THE RELATION OF TERMINAL GROWTH
TO FRUITING IN PECANS

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TO FRUITING IN PECANS

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INTRODUCTION

Without a doubt the pecan is truly the king of nuts. It is the most valuable tree nut grown in the United States and is the only major tree nut native to this country, particularly adapted to the Mississippi Valley (3). In American history, early explorers left accounts of Indian tribes of the Mississippi Valley using as a main source of foodstuff the "pecan" or "pecane" as the Indians called the nut that was so hard it required a stone to crack. The Indians as well as the early day settlers noticed that the pecan has a distinguishing characteristic of producing a heavy crop and a light crop during alternate years.

The pecan industry has not developed to its full potential. Erratic annual production has made the pecan supply unstable, causing fluctuating prices and a variable market. The annual pecan production for Oklahoma has, during the past twenty years, fluctuated yearly from a low of three million pounds per season to a peak of forty-four million pounds.[1] This variation in seasonal production has caused the average price received by Oklahoma growers for seedling pecans to vary from fifteen cents to thirty-two cents per pound in the past ten years. This industry has, nevertheless, increased over the years because of increased consumer demands and higher prices.

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[1]Figures taken from Okla. Agri. Marketing Service, U.S.D.A.

When the grower understands the relationship between optimum terminal shoot growth and maximum production for each variety, he will be in a position to select cultural practices accordingly. The work reported herein is concerned with the production that can be expected from the certain variations in one year old terminal growth. Within this study, terms such as length, diameter, number of nodes, amount of late growth, and whether twigs produced pecans the previous years were used as descriptive characteristics and measurements of terminal growth.

The objectives of this study are to:

(a) determine the optimum terminal growth for production in pecans,

(b) determine the range of terminal growth on which production occurs, and

(c) determine the differences of productive terminal growth between varieties.

REVIEW OF LITERATURE

Growth is an outward expression of the nutritional condition within the tree and is an evident measure of tree vigor (9). Many pecan orchards vary in their growth characteristics and production schedule. In 1930, Crane (4) of the United States Pecan Field Station, Albany, Georgia, found that some orchards decline in production with years. Others maintain a rather constant but erratic biennial type bearing while still others increase in production with age. Some factors that affect these various production habits are moisture, insects, diseases, and nutritional condition such as the carbohydrate-nitrogen content balance of the shoots. One of the more important factors is the physiological condition of the tree as indicated by the termination growth (4).

The general condition represented by the growth range of a tree may be termed its physiological age. This does not necessarily coincide with its age in years. Gossard (9) in 1954, suggested that the best physiological age and range of growth for a pecan tree would provide sufficient vigor to produce eight-inch terminal shoots. These should be capable of producing male and female flowers and strong non-blossoming shoots the following year. In similar fashion, the inner branches should produce thick four-inch shoots capable of fruiting. These conditions would provide for more even distribution of the crop over the tree.

Length of terminal growth is the characteristic most commonly observed by growers who associate it with nutrition and tree vigor. Isbell (17) concluded that diameter of shoots and number and quality of leaves should, also, be important measuring traits. Growers commonly observe shoots on main branches as an index in making observations regarding production. Crane (4) reported that the terminals on main branches of the periphery of the tree are usually longer and more vigorous than the inside lateral shoots. This suggests that all shoots should be observed in order to more closely determine nutrition and vigor.

Trees that are slow coming into bearing are usually the ones that do not produce on long shoots. Heavy production must await shoots of medium length as young trees usually produce long shoots and old trees tend to produce short shoots.

Crane (4), in his work with terminal growth, found a large variation in shoot growth on the same tree. On older trees the majority of the shoots were less than one inch long and were slender. These shoots had short internodes with small leaves at the end of main branches. Some shoots were over two feet in length and willowy, varying in diameter from tip to base and had long internodes.

Isbell (17) in 1928, and Ambling (1) in 1959, reported the following similar results: (a) very short and long shoots as a rule are not fruitful, (b) some varieties fruit over a longer length range than others, and (c) within each variety there appears to be an optimum shoot length range for optimum fruit production. Isbell (17) further stated that the longer shoots within the productive length range produce more nuts. Ambling (1) also found, with the exception of the Stuart variety, fifty percent of the non-productive shoots fell within the optimum shoot length range. From this there appears to be something other than shoot length that is indicative of and responsible for production. According to Isbell (17), the Stuart variety produces over a wide range of growth length and partly for this reason it is the most popular variety planted because it is better adapted to various growing conditions.

Ambling (1) hypothesized that as the productive length range decreases, the more ideal the environmental conditions must be for the variety to bear heavy crops of well-filled nuts, since these trees are usually low in vigor.

Very weak short shoots usually die after catkins fall (17). Gossard (8) pointed out that shoots of limited growth rate and of little total growth drop most of the blossoms or nuts before they are matured. Crane (4), also, found similar results when he noted that nuts set on short shoots are the first to drop either from physiological trouble such as dry weather or from insects and disease.

Isbell (17), while studying the characteristics of secondary growth which has reference to late growth, noted that long shoots which did not abscise terminal buds of the primary growth tend to make second growth and are not likely to fruit the following season. On the other hand, he hypothesized that the abscission of the terminal bud increased food reserves in the lateral buds with subsequent initiation of pistillate flowers the following year. Isbell also noted the following differences: (a) the number of catkins and nut clusters per shoot increased with secondary growth, (b) there were more catkins, nuts, and nut clusters on secondary growth than primary growth of the same shoot, (c) average weight per nut was greater while the average weight per cluster was less where there was no secondary growth, (d) shoots which carried the greatest number of nuts were more likely to produce secondary growth, (e) he noted that secondary growth was associated with heavy rainfall during the early growing period, whereas, (f) rain which occurred in late summer primarily influenced the filling of and total weight of nuts.

Overholser, Overley, and Barnhill (19), in their work with twenty-seven year old apple trees, reported that conditions favoring greater terminal growth during any one year favored greater production the same year. The higher level of nutrition was more favorable for fruit set and thereby decreased the tendency for abscission. These conditions also favored terminal growth and, in turn, more leaves to provide more carbohydrates for maturing the crop. HofMann (13), working with York Imperial apples, also found there are significant relationships between terminal growth in apples and yield. Approximate or comparative degrees of production potentialities can be determined from this.

In pecans, the size of buds below nut clusters and the more terminal ones on non-fruiting shoots are good indications of next year's female flowering potential. Isbell (17) found that buds toward the terminal section of the shoot become very much larger than those toward the basal section of the shoot.

Buds are formed the previous year and during the winter chemical changes take place, which, depending on the amount and kind of food reserves, determine whether buds will produce pistillate flowers or non-blossoming shoots. Gourley (10) noted that flower formation was the result of a flower-forming substance, presumably of the nature of carbohydrate. He also noted that the carbohydrate and nitrogen balance must be maintained within certain levels. Smith and Waugh (23) found that, due to a large crop one year, the carbohydrate content of pecan roots in the fall was low. This was presumed to be due to the use of most of the available carbohydrate reserves for filling of the pecans. This low level of carbohydrate in the fall in turn resulted in limited pistillate flower formation the following spring.

Excess vegetative growth resulted in little or no blossoming and nut production (9). Under these conditions the level of nitrogen to carbohydrates was high. Less nitrogen and more carbohydrates were needed for extensive blossom bud production. On the opposite end of the scale, short non-vigorous shoots were non-productive. Between the levels of maximum and minimum growth, well-filled crops were produced and a favorable nitrogen-carbohydrate balance was maintained which would, also, produce a satisfactory yield the following year.

In 1931, Finch (7) in Georgia, was of the opinion that part of the difference in productivity might be due to nutritional variation between shoots. He noted that short weak shoots were relatively high in carbohydrates. Crane and Finch (5) found that there was no starch in any of the shoots in early summer whereas starch content reached a maximum in the fall.

Dodge (6) in 1946, concluded, from work performed in Louisiana on fourteen year old trees, that a ratio of ten or more leaves per nut is necessary for proper development of most varieties. Due to differences in environmental conditions and decreased efficiency, more leaves are required per nut to develop in some years than in others.

Hinrichs (11) in Oklahoma conclusively demonstrated the value and relationship of leaves for flower formation the following year. He found that removal of leaves from the tree, between August 15 and September 15, greatly reduced the number of catkin flowers and prevented the development of pistillate flowers the following year. Hinrichs concluded that normal functioning leaves should be allowed to remain on the trees until October 15 for satisfactory differentiation and development of flowers. Ambling (1) agreed by saying that early defoliation and cessation of stored food reserves limited yield the following year.

Crane (4) noted there was a definite link between leaves, shoots, and nuts. Large, dark green leaves produce vigorous shoots which thicken in the fall. They should also produce an elaborate supply of food materials for fruit bud formation and higher yields.

In 1927, Shuhart (21), in a study of flower formation and development at Oklahoma A & M, found that hindering the downward flow of food materials increased pistillate blossom set. This interference of downward flow of manufactured sap can be brought about by bending down and tying the limbs of trees. Nature brings about the same results by a drouthy condition which results in bending limbs and, also, by injury to the roots caused by insects or disease. In the spring, irrigation of bearing trees should be delayed until after fruit set. In similar fashion, turning under cover crops too early in wet springs is harmful to optimum fruit set.

In 1924, Woodroof (25) in Georgia suggested that nutritive conditions of the soil and vitality of the tree should be optimal in early summer. During April and May the following four-fold draft is made upon a tree: (a) catkins are developing pollen, (b) pistillate flowers are rapidly developing, (c) catkin buds for pollen next year are being differentiated, (d) vegetative shoots are rapidly growing.

A certain amount of vigorous growth is necessary for abundant set and maturity, though many growers are afraid to increase vigor by fertilizing because of unfruitfulness. Crane (4) in 1930, assured growers that there is little danger of the trees which are coming into bearing becoming too vigorous.

Hunter and Lewis (14) in Georgia found in 1942, that fertilizer applied in April and June stimulated vegetative activity and prevented accumulation of starch needed for the nut filling process later on. They found that vigor and yield could be increased economically by a single application of fertilizer in February.

Hinrichs (12) in 1961, and Zimmerman (26) in 1963, found that maximum production occurred when the density of the trees was thirty square feet of cross-sectional trunk area per acre measured at breast height. Thinning of the trees in many thickly growing groves was necessary to obtain increased production per tree and per acre.

Childers (2) stated that in New Mexico alternate bearing was not a major problem in the eastern area where the Pecan Nut Casebearer destroyed a portion of the nuts and as a result thinned the crop. However, working with three standard varieties, he found that alternate bearing was not corrected by experimentally thinning nuts within the clusters. The thinning of nuts on the trees resulted in an increase in the size of kernel. It is possible, where alternate bearing is a problem, that overall moderate pruning to reduce the number of pistillate flowers before an expected heavy crop would help to control irregular bearing. Chemical thinning is effective in apples to control bearing and eventually may be used in pecans. Gourley (10) reported that fruitfulness can be increased by pruning trees deficient in nitrogen, whereas pruning young vigorous trees tends to delay fruiting.

Gossard (9) states that insects, hail, diseases, and other similar natural causes may bring about crop failures, but they do not directly cause irregular bearing in the pecan. These environmental effects may, on the other hand, contribute to irregular bearing by upsetting the nutritional balance within the trees. Healthy pecan trees, with reasonable crops, may produce a reserve food supply which is the principal factor associated with regularity of bearing.

According to Finch (7), biennial bearing can be overcome when potentially productive shoots dominate the tree. Isbell (17) reported that the correct pecan management practice was to handle trees where a larger percent of shoot growth falls within an optimum productive growth range for that variety.

The nature of the terminal growth of trees appears to be the principal measuring stick of success or failure in pecan production. Because of different fruiting habits and other varietal differences, it appears that each variety should be considered separately when determining specific fertilizer and cultural needs.

MATERIALS AND METHODS

The work reported herein was conducted at the Oklahoma State University Horticulture Research farm at Stillwater and the Pecan Research Station at Sparks.

In October of 1963, three hundred terminal shoots were tagged on each of the varieties Stuart, Western, Burkett, and Success. The tags were white, one inch by one and a quarter inches, and attached by light twine string. String was used rather than wire to minimize the tag's pulling free from the wire; also, the use of string would not necessitate the removal of the tags manually from the shoots upon completion of the work.

Two hundred terminal shoots were tagged on two Stuart trees at Stillwater and one hundred on two Stuart trees at Sparks. Three hundred Burkett shoots were tagged on two trees at Stillwater. Two hundred and fifty shoots were tagged on two Success trees at Stillwater and fifty shoots on two Success trees at Sparks. The three hundred Western shoots were tagged on three trees at Sparks.

Stuart and Success shoots were tagged at both locations. This was to determine if there was difference in production between the younger trees at Sparks and the older trees at Stillwater.

From each tagged terminal shoot, the following information was obtained: (1) length in inches, (2) diameter in centimeters between the fourth and fifth nodes from the terminal, (3) number of nodes from the base to the apex of the primary growth or late growth, and (4) whether a cluster of pecans had been produced in 1963. The tags were placed on the shoots that could be reached from the ground beginning on the east side of the tree and continuing counter clockwise.

The diameter measurement was close enough to the apex that most shoots would contain at least this many nodes. The number of nodes represents the number of leaves, however, occasionally some of the basal nodes were found void of leaves at the time of counting. The amount of secondary growth as well as the knowledge of production in 1963 was recorded to determine whether this influenced the production in 1964.

The Stuart and Burkett trees at Stillwater used in this work were planted in 1922, and the Success trees were planted in 1933. The Western and Stuart trees used at the Pecan Research Station were planted in 1951, while the Success trees were planted in 1950.

Soil management consisted of clean cultivation during the summer months and a cover crop during the winter and spring months. The trees under this soil management system had good foliage at the close of the 1963 growing season.

During the 1963 growing season, March through October, the precipitation recorded at the Sparks station was 21.64 inches. The monthly distribution of precipitation was as follows: March, 1.69 inches; April, 5.10 inches; May, 2.60 inches; June, 3.10 inches; July, 2.1 inches; August, 1.14 inches; September, 2.60 inches, October, 2.07 inches.

The trees growing at Stillwater received 24.76 inches precipitation during the months from March through October in 1963. Distribution was as follows: March, 1.91 inches; April, 3.18 inches; May, 3.78 inches; June, 1.78 inches; July, 4.85 inches; August, 3.16 inches; September, 3.03 inches; October, 2.07 inches.[1]

In May of 1964, each tagged shoot was observed and a record kept indicating whether it had set pecans.

[1]Figures taken from "Climatological Data for Oklahoma," Department of Commerce, Weather Bureau, Vol. 72:3-10.

EXPERIMENTAL RESULTS

Shoot Length

The length of pecan shoots was related to fruiting. In the Western variety, pecans were produced on shoots varying from 1 to 18 inches in length as shown in Table I. Eighty percent and above fruiting occurred on shoots from 4 to 15 inches in length. There were two shoots recorded over 18 inches in length. They did not initiate pistillate flowers.

The percentage of fruiting of various length shoots for the Burkett variety is shown in Table II. Fruiting occurred on shoots from 1 to 18 inches in length. Shoots under 1 inch in length failed to develop pistillate flowers. At the 80 percent and above level of fruiting, shoot length ranged between 4 and 18 inches. There were no shoots recorded over 19 inches in length. It, therefore, could not be determined at what length long shoots would fail to initiate pistillate flowers.

In Table III, the percent of fruiting of different length shoots is shown for the Stuart variety. The length range for pistillate flower development was from 1 to 18 inches. Shoots under 1 and over 18 inches in length failed to produce pistillate flowers. At the 80 percent or above level, fruiting occurred on shoots between 4 and 9 inches in length.

TABLE I

RELATIONSHIP OF SHOOT LENGTH TO FRUITING IN THE WESTERN VARIETY PECAN

Length in Inches	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
1- 1.9	18	11	61.1%
2- 2.9	44	31	70.4
3- 3.9	62	45	72.5
4- 4.9	52	43	82.6
5- 5.9	42	38	90.4
6- 6.9	24	23	95.8
7- 7.9	6	6	100.0
8- 8.9	9	9	100.0
9- 9.9	7	6	85.7
10-10.9	7	5	71.4
11-11.9	2	2	100.0
12-12.9	2	2	100.0
13-13.9	3	2	66.6
14-14.9	1	1	100.0
15-15.9	1	1	100.0
16-16.9	1	0	.0
17-17.9	1	1	100.0
18-18.9	1	0	.0
21-21.9	1	0	.0

TABLE II

RELATIONSHIP OF SHOOT LENGTH TO FRUITING IN THE BURKETT VARIETY PECAN

Length in Inches	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
0- .9	3	0	.0%
1- 1.9	7	5	71.4
2- 2.9	19	12	63.1
3- 3.9	38	30	78.9
4- 4.9	42	31	73.8
5- 5.9	42	36	85.7
6- 6.9	38	38	100.0
7- 7.9	37	34	91.8
8- 8.9	16	15	93.7
9- 9.9	13	11	84.6
10-10.9	11	10	90.6
11-11.9	3	3	100.0
13-13.9	3	3	100.0
14-14.9	2	2	100.0
17-17.9	1	1	100.0

TABLE III

RELATIONSHIP OF SHOOT LENGTH TO FRUITING IN THE STUART VARIETY PECAN

Length in Inches	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
0-	3	0	.0%
1- 1.9	32	9	28.1
2- 2.9	45	23	51.1
3- 3.9	49	30	61.2
4- 4.9	44	37	84.0
5- 5.9	35	26	74.2
6- 6.9	26	22	84.6
7- 7.9	12	10	83.3
8- 8.9	13	10	76.9
9- 9.0	7	5	71.4
10-10.9	6	4	66.6
11-11.9	3	2	66.6
12-12.9	3	3	100.0
13-13.9	2	1	50.0
14-14.9	2	1	50.0
15-15.9	2	1	50.0
16-16.9	1	0	.0
17-17.9	1	1	100.0
18-18.9	1	0	.0
30-30.9	1	0	.0
31-31.9	2	0	.0
33-33.9	1	0	.0

Shoot lengths of the Success variety are shown in Table IV. Fruiting occurred on shoots ranging from 1 to 21 inches in length. All shoots over 21 inches in length failed to develop pistillate flowers except for one that was 30.9 inches long. Eighty percent or better fruiting occurred on shoots ranging in length from 2.5 to 8 inches.

Figure 1 compares the four varieties in relation to fruiting at different shoot lengths. Western, Burkett, and Success were more productive over a wider range than Stuart. Stuart was less productive on the short shoots and had a shorter shoot length range of high production.

Figure 2 shows the relative proportion of fruiting of shoots selected from the four varieties of trees examined. Success fruited over a range between 1 to 20 inches with one shoot fruiting at 30 inches in length. Stuart, Burkett, and Western fruited over about the same length range of 1 to 18 inches, although in the instance of Burkett no shoots were selected that were over 18 inches in length. Stuart and Western had the highest percent fruiting between 2 and 6 inches, whereas the highest percent fruiting with Success and Burkett was on shoots which ranged from 2 to 9 inches in length.

Number of Nodes

The number of nodes per shoot influenced production. In the Western variety, pecans were produced from shoots containing between 4 and 21 nodes as shown in Table V. There was one shoot with 3 nodes and one containing 23 nodes that did not initiate pistillate flowers.

TABLE IV

RELATIONSHIP OF SHOOT LENGTH TO FRUITING IN THE SUCCESS VARIETY PECAN

Length in Inches	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
1- 1.9	9	6	66.6%
2- 2.9	21	17	80.9
3- 3.9	40	29	72.5
4- 4.9	36	25	69.4
5- 5.9	33	29	87.8
6- 6.9	25	18	72.0
7- 7.9	22	14	63.6
8- 8.9	16	14	87.5
9- 9.9	13	8	61.5
10-10.9	12	8	66.6
11-11.9	9	7	77.7
12-12.9	6	4	66.6
13-13.9	6	3	50.0
14-14.9	4	1	25.0
15-15.9	3	1	33.3
16-16.9	4	2	50.0
17-17.9	3	1	33.3
18-18.9	5	2	40.0
19-19.9	2	0	.0
20-20.9	3	1	33.3
21-21.9	2	0	.0
22-22.9	2	0	.0
23-23.9	1	0	.0
24-24.9	2	0	.0
25-25.9	1	0	.0
26-26.9	3	0	.0
28-28.9	1	0	.0
29-29.9	1	0	.0
30-30.9	1	1	100.0

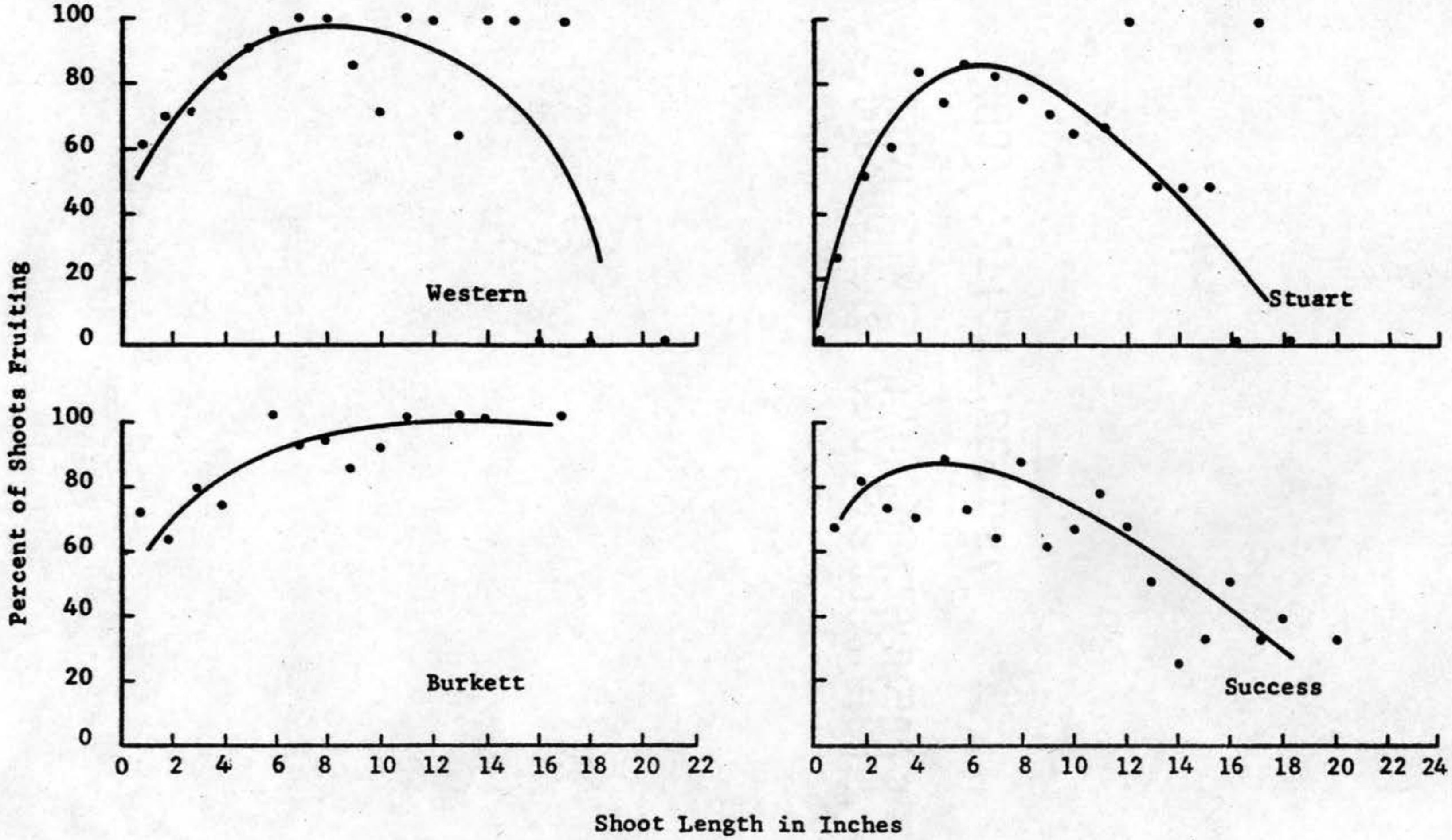

Figure 1. Relationship of Shoot Length to Percent Fruiting of Western, Burkett, Stuart and Success Varieties of Pecans.

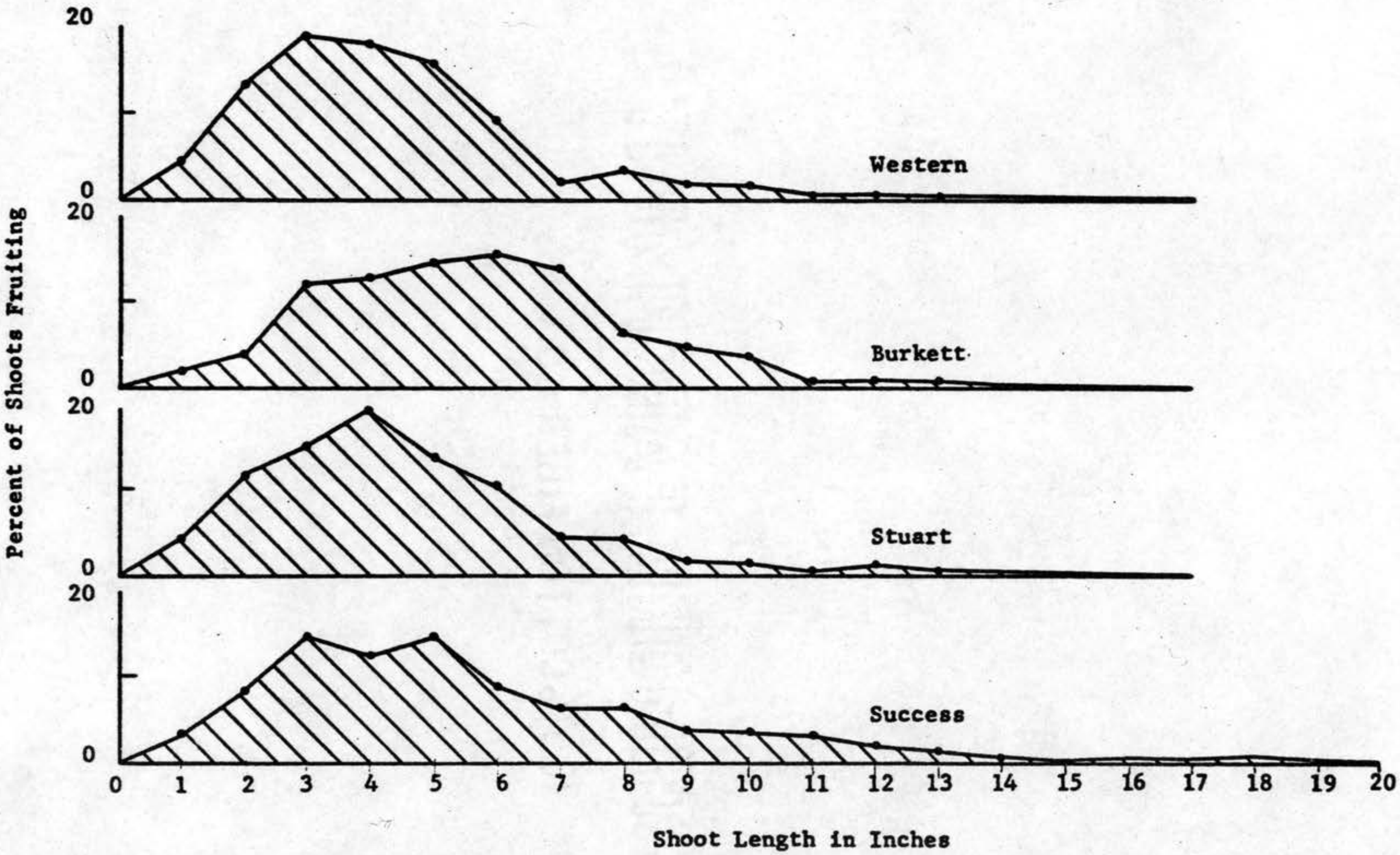

Figure 2. Relative Proportion of Fruiting Shoots Throughout the Productive Shoot Length Range of Western, Burkett, Stuart and Success Pecan Varieties.

TABLE V

RELATIONSHIP OF THE NUMBER OF NODES PER SHOOT TO FRUITING IN THE WESTERN VARIETY OF PECAN

Number of Nodes	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
3	1	0	.0%
4	3	3	100.0
5	5	3	60.0
6	31	18	58.0
7	42	33	78.5
8	52	41	78.8
9	69	60	86.9
10	35	29	82.8
11	16	16	100.0
12	7	7	100.0
13	6	5	66.6
14	5	4	80.0
15	5	5	100.0
16	1	0	.0
17	0	0	.0
18	2	2	100.0
19	2	0	.0
20	0	0	.0
21	1	1	100.0
22	0	0	.0
23	1	0	.0

Eighty percent and above fruiting occurred on shoots containing between 9 and 16 nodes.

In Burkett, fruiting occurred on shoots containing 6 to 21 nodes as shown in Table VI. Shoots with less than 6 nodes failed to develop pistillate flowers. At the 80 percent and above level of fruiting, the shoots contained from 11 to 21 nodes. There were no shoots recorded that had over 21 nodes, therefore, it could not be determined at what nodal number long shoots would fail to initiate pistillate flowers.

In Table VII the percent fruiting of shoots containing various numbers of nodes is shown for the Stuart variety. The range of flowering was from 5 to 24 nodes. All shoots with less than 5 and more than 24 nodes failed to fruit. Only on shoots containing 13 nodes did 80 percent or above fruiting occur.

The number of nodes and fruiting of the Success variety is shown in Table VIII. Fruiting occurred on shoots containing from 5 to 31 nodes. Of the 19 shoots which contained 26 or more nodes, 17 failed to produce pistillate flowers. The 2 shoots which fruited, contained 29 and 31 nodes. Eighty percent or better fruiting occurred on shoots ranging from 9 to 14 nodes.

Figure 3 compares four pecan varieties in relation to fruiting in regards to the number of nodes. The western and Burkett varieties had the highest percentage of fruiting at their optimum range while the Burkett had the longest range of optimum fruiting. The Success variety fruited better at a lower nodal range than either Stuart, Western, or Burkett. The Stuart variety was more variable between fruiting and non-fruiting shoots at various numbers of nodes. At maximum fruiting, only

TABLE VI

RELATIONSHIP OF THE NUMBER OF NODES PER SHOOT TO FRUITING IN THE BURKETT VARIETY OF PECAN

Number of Nodes	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
5	2	0	.0%
6	2	1	50.0
7	6	4	66.6
8	7	6	85.7
9	13	8	61.5
10	35	20	57.1
11	39	34	87.1
12	69	62	89.8
13	64	60	93.7
14	25	24	96.0
15	10	9	90.0
16	2	2	100.0
21	1	1	100.0

TABLE VII

RELATIONSHIP OF THE NUMBER OF NODES PER SHOOT TO FRUITING IN THE STUART VARIETY OF PECAN

Number of Nodes	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
3	1	0	.0%
4	1	0	.0
5	2	1	50.0
6	12	0	.0
7	11	5	45.5
8	22	12	54.5
9	30	18	60.0
10	35	26	74.2
11	43	30	69.7
12	47	34	72.3
13	36	29	80.5
14	17	13	76.4
15	12	8	66.6
16	7	3	42.8
17	5	3	60.0
18	1	1	100.0
19	2	0	.0
20	2	0	.0
23	2	1	50.0
24	1	1	100.0
25	2	0	.0

TABLE VIII

RELATIONSHIP OF THE NUMBER OF NODES PER SHOOT TO FRUITING
IN THE SUCCESS VARIETY OF PECAN

Number of Nodes	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
5	2	2	100.0%
6	9	6	66.6
7	11	8	72.7
8	26	17	65.3
9	32	28	87.5
10	45	32	71.1
11	32	24	75.0
12	36	26	72.2
13	30	23	76.6
14	12	11	91.6
15	4	2	50.0
16	4	2	50.0
17	6	1	16.6
18	1	1	100.0
19	4	2	50.0
20	3	1	33.3
21	2	1	50.0
22	2	0	.0
23	0	0	.0
24	3	1	33.3
25	3	1	33.3
26	1	0	.0
27	4	0	.0
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30	2	0	.0
31	3	1	33.3
32	5	0	.0

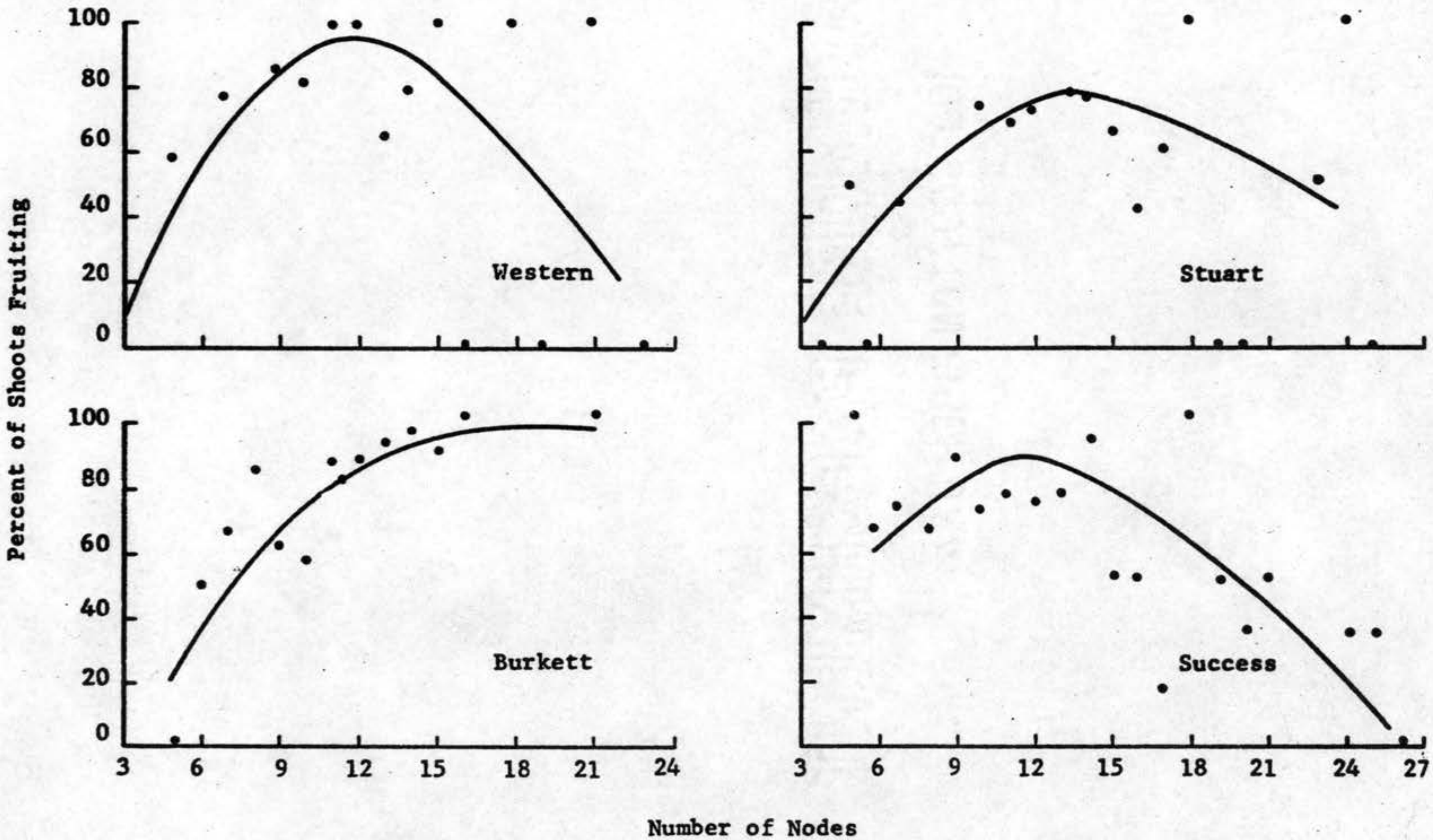

Figure 3. Relationship Between Number of Nodes to Percent Fruiting in Western, Burkett, Stuart and Success Pecan Varieties.

80 percent of the shoots were productive.

Stem Diameter

In the Western variety, fruiting occurred on shoots ranging from .30 to .63 centimeters in diameter. Eighty percent and above fruiting ranged from .34 to .63 centimeters in diameter. These results are shown in Table IX. There were no shoots recorded under .30 or over .63 centimeters in diameter, therefore it could not be determined at what diameter shoots would fail to set pistillate flowers.

The percentage of fruiting at various stem diameters for the Burkett variety is shown in Table X. Fruiting occurred on shoots ranging from .34 to .69 centimeters in diameter. Eighty percent of better fruiting ranged from .42 to .69 centimeters in diameter. Two shoots below .34 centimeters in diameter did not set fruit. There were no shoots measured over .69 centimeters in diameter, therefore, the maximum diameter at which fruiting might occur was not available from these data.

In Table XI, the percent of shoots fruiting in relation to various stem diameters is shown for the Stuart variety. Shoots .37 or over .83 centimeters in diameter were recorded, it could not be determined at what stem diameter shoots would fail to fruit. At the 80 percent or above level, optimum fruiting occurred between .63 and .83 centimeters in diameter.

The relationship of stem diameter to fruiting in the Success variety is shown in Table XII. Fruiting occurred on shoots from .38 to .72 centimeters in diameter. Two shoots above .72 centimeters in

TABLE IX

RELATIONSHIP OF STEM DIAMETER PER SHOOT TO FRUITING
IN THE WESTERN VARIETY OF PECAN

Diameter in Centimeters	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
.30	6	3	50.0%
.31	4	3	75.0
.32	4	3	75.0
.33	6	2	33.3
.34	5	4	80.0
.35	2	2	100.0
.36	13	11	84.6
.37	15	13	86.6
.38	19	16	84.2
.39	14	9	64.2
.40	17	13	76.4
.41	14	13	92.8
.42	23	20	86.9
.43	19	16	84.2
.44	9	7	77.7
.45	19	2	73.6
.46	14	10	71.4
.47	9	6	66.6
.48	19	17	100.0
.49	4	2	80.0
.50	16	14	87.5
.51	3	2	66.6
.52	6	6	100.0
.53	5	4	80.0
.54	3	2	66.6
.55	1	1	100.0
.56	1	0	.0
.57	1	1	100.0
.58	1	0	.0
.59	1	1	100.0
.60	3	3	100.0
.61	1	1	100.0
.63	1	1	100.0

TABLE X

RELATIONSHIP OF STEM DIAMETER PER SHOOT TO FRUITING IN THE BURKETT VARIETY OF PECAN

Diameter in Centimeters	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
.30	1	0	.0%
.32	1	0	.0
.34	2	2	100.0
.36	2	1	50.0
.37	3	2	66.6
.38	4	3	75.0
.39	3	3	100.0
.40	12	8	66.6
.41	8	6	75.0
.42	15	12	80.0
.43	15	13	86.6
.44	10	8	80.0
.45	9	9	100.0
.46	9	8	88.8
.47	21	16	76.1
.48	29	23	79.3
.49	16	12	75.0
.50	24	21	87.5
.51	7	7	100.0
.52	12	12	100.0
.53	12	9	75.0
.54	12	11	91.6
.55	14	14	100.0
.56	5	5	100.0
.57	8	7	87.5
.58	3	5	100.0
.59	2	2	100.0
.60	6	6	100.0
.61	1	0	.0
.62	2	1	50.0
.63	1	1	100.0
.64	1	1	100.0
.65	1	1	100.0
.68	1	1	100.0
.69	1	1	100.0

TABLE XI

RELATIONSHIP OF STEM DIAMETER PER SHOOT TO FRUITING IN THE STUART VARIETY OF PECAN

Diameter in Centimeters	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
.37	1	1	100.0%
.38	1	1	100.0
.39	1	1	100.0
.40	6	2	33.3
.41	2	0	.0
.42	5	1	20.0
.43	6	3	50.0
.44	3	2	66.6
.45	4	3	75.0
.46	12	5	41.6
.47	10	6	60.0
.48	10	5	50.0
.49	17	11	64.7
.50	27	20	74.0
.51	16	9	56.2
.52	17	9	52.9
.53	11	6	54.5
.54	15	11	73.3
.55	17	12	70.6
.56	10	7	70.0
.57	7	5	71.4
.58	16	12	75.0
.59	20	12	60.0
.60	14	9	64.2
.61	6	5	83.3
.62	7	5	71.4
.63	8	7	87.5
.64	5	4	80.0
.65	1	1	100.0
.66	4	3	75.0
.67	4	3	75.0
.68	1	0	.0
.69	2	0	.0
.70	2	2	100.0
.73	1	1	100.0
.83	1	1	100.0

TABLE XII

RELATIONSHIP OF STEM DIAMETER PER SHOOT TO FRUITING IN THE SUCCESS VARIETY OF PECAN

Diameter in Centimeters	Number of Shoots	Number of Shoots Fruiting	Percent Fruiting
.38	2	1	50.0%
.39	--	--	--
.40	2	1	50.0
.41	1	1	100.0
.42	1	0	.0
.43	3	2	66.6
.44	2	1	50.0
.45	2	1	50.0
.46	5	5	100.0
.47	3	1	33.3
.48	7	5	71.4
.49	8	6	75.0
.50	19	15	78.9
.51	15	10	66.6
.52	11	9	81.8
.53	15	11	73.3
.54	19	14	73.6
.55	29	19	65.5
.56	9	4	44.4
.57	8	4	50.0
.58	25	22	88.0
.59	14	11	78.5
.60	21	9	42.8
.61	7	4	57.1
.62	7	5	71.4
.63	5	4	80.0
.64	14	9	64.2
.65	6	2	33.3
.66	6	5	83.3
.67	3	1	33.3
.68	8	5	62.5
.69	3	1	33.3
.70	1	0	.0
.71	--	--	--
.72	2	1	50.0
.73	1	0	.0
.83	1	0	.0

diameter did not fruit, while no shoots were recorded below .38 centimeters in diameter. Therefore, it could not be determined at what smaller diameter shoots would fail to fruit. Seventy percent or above fruiting occurred on shoots ranging from .48 to .61 centimeters in diameter. The percentage of fruiting decreased below .48 centimeters and above .60 centimeters in diameter.

Figure 4 compares the four varieties in relation to fruiting at different stem diameters. Western, Burkett, and Stuart continued to increase in fruiting as stem diameters increased, although Stuart had a lower percent of fruiting at smaller diameters than the Western or Burkett varieties. The Success variety had a lower percent of fruiting throughout the range of stem diameters than did the other three varieties. The maximum fruiting in Success occurred at .53 to .56 centimeters in diameter.

Late Growth

Tables XIII through XVI show the influence of late growth on fruiting of four pecan varieties. Western, Stuart, and Burkett shoots that were from 1 to 17 inches in length and made late growth in 1963, fruited well in 1964. The Success variety decreased in fruiting when shoots made late growth and were over 12 inches long. Success shoots from 5 to 8 inches long that made late growth had the highest percent fruiting the following year.

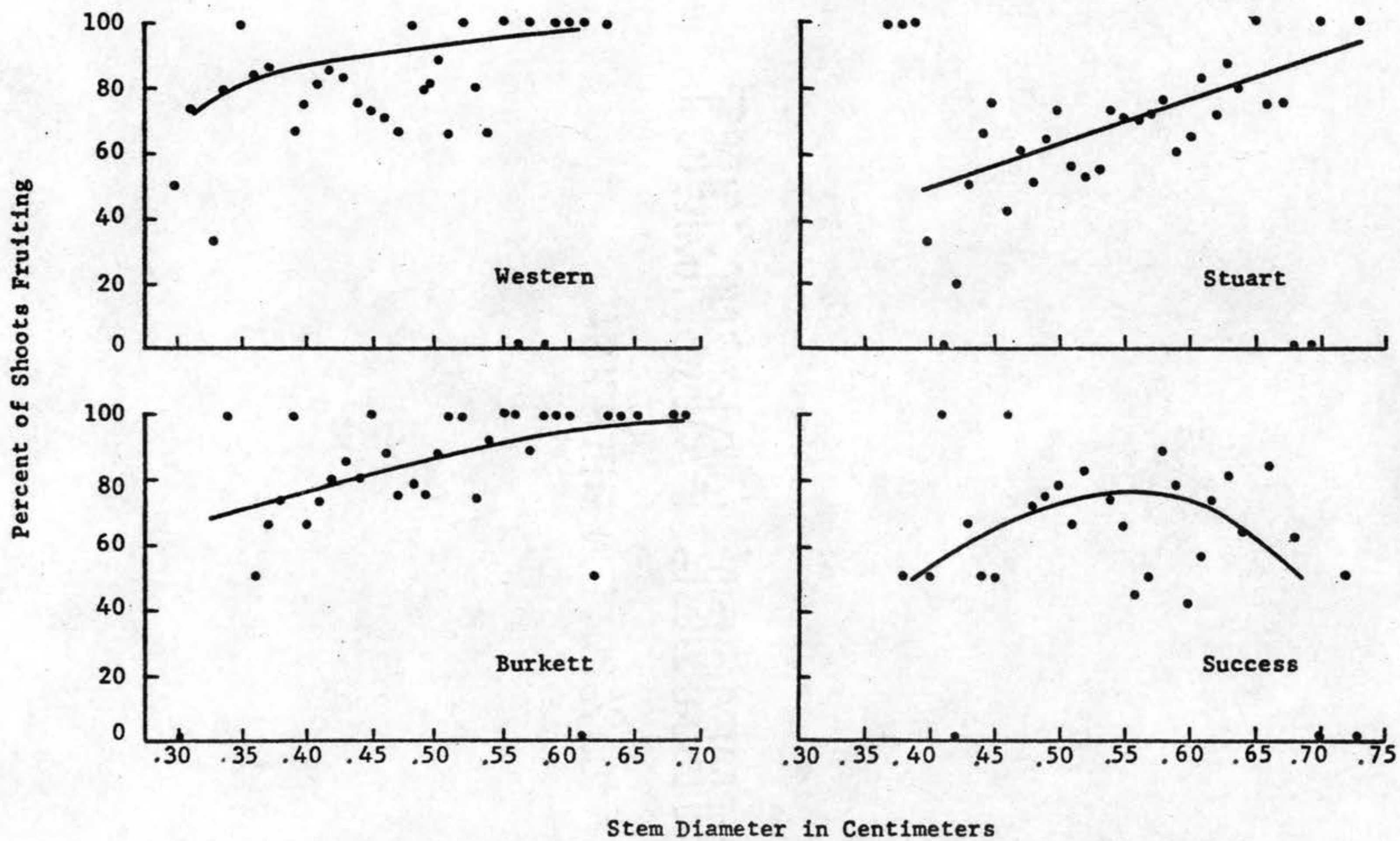

Figure 4. Relationship of Stem Diameter to Percent of Fruiting in Western, Burkett, Stuart and Success Pecan Varieties.

TABLE XIII

INFLUENCE OF LATE GROWTH ON FRUITING AT VARIOUS SHOOT LENGTHS OF WESTERN VARIETY PECAN

Length in Inches	Number Shoots With Late Growth	Number Fruiting	Percent Fruiting
1- 1.9	3	2	66.6%
2- 2.9	21	16	76.1
3- 3.9	23	14	60.8
4- 4.9	13	11	84.6
5- 5.9	6	6	100.0
6- 6.9	8	8	100.0
7- 7.9	1	1	100.0
8- 8.9	1	1	100.0
9- 9.9	2	1	50.0
10-10.9	4	2	50.0
11-11.9	2	2	100.0
12-12.9	1	1	100.0
13-13.9	2	1	50.0
14-14.9	1	1	100.0
15-15.9	1	1	100.0
17-17.9	1	1	100.0
18-18.9	1	0	.0
21-21.9	1	0	.0

TABLE XIV

INFLUENCE OF LATE GROWTH ON FRUITING AT VARIOUS SHOOT LENGTHS OF BURKETT VARIETY PECAN

Length in Inches	Number Shoots With Late Growth	Number Fruiting	Percent Fruiting
1- 1.9	0	0	.0%
2- 2.9	8	7	87.5
3- 3.9	8	6	75.0
4- 4.9	8	5	62.5
5- 5.9	7	6	85.7
6- 6.9	1	1	100.0
7- 7.9	2	2	100.0
8- 8.9	2	2	100.0
9- 9.9	1	1	100.0
10-10.9	2	2	100.0
11-11.9	2	2	100.0
12-12.9	1	1	100.0
13-13.9	3	3	100.0
14-14.9	1	1	100.0
17-17.9	1	1	100.0

TABLE XV

INFLUENCE OF LATE GROWTH ON FRUITING AT VARIOUS SHOOT LENGTHS OF STUART VARIETY PECAN

Length in Inches	Number Shoots With Late Growth	Number Fruiting	Percent Fruiting
1- 1.9	23	5	21.7%
2- 2.9	38	19	50.0
3- 3.9	42	25	59.5
4- 4.9	31	26	83.8
5- 5.9	15	10	73.3
6- 6.9	11	11	100.0
7- 7.9	9	7	77.7
8- 8.9	10	7	70.0
9- 9.9	4	3	75.0
10-10.9	3	1	33.3
11-11.9	1	0	.0
12-12.9	3	3	100.0
13-13.9	2	1	50.0
14-14.9	1	1	100.0
15-15.9	2	1	50.0
16-16.9	1	0	.0
17-17.9	1	1	100.0
30-30.9	1	0	.0
31-31.9	2	0	.0
33-33.9	1	0	.0

TABLE XVI

INFLUENCE OF LATE GROWTH ON FRUITING AT VARIOUS SHOOT LENGTHS OF SUCCESS VARIETY PECAN

Length in Inches	Number Shoots With Late Growth	Number Fruiting	Percent Fruiting
1- 1.9	6	4	66.6%
2- 2.9	13	11	84.6
3- 3.9	30	23	76.6
4- 4.9	24	19	79.1
5- 5.9	19	18	94.7
6- 6.9	15	13	86.6
7- 7.9	10	8	80.0
8- 8.9	13	11	84.6
9- 9.9	9	5	55.5
10-10.9	11	8	72.7
11-11.9	8	7	87.5
12-12.9	5	4	80.0
13-13.9	6	3	50.0
14-14.9	4	1	25.0
15-15.9	2	1	50.0
16-16.9	4	2	50.0
17-17.9	2	0	.0
18-18.9	4	2	50.0
19-19.9	2	0	.0
20-20.9	3	1	33.3
21-21.9	2	0	.0
22-22.9	2	0	.0
23-23.9	1	0	.0
24-24.9	2	0	.0
25-25.9	1	0	.0
26-26.9	3	0	.0
28-28.9	1	0	.0
29-29.9	1	0	.0

Age of Trees

A comparison of fruiting was made between shoots on old and young trees of the Stuart variety, Table XVII. The shoots from the older trees had a higher percentage of fruiting than the shoots from young trees.

Influence of Fruiting in 1963 on Fruiting in 1964

The maximum amount of fruiting in 1964 from Western, Stuart, and Success was on shoots that were non-fruiting in 1963, as shown in Tables XVIII, XX, and XXI. Shoots that exceeded 9 inches in length in Western, 12 inches in Success, and 11 inches in Stuart were non-fruiting in 1963.

Table XIX shows that in Burkett there was no significant difference in fruiting in 1964 from fruiting and non-fruiting shoots of 1963.

TABLE XVII

RELATIONSHIP OF FRUITING FROM SHOOTS AT VARIOUS LENGTHS BETWEEN OLD AND YOUNG STUART VARIETY PECAN TREES

Length in Inches	Number of Shoots		Number of Shoots Fruiting		Percent Fruiting	
	Old	Young	Old	Young	Old	Young
0- .9	-	2	2	0	-%	.0%
1- 1.9	3	17	1	1	33.3	5.8
2- 2.9	13	25	10	8	76.9	32.0
3- 3.9	15	11	12	3	80.0	27.2
4- 4.9	19	7	16	4	84.2	57.1
5- 5.9	14	9	11	2	78.5	22.2
6- 6.9	12	3	11	2	91.6	66.6
7- 7.9	7	2	7	0	100.0	.0
8- 8.9	2	7	2	4	100.0	57.1
9- 9.9	4	1	3	0	75.0	.0
10-10.9	1	2	1	0	100.0	.0
11-11.9	-	2	-	0	-	.0
12-12.9	1	1	1	1	100.0	100.0
13-13.9	1	1	0	1	.0	100.0
14-14.9	-	1	-	0	-	.0
15-15.9	-	2	-	1	-	50.0
16-16.9	-	1	-	0	-	.0
17-17.9	1	-	1	-	100.0	-
18-18.9	-	1	-	0	-	.0
31-31.9	-	2	-	0	-	.0
33-33.9	1	-	0	-	.0	-

TABLE XVIII

NUMBER AND PERCENT OF TERMINAL SHOOTS AT VARIOUS LENGTHS OF THE WESTERN VARIETY FRUITING IN 1964 AS RELATED TO FRUITING AND NON-FRUITING IN 1963

Length in	Shoots Fruiting 1963		Shoots Non-Fruiting 1963	
Inches	Number	% Fruiting '64	Number	% Fruiting '64
1- 1.9	3	66.7%	15	60.0%
2- 2.9	8	50.0	36	85.0
3- 3.9	36	61.1	26	90.0
4- 4.9	40	77.5	12	100.0
5- 5.9	28	92.9	14	85.1
6- 6.9	13	93.3	9	100.0
7- 7.9	3	100.0	4	100.0
8- 8.9	4	100.0	5	100.0
9- 9.9	-	-	7	85.7
10-10.9	1	.0	6	16.6
11-11.9	-	-	2	100.0
12-12.9	1	100.0	1	100.0
13-13.9	-	-	3	66.7
14-14.9	-	-	1	100.0
15-15.9	-	-	1	100.0
16-16.9	-	-	1	.0
17-17.9	-	-	1	100.0
18-18.9	-	-	1	.0
21-21.9	-	-	1	.0

TABLE XIX

NUMBER AND PERCENT OF TERMINAL SHOOTS AT VARIOUS LENGTHS OF THE BURKETT VARIETY FRUITING IN 1964 AS RELATED TO FRUITING AND NON-FRUITING IN 1963

Length in Inches	Shoots Fruiting 1963		Shoots Non-Fruiting 1963	
	Number	% Fruiting '64	Number	% Fruiting '64
1- 1.9	-	-%	10	50.0%
2- 2.9	5	60.0	14	64.2
3- 3.9	24	75.0	14	71.4
4- 4.9	24	76.4	8	62.5
5- 5.9	28	85.7	14	81.4
6- 6.9	30	100.0	8	100.0
7- 7.9	35	91.4	2	100.0
8- 8.9	14	92.8	2	100.0
9- 9.9	12	83.3	1	100.0
10-10.9	10	90.0	1	100.0
11-11.9	2	100.0	1	100.0
13-13.9	2	100.0	1	100.0
14-14.9	1	100.0	1	100.0
17-17.9	0	-	1	100.0

TABLE XX

NUMBER AND PERCENT OF TERMINAL SHOOTS AT VARIOUS LENGTHS OF THE STUART VARIETY FRUITING IN 1964 AS RELATED TO FRUITING AND NON-FRUITING IN 1963

Length in Inches	Shoots Fruiting 1963		Shoots Non-Fruiting 1963	
	Number	% Fruiting '64	Number	% Fruiting '64
0- .9	-	-%	3	.0%
1- 1.9	5	20.0	18	11.1
2- 2.9	15	33.3	23	56.5
3- 3.9	14	42.8	13	76.9
4- 4.9	14	57.1	13	92.3
5- 5.9	22	59.9	3	100.0
7- 7.9	5	100.0	4	50.0
8- 8.9	2	100.0	7	57.1
9- 9.9	3	66.7	2	50.0
10-10.9	1	100.0	2	.0
11-11.9	-	-	3	66.7
12-12.9	-	-	2	100.0
13-13.9	-	-	2	50.0
14-14.9	-	-	2	50.0
15-15.9	-	-	2	.0
16-16.9	-	-	1	100.0
17-17.9	-	-	1	.0
18-18.9	-	-	1	.0
30-30.9	-	-	1	.0
31-31.9	-	-	2	.0
33-33.9	-	-	1	.0

TABLE XXI

NUMBER AND PERCENT OF TERMINAL SHOOTS AT VARIOUS LENGTHS OF THE SUCCESS VARIETY FRUITING IN 1964 AS RELATED TO FRUITING AND NON-FRUITING IN 1963

Length in Inches	Shoots Fruiting 1963		Shoots Non-Fruiting 1963	
	Number	% Fruiting '64	Number	% Fruiting '64
1- 1.9	2	50.0%	7	71.4%
2- 2.9	8	50.0	13	100.0
3- 3.9	21	61.9	19	83.3
4- 4.9	17	50.0	19	89.4
5- 5.9	14	78.5	19	94.7
6- 6.9	16	68.7	9	77.7
7- 7.9	10	50.0	12	75.0
8- 8.9	6	100.0	10	80.0
9- 9.9	6	50.0	7	71.4
10-10.9	3	66.7	9	66.7
11-11.9	3	100.0	6	66.7
12-12.9	1	.0	5	80.0
13-13.9	-	-	6	50.0
14-14.9	-	-	4	25.0
15-15.9	-	-	3	33.3
16-16.9	-	-	4	50.0
17-17.9	-	-	3	33.3
18-18.9	1	.0	4	50.0
19-19.9	-	-	2	.0
20-20.9	-	-	3	33.3
21-21.9	-	-	2	.0
22-22.9	-	-	2	.0
23-23.9	-	-	1	.0
24-24.9	-	-	2	.0
25-25.9	-	-	1	.0
26-26.9	-	-	3	.0
28-28.9	-	-	1	.0
29-29.9	-	-	1	.0
30-30.9	-	100.0	-	-

DISCUSSION AND CONCLUSIONS

The results of this study show that there is an optimum range of shoot growth for greatest production for each of the varieties studied. This work is in general agreement with the findings of Ambling (1), Crane (4), and Isbell (17).

There is a direct relationship between the number of leaves as expressed in number of nodes, the stem diameter, and the shoot length on bearing. The number and quality of leaves present relate to the potential food material manufactured, the amount of food reserves stored, and the formation of pistillate flowers. The leaves also affect shoot length and stem diameter which in turn are associated with the number of nodes and leaves produced the following year.

Length of shoot may be readily used by growers as an indicator of tree vigor, nutrition and production potential.

Data from these studies show that there are variations in shoot length between varieites in relation to fruiting.

The pecan variety, Success, fruited best on shorter shoots, although some fruiting occurred on longer shoots the percentage was low.

Under the conditions of these tests, the Stuart fruited best over a relatively short range of shoot lengths. It appears that the Stuart requires more specific growing conditions for best production. This does not agree with Isbell (17), who reported that the Stuart variety produced over a wider range of shoot lengths.

Western and Burkett produced pecans over a length range greater than did Stuart and Success. The Burkett variety fruited on longer shoots better than did either Western, Stuart or Success.

It is concluded that Success fruited best on shoots 2 1/2 to 8 inches long, whereas the Stuart fruited best on shoots 4 to 9 inches long. Optimum fruiting with the Western variety was found on shoots 4 to 15 inches long while the Burkett fruited best on shoots 4 to 18 inches long.

In this study, the number of nodes had reference to the number of leaves. The Stuart had a lower percentage of fruiting at the various number of nodes than the other three varieties. Eighty percent fruiting occurred at 13 nodes.

The optimum fruiting from the Western variety occurred on shoots containing from 9 to 16 nodes. This was similar to the Success, which fruit best on shoots with 9 to 14 nodes.

Burkett fruited best over a longer range of nodes than the other three varieties. This varied from 11 to 21 nodes.

Results from this study show that diameter of the shoot measured between the fourth and fifth nodes from the terminal served as an indicator of potential production. The optimum fruiting range in stem diameter was as follows: Western, .34 to .63 centimeters; Burkett, .42 to .69 centimeters; Stuart, .63 to .83 centimeters; and Success, .34 to .61 centimeters. It was also found that Western, Burkett, and Stuart fruited at the largest diameters measured, whereas Success fruiting decreased on shoots over .61 centimeters in diameter.

Gossard (9) and Isbell (17) found that shoots which made secondary growth late in the season were not as productive as shoots making only primary growth. It is believed this late growth used stored food for making new cells and prevented differentiation of pistillate flowers for the following spring.

Results from this study reveal that the Western, Stuart, and Burkett varieties fruited well on shoots making late growth provided they were from 1 to 17 inches in length. Late growth on Success shoots which were less than 21 inches long, did not affect fruiting but all shoots over 21 inches in length producing late growth failed to initiate pistillate flowers.

A comparison was made in this study of the relationship between old and young trees of the Stuart variety to fruiting. The younger trees produced more shoots of greater length. The older trees had a higher percent of fruiting at the various shoot lengths than did the younger trees at the same shoot length. This may be, in part, due to the high nitrogen to carbohydrate ratio in the younger trees, which does not favor pistillate flower formation.

Biennial bearing in pecans appears to, in the main, result from large exhaustive crops that upset the nutritional balance of the tree. A low level of food reserve within the plant occurs in the fall and winter, markedly limiting pistillate flower formation the following spring.

This work conclusively demonstrated that production from the short, weaker shoots was less the following year with each of the varieties used in this study. The varieties Western, Stuart, and

Success fruited best on shoots that did not produce pecans the previous year.

The longest growth was made from shoots that were non-bearing the previous year.

In Burkett there was no significant difference in fruiting between shoots which were either fruiting or non-fruiting the previous year.

From the accumulated data of this study it can be conclusively stated that to obtain continuous maximum production, a majority of terminal shoots produced on the tree must be within the optimum growth range both as to length and diameter.

SUMMARY

The objectives of this study were to determine: (1) the optimum terminal growth for fruiting in pecans, (2) the range in terminal growth on which fruiting occurs, and (3) the differences of productive terminal growth between varieties.

Three hundred terminal shoots of each of the varieties Western, Burkett, Stuart, and Success were analyzed for fruiting according to: (1) length, (2) number of nodes, (3) stem diameter, (4) presence of late growth and (5) whether pecans had been produced that year.

Results of this study indicate:

(1) The fruiting of a pecan shoot is correlated with stem length, number of nodes, and stem diameter.

(2) The optimum fruiting range in the Western variety was on shoots 4 to 15 inches long with 9 to 16 nodes and a stem diameter between the fourth and fifth nodes of .34 to .63 centimeters.

(3) The Burkett variety fruited best on shoots 4 to 18 inches long with 11 to 21 nodes and a stem diameter of .42 to .69 centimeters.

(4) Optimum fruiting in the Stuart variety was on shoots 4 to 9 inches long containing 13 nodes and with a stem diameter of .63 to .83 centimeters.

(5) The Success variety fruited best on shoots 2 1/2 to 8 inches long with 9 to 14 nodes and a stem diameter of .48 to .61 centimeters.

(6) Short, weak shoots were less likely to fruit the following year than shoots of the optimum fruiting range.

(7) Late growth did not significantly influence pecan fruiting the following seasons with the Western, Burkett and Stuart varieties. In the instance of the Success variety, all long shoots which made late growth did not produce pistillate flowers the following season.

(8) Forty-two year old Stuart trees produced shorter shoots and proportionately more fruiting shoots than did thirteen year old Stuart trees.

For future studies the following points merit consideration:

(1) Obtain a uniform number of shoots for each shoot length. At least 25 shoots should be selected.

(2) A more complete analysis relative to late growth should be made.

(3) Select trees growing under various cultural conditions.

(4) Further test should be made under various climatic conditions during the period of shoot development.

(5) Determine the number of leaves per shoot instead of, or in addition to, the number of nodes.

(6) Develop correlations between shoot vigor, leaf area, leaf number, and nuts per cluster to production and fruiting the following season.

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