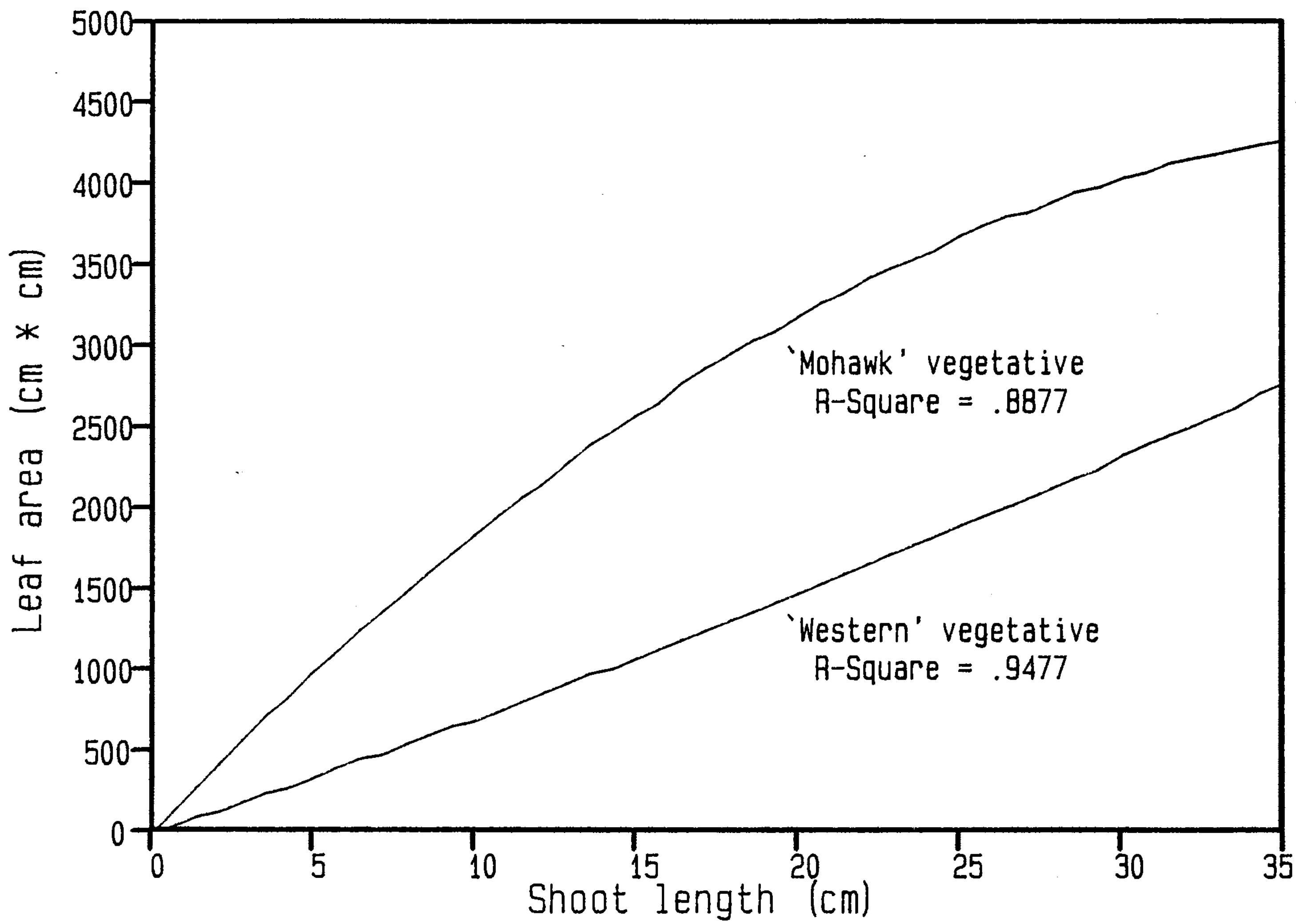
[y]Mean square for error.

Table 3. Equations developed to estimate leaf area for 'Mohawk' and 'Western' in 1985.[z]

Shoot Type	Shoot length	Number of leaves
'Mohawk' fruiting	$x=614.6+98.4y$	$x=-620.2+343.3y$
'Mohawk' vegetative	$x=-25.4+210.6y-2.5y^2$	$x=-365.3+264.4y+6.7y^2$
'Western' fruiting	$x=284.7+54.7y$	$x=-219.2+160.4y$
'Western' vegetative	$x=-21.7+67.6y+.3y^2$	$x=-169.6+106.2y+3.5y^2$

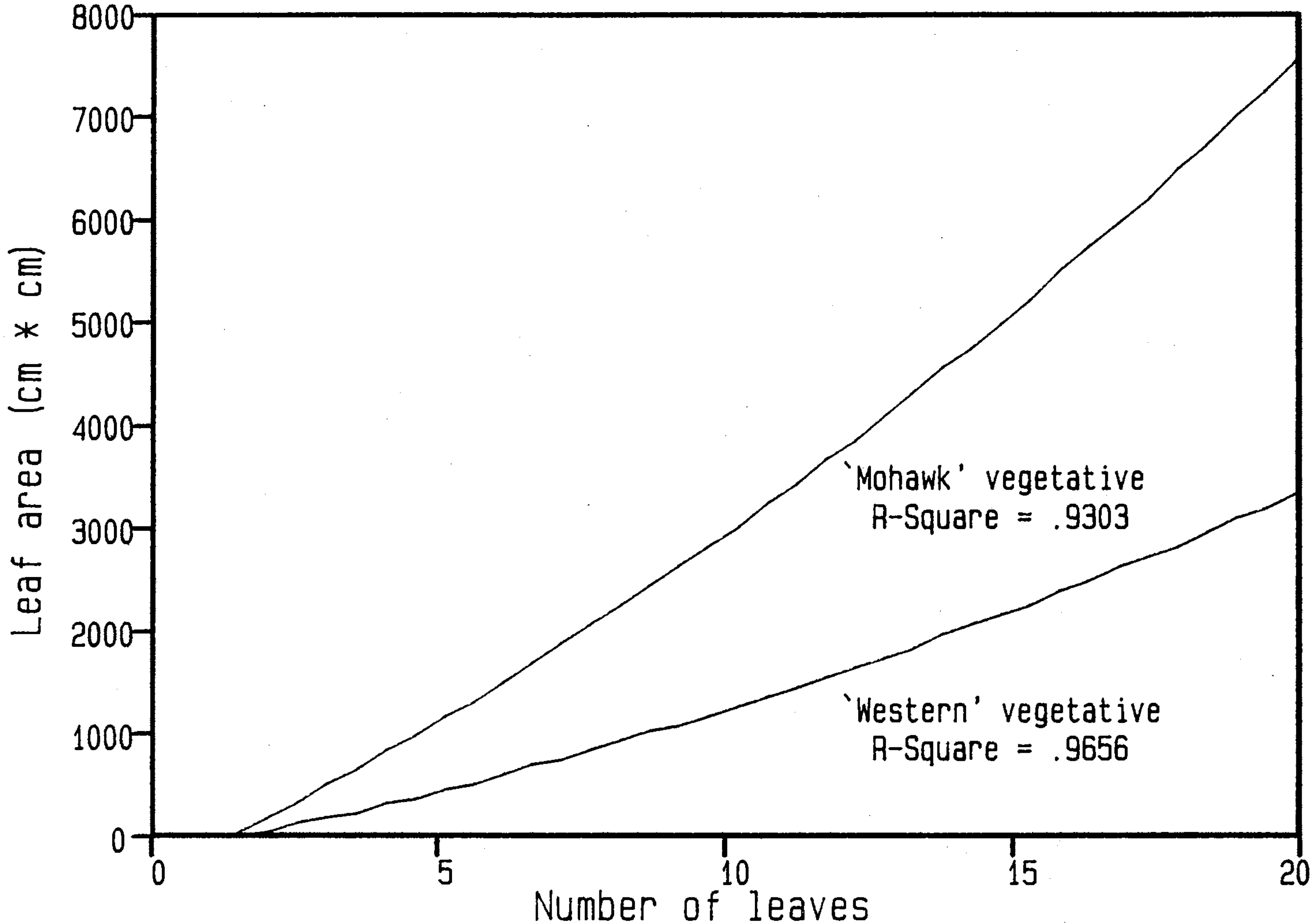
[z]Equations are quadratic for vegetative shoots and linear for fruiting shoots in all cases.

Figure 1. Relationships of leaf areas with shoot length for vegetative shoots of 'Mohawk' and 'Western' in 1985.



5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Leaf area (cm * cm)
`Mohawk' vegetative
R-Square = .8877
`Western' vegetative
R-Square = .9477
0
5
10
15
20
25
30
35
Shoot length (cm)

Figure 2. Relationships of leaf areas with number of leaves for vegetative shoots of 'Mohawk' and 'Western' in 1985.


8000
7000
6000
5000
4000
3000
2000
1000
0
Leaf area (cm * cm)
0
5
10
15
20
Number of leaves
`Mohawk' vegetative
R-Square = .9303
`Western' vegetative
R-Square = .9656

CHAPTER III

DEVELOPMENT OF FRUIT THINNING GOALS FOR PECAN: EFFECTS OF CLUSTER SIZE ON FRUIT QUALITY AND RETURN BLOOM

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Key Words: Carya illinoensis, fruit thinning, fruit quality, return bloom, alternate bearing

Abstract. The purpose of this study was to determine whether thinning fruit of pecan (Carya illinoensis (Wangenh.) C. Koch) by removing fruit from clusters would encourage annual cropping. 'Mohawk' and 'Western' cultivar pecan trees were used. Thinning to two fruits per cluster did not affect mean leaf area per fruit or mean nut mass in either cultivar. Percent kernel was increased by the two-weeks after anthesis thinning in 'Western', but was not affected in 'Mohawk'. The most significant effect on return bloom was the difference between 1985 and 1986 seasons.

Alternate bearing is the most severe problem facing pecan growers (11). It is characterized by a pattern of a large crop followed by one or more years of very small crops (5,11). Causes for alternate bearing may include production of substances by pecan fruit which inhibit formation of pistillate flowers the next season (11,16), a flower promoting substance produced by leaves (18), and lack of

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sufficient carbohydrate reserves following a large crop to support flowering the following year (9,11,17). The amount of carbohydrate reserves is positively related to the amount of leaf area per fruit.

Leaf area per fruit has been measured for several cultivars (6,8,11). The optimum shoot length for fruiting shoots is different between cultivars (1,8,14), and may be different within cultivars from year to year (12). Optimum leaf:fruit ratios have been estimated, but branch ringing was used to restrict translocation between shoots (8). This may give a biased estimate since ringing restricts photosynthetic rates, and may decrease flowering (5). Leaf areas may be estimated by sampling vegetative and fruiting shoots for a particular season, and then using regression analysis to obtain an appropriate equation (12). In general, as leaf area per fruit increases, the fruit size and kernel percent of the fruit also increases (6,7,8,11).

Another factor which is closely related to leaf area per fruit, fruit size, and kernel percent is the total crop load of the tree. Crop size is inversely related to fruit size and kernel percent (6). Adequate data are not available to determine optimum leaf to fruit ratios for each cultivar. These ratios may vary with economic conditions (3). The association of high yields with poor quality fruit may make large crops undesirable (3,8,19) Furthermore, high yields of fruit year after year may be impossible to achieve due to alternate bearing (11) and winter damage (15).

Pecan yield for one season is negatively correlated with pecan yield for the previous season (11). Large crops of fruit reduce available carbohydrates for fruit development and stored reserves for the next season's growth and flowering (9). This results in a weakened tree, decreased winter hardiness, slow initiation of growth, and poor pistillate flower differentiation early the next spring (9,15).

Alternate bearing occurs on whole trees and on individual shoots within a tree (6,7). Shoots which did not produce fruit the previous year had more pistillate lowers (5,8) and yielded more nuts at harvest (7) than shoots which fruited the previous year. It may be argued that one can estimate effects of treatment for whole trees by treating individual shoots or limbs, if it is assumed that the influence of the individual shoots or limbs on others is minimal.

Studies have shown that carbohydrates synthesized in a pecan shoot during one growing season tend to return to the same shoot and to shoots in direct line with that shoot the next season (5). This would seem to indicate that the treatment of individual branches as experimental units would be justified without concern about the influence of branches upon each other.

Thinning of pecan fruit is a logical way to increase leaf area per fruit, which should increase fruit size and degree of filling (13). In typical situations, thinning has increased return bloom and fruit set, improved the size and weight of fruits, and increased the yield of the tree throughout its life (13).

The stage of fruit development at which thinning should be done may vary with cultivar due to different rates of fruit growth (14). However, most cultivars exhibit a pattern of filling in which the rapid transport of carbohydrates associated with the increase in size of the cotyledons occurs during the last three months of fruit development (3). Thinning prior to this transport would be expected to result in the greatest amount of carbohydrate storage and flower induction.

The research project discussed herein involves thinning of pecan fruit. The objectives of this research were to determine the effects of intensity andtime of pecan fruit thinning on fruit quality and return bloom the next season. Factors considered include: time of thinning, leaf area to fruit ratio, amount of thinning, and how thinning based on the number of fruit per cluster affects yield, quality, and return bloom.

Materials and Methods

The research was conducted at the Oklahoma Pecan Research Station near Sparks, Oklahoma. The trees were located on loamy bottomland soil which is frequently flooded, and were fertilized according to recommendations based on results analysis of leaf samples. The thinning treatments were applied in 1985 and included control (no thinning), thinning to a maximum of 2 fruits per cluster, and removal of all fruit. Thinning treatments were at about two weeks, six weeks, and ten weeks after anthesis. A randomized complete block design, using trees as blocks, with 4 'Mohawk' and 5 'Western' trees was used. Individual clusters were tagged on control branches, and the number of fruits in individual clusters was recorded. Numbers of fruits dropped naturally and the stage of maturity of the fruits were also recorded at this time. Developing fruits were sampled throughout the season to obtain specific gravity curves. Leaf areas were estimated (see Chapter 2), in August, 1985, and leaf area per fruit was calculated for each limb. At harvest, data on nut mass and percent kernel were recorded in order to determine the productivity of individual limbs. Wet weather prevented final yield and nut count data being taken.

The next spring, return bloom was recorded for each of the limbs. One of the 'Mohawk' trees was not included in this data due to dieback caused by severe winter damage. Thinning to two fruits per cluster was compared to no thinning and to complete defruiting for the number of fruiting and vegetative shoots, percent fruiting shoots, number of fruit per limb, mean fruit per shoot, and cluster size.

Results and Discussion

Specific gravity curves developed from fruit sampling throughout the season indicated that the two-weeks after anthesis thinning occurred during cell division, while the six and ten-weeks after anthesis thinnings were during cell elongation (Fig. 1).

Thinning to two fruits per cluster did not affect mean leaf area per fruit in either 'Mohawk' or 'Western' in 1985 (data not shown). In 'Mohawk', leaf area per fruit was positively correlated with average nut size ($P \geq .001$), but no significant correlation was found for 'Western' ($P \geq .05$) (Table 2). Percent kernel was not affected by leaf area per fruit (Table 2).

Thinning did not affect mean nut mass in either cultivar (Table 1). Percent kernel was not affected in 'Mohawk', but in 'Western' the two weeks after anthesis thinning resulted in a higher percent kernel than the control (Table 1). Since this was the only thinning treatment applied during cell division, the higher percent kernel may be due to an increase in cell number. In apples, cell number has a greater effect on fruit size than does cell size (2). This may also be true of pecan.

In 1986, return bloom was assessed on all limbs, including the limbs which were entirely defruited in 1985. Flowers were counted on 'Western' as soon as possible after anthesis, but wet weather prevented data being taken on 'Mohawk' trees until several weeks later. Therefore, fruit counts for 'Mohawk' are for ten week old fruit, while flowers were counted on 'Western'. Return bloom data indicated that the most significant effect on fruiting was the difference between 1985 and 1986 seasons (Table 3). In 1986, both cultivars were in alternate bearing regardless of treatment. 'Mohawk' had very little return bloom, while 'Western' bloomed profusely. The reasons for the large return bloom on 'Western' is unknown. The 'Mohawk' trees may have been affected by very wet soil in that part of the orchard.

Cluster size in 1986 was not affected by the 1985 treatments in either cultivar (Table 4). The lack of response to thinning may be due to the trees' history of alternate bearing. Also, the extremely wet weather in 1985 contributed to pecan scab (<u>Fusicladium</u> <u>effusum</u> (Wint.)) on 'Western', and this effect has not been evaluated. This study may require up to 5 years to complete, since fruiting is extremely variable on pecan. Several years of thinning may be necessary to stablize alternate bearing and show the effects of fruit thinning.

LITERATURE CITED

1. Amling, H.J. 1968. Shoot growth and pecan fruiting. Proc. S.E. Pecan Growers Assn. 52:45-48.

2. Bain, J.M., and R.N. Robertson. 1951. The physiology of growth of apple fruits I. Cell size, cell number, and fruit development. Aust. J. Sci. Res. 4:75-91.

3. Davis, J.T., and D. Sparks. 1974. Assimilation and translocation patterns of Carbon-14 in the shoot of fruiting pecan trees, _Carya illinoensis_ Koch. J. Amer. Soc. Hort. Sci. 99:468-480.

4. Hunter, J.H. 1968. The relation of yield and quality in pecans. Proc. S.E. Pecan Growers Assn. 158-159.

5. Lockwood, D.W., and D. Sparks. 1978. Translocation of ^{14}C in 'Stuart' pecan in the spring following assimilation of $^{14}CO_2$ during the previous growing season. J. Amer. Soc. Hort. Sci. 103:38-45.

6. Malstrom, H.L., and D. Sparks. 1973. Analysis of yield components in mature trees of 'Schley' pecan, _Carya illinoensis_ Koch. J. Amer. Soc. Hort. Sci. 98: 496-500.

7. Malstrom, H.L., and J.L. McMeans. 1982. Shoot length and previous fruiting affect subsequent growth and nut production of 'Moneymaker' pecan. HortScience 17:970-972.

8. Sitton, B.G. 1931. A preliminary report on the relation of foliage to filling of the pecan. Nat. Pecan Growers Assn. Bul. 25:42-46.

9. Smith, C.L., and J.G. Waugh. 1938. Seasonal variations in the carbohydrate and nitrogen content of roots of bearing pecan trees. J. Agr. Res. 57:449-460.

10. Smith, M.W., R.W. McNew, P.L. Ager, and B.C. Cotten. 1986. Seasonal changes in the carbohydrate concentration in pecan shoots and their relationship to flowering. J. Amer. Soc. Hort. Sci. 111:558-561.

11. Sparks, D. 1974. The alternate fruit bearing problem in pecans. Northern Nut Growers Assn. Proc. 47:80-85.

12. Sparks, D. 1966. A rapid method for estimating the leaf area of the Stuart pecan, Carya illinoensis Koch. HortScience 1:93-94.

13. Sparks, D., and C.E. Brack. 1972. Return bloom and fruit set of pecan from leaf and fruit removal. HortScience 1:131-132.

14. Thompson, T.E. 1983. Genetic variability in pecan fruit development. HortScience 18:955-957.

15. Wood, B.W. 1986. Cold injury susceptibility of pecan as influenced by cultivar, carbohydrates, and crop load. HortScience 21:285-286.

16. Wood, B.W. 1983. Fruit thinning of pecan with ethephon. HortScience 18:53-54.

17. Worley, R.E. 1979. Fall defoliation date and seasonal carbohydrate concentration of pecan wood tissue. J. Amer. Soc. Hort. Sci. 104:195-199.

18. Worley, R.E., W.A. Harmon, and R.L. Carter. 1972. Correlation among growth, yield, and nutritional factors for pecan (Carya illinoensis W. cv. Stuart): Correlations with yield, quality, and terminal shoot growth. J. Amer. Soc. Hort. Sci. 97:511-514.

Table 1. 'P' values for comparisons of means for thinning to two fruits per cluster with no thinning on 'Mohawk' and 'Western' in 1985[z].

Cultivar	Week of thinning[y]	Leaf area per fruit	Nut mass	Percent kernel
'Mohawk'	2	.903	.130	.312
'Western'	2	.280	.014*	.280
'Mohawk'	6	.115	.068	.812
'Western'	6	.449	.316	.445
'Mohawk'	10	.707	.056	.518
'Western'	10	.010**	.241	.510

[z]Significantly different from unthinned control, * = .05 level, ** = .01 level.

[y]Weeks after anthesis.

Table 2. Pearson correlation coefficients (r) and 'P' values for correlations of leaf area per fruit with mean nut mass and percent kernel for 'Mohawk' and 'Western' in 1985.[z]

Cultivar	Mean nut mass 'r'	Mean nut mass 'P'	Percent kernel 'r'	Percent kernel 'P'
'Mohawk'	.625***	.001	.286	.175
'Western'	.163	.388	-.235	.211

[z]*** = significant at .001 level.

Table 3. Means for 'Mohawk' and 'Western' for 1985 and 1986

	'Mohawk'		'Western'	
Parameter	1985	1986	1985	1986
Fruiting Shoots	11.9± 3.0[z]	3.6± 1.3	23.5± 1.9	25.9± 1.8
Vegetative Shoots	21.4± 2.5	39.9± 7.1	22.0± 2.4	26.1± 2.3
Total Shoots	33.3± 3.4	51.3± 6.6	45.5± 2.3	52.0± 3.0
Percent Fruiting Shoots	33.5± 7.0	8.2± 3.0	52.5± 3.9	50.4± 3.1
Number of Fruit per Limb	45.8±12.4	16.4± 6.6	65.8± 6.2	104.5± 9.0
Fruit per Shoot	1.2± 0.3	0.4± 0.2	1.5± 0.1	2.0± 0.2

[z]Means and standard errors.

Table 4. Comparison of control to other 1985 treatments for cluster size in 1986

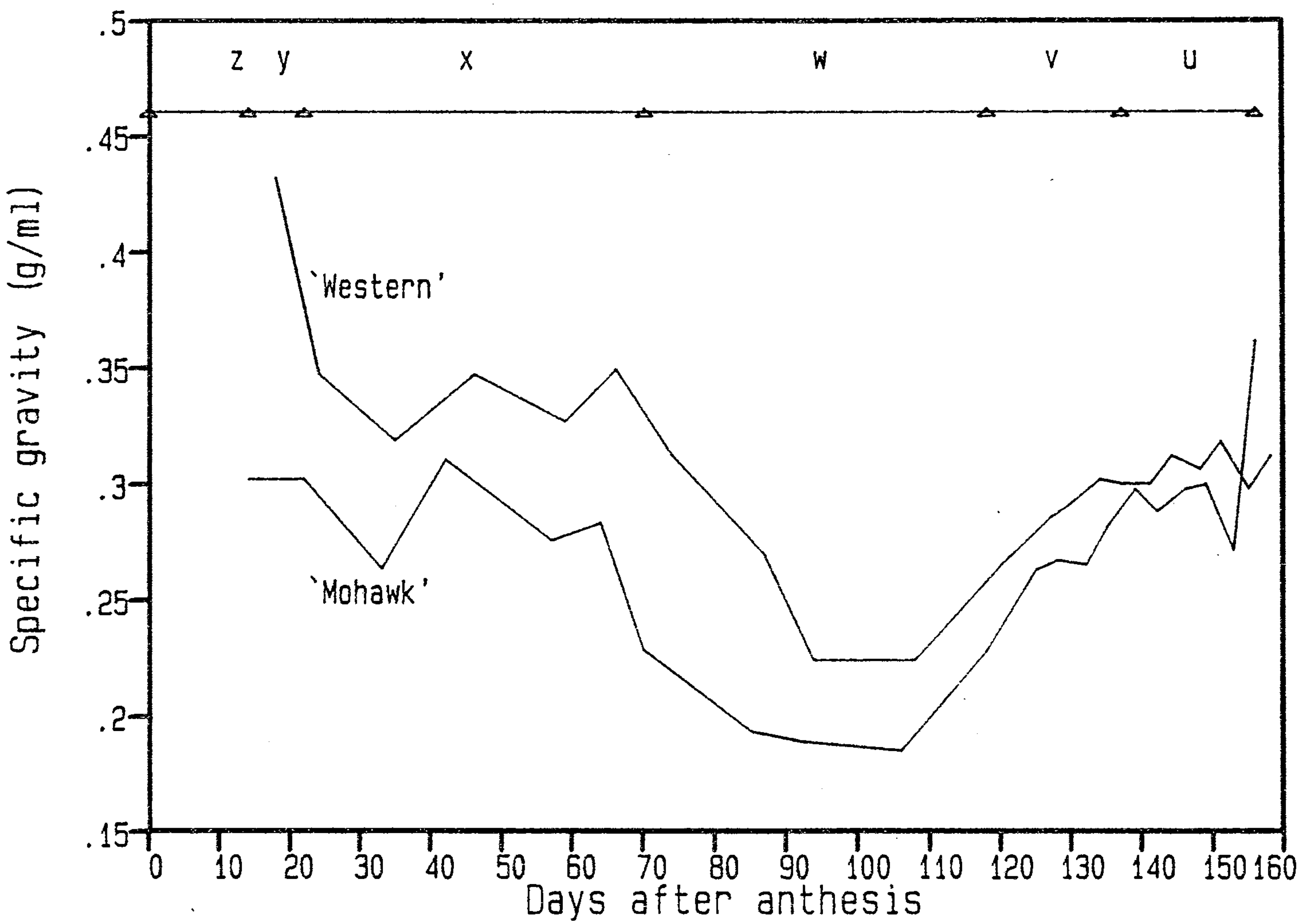
Treatment		Fruit Number/Cluster^z	
Week^y	Amount^x	'Mohawk'	'Western'
Not thinned		2.9	3.1
2	0	2.4	3.4
2	2	2.5	3.1
6	0	2.7	3.4
6	2	2.5	3.1
10	0	2.5	3.4
10	2	2.3	3.2

^{z}Least square means

^{y}Weeks after anthesis

^{x}Number of fruit left per cluster

Figure 1. Specific gravity and development of 'Mohawk' and 'Western' fruit from bloom until harvest. z = bloom, y = cell division, x = cell elongation, w = liquid endosperm, v = enlargment of cotyledons, u = maturation.


z
y
x
w
v
u
`Western'
`Mohawk'
Specific gravity (g/ml)
.5
.45
.4
.35
.3
.25
.2
.15
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Days after anthesis

CHAPTER IV

DEVELOPMENT OF FRUIT THINNING GOALS FOR PECAN: EFFECTS OF PERCENT FRUITING SHOOTS ON FRUIT QUALITY AND RETURN BLOOM

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Key Words: _Carya illinoensis_, fruit thinning, fruit quality, return bloom, alternate bearing

Abstract. The purpose of this study was to determine whether thinning fruit of pecan (_Carya illinoensis_ (Wangenh.) C. Koch) by removing clusters to leave 25% or 50% fruiting shoots would encourage annual cropping. This is the first year's data from a five year experiment. 'Mohawk' and 'Western' cultivar pecan trees were used. Although some differences were found between control and thinning treatments for cluster size, flower number, and percent fruiting shoots, these differences did not form a recognizable pattern. The largest differences found were between the 1985 and 1986 seasons. Neither cultivar showed differences between control and thinning treatments for mean nut mass or percent kernel.

Alternate bearing is the most severe problem facing pecan growers (10). It is characterized by a pattern of a large crop followed by one or more years of very small crops (4,10). Proposed causes for alternate bearing include production of substances by pecan fruit which inhibit

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formation of pistillate flowers the next season (10,15), a flower promoting substance produced by leaves (17), and lack of sufficient carbohydrate reserves following a large crop to support flowering the following year (8,10,16). The carbohydrate reserves are related to the amount of leaf area per fruit.

Leaf area per fruit has been measured for several cultivars (5,7,10). The optimum shoot length for fruiting is different between cultivars (1,7,13), and may be different within cultivars from year to year (11). Optimum leaf:fruit ratios have been estimated, but branch ringing was used to restrict translocation between shoots (7). This may give a biased estimate since ringing restricts photosynthetic rates, and may decrease flowering (4). Leaf areas may be estimated by sampling vegetative and fruiting shoots for a particular season, and then using linear regression analysis to obtain an appropriate equation (11). In general, as leaf area per fruit increases, the fruit size and kernel percent of the fruit also increases (5,6,7,10).

Another factor which is closely related to leaf area per fruit, fruit size, and kernel percent is the total crop load of the tree. Crop size is inversely related to fruit size and kernel percent (5). Adequate data are not available to determine optimum leaf to fruit ratios for each cultivar. These ratios may vary with economic conditions (2). The association of high yields with poor quality fruit may make large crops undesirable (2,7,18) Furthermore, high yields of fruit year after year may be impossible to achieve due to alternate bearing (10) and winter damage (14).

Pecan yield for one season is negatively correlated with pecan yield for the previous season (10). Large crops of fruit reduce available carbohydrates for fruit development and stored reserves for the next season's growth and flowering (8). This results in a weakened tree, decreased winter hardiness and poor initiation of growth and pistillate flower differentiation early the next spring (8,14).

Alternate bearing occurs on whole trees and on individual shoots within a tree (5,6). Shoots which did not produce fruit the previous year had more pistillate lowers (4,7) and yielded more nuts at harvest (6) than shoots which fruited the previous year. It may be argued that one can estimate effects of treatment for whole trees by treating individual shoots or limbs, if it is assumed that the influence of the individual shoots or limbs on others is minimal.

Studies have shown that carbohydrates synthesized in a pecan shoot during one growing season tend to return to the same shoot and to shoots in direct line with that shoot the next season (4). This would seem to indicate that the treatment of individual branches as experimental units would be justified without concern about the influence of branches upon each other.

Thinning of pecan fruit is a logical way to increase leaf area per fruit, which should increase fruit size and degree of filling (12). In typical situations, thinning has been shown to increase return bloom and fruit set, the size and weight of fruits, and the yield of the tree throughout its life (12).

The stage of fruit development at which thinning should be done may vary with cultivar due to different rates of fruit growth (13). However, most cultivars exhibit a pattern of filling in which the increase in size of the cotyledons occurs during the last three months of fruit development (2). Thinning prior to this rapid transport of carbohydrates to the fruit would be expected to result in the greatest amount of carbohydrate storage and flower induction.

The research project discussed herein involves thinning of pecan fruit. The objectives of this research were to determine the effects of pecan fruit thinning intensity and time on fruit quality and return bloom the next season. Factors considered include: time of thinning, leaf area to fruit ratio, amount of thinning, and how thinning based on the number of fruit per cluster affects yield, quality, and return bloom.

Materials and Methods

The thinning treatments included control (no thinning), thinning to leave about 50% fruiting shoots, thinning to leave about 25% fruiting shoots, and removal of all fruit.

The 50% treatment was not applied on 'Mohawk' due to insufficient fruiting shoots. Thinning treatments were applied at about two weeks, six weeks, and ten weeks after anthesis. A randomized complete block design, was used, using trees as blocks. There were 3 'Mohawk' and 5 'Western' trees in the experiment. Individual clusters were tagged on control branches, and the number of fruits in individual clusters was recorded. Numbers of fruits dropped naturally and the stage of maturity of the fruits were also observed throughout the season, and developing fruits were sampled to obtain specific gravity curves. Leaf areas were estimated (see Chapter 2), and leaf area per fruit were calculated for each limb. At harvest, data on nut mass and kernel percent were recorded in order to determine the productivity of individual limbs. Wet weather prevented final yield and nut count data being taken in 1985.

The next spring, return bloom was recorded for each of the limbs. Thinning treatments were compared to no thinning for the amount of return bloom.

Results and Discussion

Specific gravity curves indicated that the two-weeks after anthesis thinning occurred during cell division, while the six and ten-weeks after anthesis thinnings were during cell elongation (Chapter 3).

In 1985, thinning to 25% fruiting shoots increased mean leaf area per fruit in both 'Mohawk' ($P \geq .01$) and 'Western)

(P $\geq$ .0001) (Table 1). In 'Mohawk', leaf area per fruit was positively correlated with average nut size (P $\geq$ .01) but no significant correlation was found for 'Western' (P $\geq$ .05) (Table 2). Percent kernel was not affected by leaf area per fruit (Table 2). Thinning did not affect mean nut mass or percent kernel in either cultivar (Table 1).

In 1986, return bloom was assessed on all limbs, including the limbs which were entirely defruited in 1985. Flowers were counted on 'Western' as soon as possible after anthesis, but wet weather prevented data being taken on 'Mohawk' trees until several weeks later. Therefore, fruit counts for 'Mohawk' are for ten week old fruit, while those for 'Western' are flowers.

Return bloom data indicated that the most significant effect on fruiting was the difference between 1985 and 1986 seasons (Table 3). In 1986, both cultivars were in alternate bearing, regardless of treatment. 'Mohawk' had very little return bloom, while 'Western' bloomed profusely The reasons for the large return bloom on 'Western' is unknown. The 'Mohawk' trees may have been affected by very wet soil in that part of the orchard.

Although some significant differences were found for 'Western' between control and other treatments for cluster size, total number of flowers, and percent fruiting shoots in 1986 (Table 4), these differences did not form a recognizable pattern. Reasons for these differences are unknown. Since only 4 limbs of 'Mohawk' fruited, no reliable tests could be done for that cultivar.

The lack of response to thinning may be due to the trees' history of alternate bearing. Also, the extremely wet weather in 1985 contributed to pecan scab (*Fusicladium effusum* (Wint.)) on 'Western'. This study may require up to 5 years to complete, since fruiting is extremely variable on pecan. Several years of thinning may be necessary to stablize alternate bearing and show the effects of fruit thinning.

LITERATURE CITED

1. Amling, H.J. 1968. Shoot growth and pecan fruiting. Proc. S.E. Pecan Growers Assn. 52:45-48.

2. Davis, J.T., and D. Sparks. 1974. Assimilation and translocation patterns of Carbon-14 in the shoot of fruiting pecan trees, Carya illinoensis Koch. J. Amer. Soc. Hort. Sci. 99:468-480.

3. Hunter, J.H. 1968. The relation of yield and quality in pecans. Proc. S.E. Pecan Growers Assn. 158-159.

4. Lockwood, D.W., and D. Sparks. 1978. Translocation of ^{14}C in 'Stuart' pecan in the spring following assimilation of $^{14}CO_2$ during the previous growing season. J. Amer. Soc. Hort. Sci. 103:38-45.

5. Malstrom, H.L., and D. Sparks. 1973. Analysis of yield components in mature trees of 'Schley' pecan, Carya illinoensis Koch. J. Amer. Soc. Hort. Sci. 98: 496-500.

6. Malstrom, H.L., and J.L. McMeans. 1982. Shoot length and previous fruiting affect subsequent growth and nut production of 'Moneymaker' pecan. HortScience 17:970-972.

7. Sitton, B.G. 1931. A preliminary report on the relation of foliage to filling of the pecan. Nat. Pecan Growers Assn. Bul. 25:42-46.

8. Smith, C.L., and J.G. Waugh. 1938. Seasonal variations in the carbohydrate and nitrogen content of roots of bearing pecan trees. J. Agr. Res. 57:449-460.

9. Smith, M.W., R.W. McNew, P.L. Ager, and B.C. Cotten. 1986. Seasonal changes in the carbohydrate concentration in pecan shoots and their relationship to flowering. J. Amer. Soc. Hort. Sci. 111:558-561.

10. Sparks, D. 1974. The alternate fruit bearing problem in pecans. Northern Nut Growers Assn. Proc. 47:80-85.

11. Sparks, D. 1966. A rapid method for estimating the leaf area of the Stuart pecan, Carya illinoensis Koch. HortScience 1:93-94.

12. Sparks, D., and C.E. Brack. 1972. Return bloom and fruit set of pecan from leaf and fruit removal. HortScience 1:131-132.

13. Thompson, T.E. 1983. Genetic variability in pecan fruit development. HortScience 18:955-957.

14. Wood, B.W. 1986. Cold injury susceptibility of pecan as influenced by cultivar, carbohydrates, and crop load. HortScience 21:285-286.

15. Wood, B.W. 1983. Fruit thinning of pecan with ethephon. HortScience 18:53-54.

16. Worley, R.E. 1979. Fall defoliation date and seasonal carbohydrate concentration of pecan wood tissue. J. Amer. Soc. Hort. Sci. 104:195-199.

17. Worley, R.E., W.A. Harmon, and R.L. Carter. 1972. Correlation among growth, yield, and nutritional factors for pecan (Carya illinoensis W. cv. Stuart): Correlations with yield, quality, and terminal shoot growth. J. Amer. Soc. Hort. Sci. 97:511-514.

Table 1. 'P' values for comparisons of means for thinning to 25% or 50% fruiting shoots with no thinning on 'Mohawk' and 'Western' in 1985.

Cultivar	Thinning Week[y]	Thinning Percent[x]	Leaf area per fruit	Nut mass	Percent kernel
'Mohawk'	2	25	.0190*	.8115	.5671
'Mohawk'	6	25	.1962	.1751	.1287
'Mohawk'	10	25	.0168*	.0175*	.0889
'Mohawk'	all[w]	25	.0070**	.0560	.0770
'Western'	2	25	.0001****	.9327	.5406
'Western'	6	25	.0001****	.0831	.7719
'Western'	10	25	.0162*	.4662	.9242
'Western'	all	25	.0001****	.5958	.7034
'Western'	2	50	.1810	.6621	.5377
'Western'	6	50	.6838	.3903	.8962
'Western'	10	50	.1024	.5685	.6498
'Western	all	50	.1127	.6386	.9876

[z]Significantly different from unthinned control: * = .05 level, ** = .01 level, *** = .001 level, **** = .0001 level.

[y]Weeks after anthesis.

[x]Percent fruiting shoots left.

[w]Average over all weeks for that thinning level.

Table 2. Pearson correlation coefficients (r) and 'P' values for correlations of leaf area per fruit with mean nut mass and percent kernel for 'Mohawk' and 'Western' in 1985[z].

Cultivar	Mean nut mass 'r'	Mean nut mass 'P'	Percent kernel 'r'	Percent kernel 'P'
'Mohawk'	.642**	.003	.442	.058
'Western'	.069	.652	.044	.772

[z]** = significant at .01 level.

Table 3. Means and standard errors for 'Mohawk' and 'Western' for 1985 and 1986

Parameter	'Mohawk' 1985	'Mohawk' 1986	'Western' 1985	'Western' 1986
Fruiting Shoots	11.8 ± 1.9	0.4 ± 0.4	25.1 ± 2.1	25.5 ± 2.4
Vegetative Shoots	18.9 ± 3.0	43.1 ± 5.8	19.8 ± 1.5	20.6 ± 2.5
Total Shoots	30.7 ± 4.3	43.6 ± 5.6	45.0 ± 3.0	45.6 ± 3.3
Percent Fruiting Shoots	39.0 ± 2.9	1.5 ± 1.5	55.3 ± 2.6	56.7 ± 4.0
Number of Fruit per Limb	40.6 ± 5.9	1.6 ± 1.6	63.7 ± 5.5	95.0 ± 9.8
Fruit per Shoot	1.3 ± 0.1	0.1 ± 0.1	1.4 ± 0.1	2.1 ± 0.2

Table 4. Comparison of control to other treatments on 'Western' in 1986[z]

Treatment		Fruit per Cluster[w]	Flowers per limb	Percent Fruiting Shoots
Week[y]	Amount[x]			
Not thinned		3.2	95.0	65.4
2	0	3.2	130.8	75.5
2	25	3.3	89.2	66.3
2	50	3.2	105.2	70.8
6	0	3.3	110.2	82.6*
6	25	2.8	78.2	72.7
6	50	3.3	87.0	74.0
10	0	3.8**	120.2	82.3*
10	25	2.7*	45.0**	52.3
10	50	2.8	105.4	72.8

[z]Significantly reduced compared to unthinned control, * = .05 level, ** = .01 level, *** = .001 level, **** = .0001 level.

[y]Weeks after anthesis

[x]Percent fruiting shoots left

[w]Least square means

CHAPTER V

SUMMARY

The research project discussed herein involves thinning of pecan fruit. The objectives of this research were to determine the effects of pecan fruit thinning intensity and time on fruit quality and return bloom the next season. Factors considered include: time of thinning, leaf area to fruit ratio, amount of thinning, and whether thinning should be based on proportion of fruiting shoots (thinning by terminal) or on fruiting intensity (thinning by cluster).

This research project required three experiments. The first study was used to determine the best way to estimate leaf areas on the experimental units. Counting leaves was compared to measuring shoot length. Samples were taken separately for vegetative and fruiting shoots of 'Mohawk' and 'Western' cultivar pecan trees. Regression analysis showed that counting leaves provided the better estimate of leaf area. The relationships for 'Mohawk' were different from those for 'Western', but the relationships between leaf area and shoot length were linear for fruiting shoots and quadratic for vegetative shoots in both cases.

The second study was used to determine whether thinning fruit of pecan by removing fruit from clusters would encourage annual cropping. 'Mohawk' and 'Western' cultivar trees were used. Thinning to two fruits per cluster did not affect mean leaf area per fruit or mean nut mass in either cultivar. Percent kernel was increased by the two-weeks after anthesis thinning in 'Western', but was not affected in 'Mohawk'. The most significant effect on bloom was the difference between 1985 and 1986 seasons. In 1986, 'Western' bloomed profusely and 'Mohawk' bloomed very little regardless of treatment.

The purpose of the third study was to determine whether thinning pecan fruit by removing clusters to leave 25% or 50% fruiting shoots would encourage annual cropping. 'Mohawk' and 'Western' cultivar pecan trees were used. Neither cultivar showed differences between control and thinning treatments for mean nut mass or percent kernel. Although some differences were found between control and thinning treatments for cluster size, flower number, and percent fruiting shoots, these differences did not form a recognizable pattern. The largest differences found were between the 1985 and 1986 seasons.

One reason that thinning was not effective in most cases was that leaf area per fruit was not affected by the thinning treatments.

SELECTED BIBIOLGRAPHY

1. Ackley, W.B., P.C. Crandall, and T.S. Russell. 1958. The use of linear measurements in estimating leaf areas. Am Soc. Hort. Sci. Proc. 72:326-30.

2. Amling, H.J. 1968. Shoot growth and pecan fruiting. Proc. S.E. Pecan Growers Assn. 52:45-48.

3. Bain,J.M., and R.N. Robertson. 1951. The physiology of growth of apple fruits I. Cell size, cell number, and fruit development. Aust. J. Sci. Res. 4:75-91.

4. Barlow, H.W.B. 1980. The relationship between leaf size and shoot length in apple. J. Hort. Sci. 55:269-283.

5. Chacko, E.K., Y.T.N. Reddy, and T.V. Ananthanarayanan. 1982. Studies on the relationship between leaf number and area and fruit development in mango (*Mangifera indica* L.) J. Hort. Sci. 57:483-492.

6. Crane, H.L. 1930. Terminal growth in relation to fruiting in the pecan. Nat. Pecan Assn. Bul. 29:24-32.

7. Crane, H.L., M.B. Hardy, N.H. Loomis, and F.N. Dodge. 1934. Effect of nut thinning on size, degree of filling, and annual yields of pecans. Proc. Amer. Soc. Hort. Sci. 32:29-32.

8. Davis, J.T., and D. Sparks. 1974. Assimilation and translocation patterns of Carbon-14 in the shoot of fruiting pecan trees, *Carya illinoensis* Koch. J. Amer. Soc. Hort. Sci. 99:468-480.

9. Davis, L.D. 1957. Flowering and alternate bearing. Proc Amer. Soc. Hort. Sci. 70:545-556.

10. Finch, A.H., and H.L. Crane. 1931. Physiological factors associated with the productiveness of pecan shoots. Nat. Pecan Assn. Bul. 30:98-107.

11. Hinrichs, H.A. 1962. Pecan industry and some research developments in Oklahoma. Northern Nut Growers Assn. Proc. 53:80-85.

12. Hunter, J.H. 1968. The relation of yield and quality in pecans. Proc. S.E. Pecan Growers Assn. 158-159.

13. Isbell, C.L. 1928. Growth studies of the pecan. Ala. Agr. Expt. Sta. Bul. 226:1-63.

14. Lipe, J.A., P.W. Morgan, and J.B. Storey. 1969. Growth substances and fruit shedding in the pecan, *Carya illinoensis*. J. Amer. Soc. Hort. Sci. 94:668-671.

15. Lockwood, D.W., and D. Sparks. 1978. Translocation of ^{14}C in 'Stuart' pecan in the spring following assimilation of $^{14}CO_2$ during the previous growing season. J. Amer. Soc. Hort. Sci. 103:38-45.

16. Malstrom, H.L., and D. Sparks. 1973. Analysis of yield components in mature trees of 'Schley' pecan, *Carya illinoensis* Koch. J. Amer. Soc. Hort. Sci. 98: 496-500.

17. Malstrom, H.L., and J.L. McMeans. 1982. Shoot length and previous fruiting affect subsequent growth and nut production of 'Moneymaker' pecan. HortScience 17:970-972.

18. McKay, J.W. 1945. Embryology of pecan. J. Agr. Res. 74:263-283.

19. Pelham, J.L. 1926. Terminal growth an indicator of cultural requirements in pecan growing. Nat. Pecan Growers Assn. Bul. 25:42-46.

20. Sitton, B.G. 1931. A preliminary report on the relation of foliage to filling of the pecan. Nat. Pecan Growers Assn. Bul. 25:42-46.

21. Smith, C.L., and J.G. Waugh. 1938. Seasonal variations in the carbohydrate and nitrogen content of roots of bearing pecan trees. J. Agr. Res. 57:449-460.

22. Smith, M.W., R.W. McNew, P.L. Ager, and B.C. Cotten. 1986. Seasonal changes in the carbohydrate concentration in pecan shoots and their relationship to flowering. J. Amer. Soc. Hort. Sci. 111:558-561.

23. Sparks, D. 1967. Effect of potassium gibberellate on fruit characteristics and flowering of the pecan, *Carya illinoensis* Koch. cv. 'Stuart'. Proc. Amer. Soc. Hort. Sci. 90:61-66.

24. Sparks, D. 1974. The alternate fruit bearing problem in pecans. Northern Nut Growers Assn. Proc. 47:80-85.

25. Sparks, D. 1966. A rapid method for estimating the leaf area of the Stuart pecan, *Carya illinoensis* Koch. HortScience 1:93-94.

26. Sparks, D., and C.E. Brack. 1972. Return bloom and fruit set of pecan from leaf and fruit removal. HortScience 1:131-132.

27. Sparks, D., and J.L. Heath. 1972. Pistillate flower and fruit drop of pecan as a function of time and shoot length. HortScience 7:402-404.

28. Thompson, T.E. 1983. Genetic variability in pecan fruit development. HortScience 18:955-957.

29. Thor, C.J.B., and C.L. Smith. 1935. A physiological study of seasonal changes in the composition of the pecan during fruit development. J. Agr. Res. 50:97-121.

30. Wood, B., and J. Payne. 1984. Influence of single applications of insecticides on net photosynthesis of pecan. HortScience 19:265-266.

31. Wood, B.W. 1986. Cold injury susceptibility of pecan as influenced by cultivar, carbohydrates, and crop load. HortScience 21:285-286.

32. Wood, B.W. 1983. Fruit thinning of pecan with ethephon. HortScience 18:53-54.

33. Wood, B.W. 1982. Gibberellin-like substances in developing fruits of pecan. HortScience 17:70-71.

34. Woodroof, J.G., N.C. Woodroof, and J.E. Bailey. 1928. Unfruitfulness of the pecan. Ga. Expt. Sta. Bul. 148: 1-40.

35. Worley, R.E. 1979. Fall defoliation date and seasonal carbohydrate concentration of pecan wood tissue. J. Amer. Soc. Hort. Sci. 104:195-199.

36. Worley, R.E. 1979. Pecan yield, quality, nutlet set, and spring growth as a response to time of fall defoliation. J. Amer. Soc. Hort. Sci. 104:192-194.

37. Worley, R.E., W.A. Harmon, and R.L. Carter. 1972. Correlation among growth, yield, and nutritional factors for pecan (*Carya illinoensis* W. cv. Stuart): Correlations with yield, quality, and terminal shoot growth. J. Amer. Soc. Hort. Sci. 97:511-514.

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