THE EFFECT OF PRE-EMERGENCE HERBICIDES ON WESTERN PECAN SEEDLINGS AND CONTROL OF ANNUAL WEEDS

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CHAPTER I

INTRODUCTION

In recent years serious consideration has been given to the use of herbicides for the control of weeds in pecan (*Carya illinoinsis*) tree nurseries. Pecan tree propagators are becoming increasingly more interested in chemical weed control because the use of hand labor and machines for this task is steadily becoming more expensive. The expense involved in manual or mechanical weed control is manifested in several ways. When mechanical methods of weed control are employed, the operation must be repeated often, it is time consuming, and with certain machines the root systems and trunks may be damaged (8). With herbicides there is no danger of cutting roots or above ground parts of pecan seedlings, as is so frequently done with hoeing or machine cultivation; and there is no danger of nitrogen tie-up which sometimes occurs when mulching is used to control weeds (9).

The value of controlling weeds around young fruit trees has long been recognized. Growers know from experience that weeds near young trees result in less tree growth due to competition for moisture, light and nutrients.

In Oklahoma, pecan seedlings are usually grown in the nursery row for three years before they are dug and transplanted to permanent production sites. The objective of the nurseryman is to produce a high percentage of seedlings of graftable size during the first two growing seasons; and then to continue with optimal growing conditions throughout the third growing season in order to produce vigorous pecan trees suitable for transplanting. According to Gray (10), competition in the nursery row is instrumental in producing "runts". "There is a high degree of likelihood that such trees will never be anything else but runts and, therefore, are rendered unfit for sale or use (10)."

Mellethin et al., (21) in 1965, stressed the importance of weed control in orchard trees during the first three years of their development. Substantial retardation of tree growth due to weed competition occurred in the early years, but significant difference in growth also extended to the third and fourth years which indicated a need for continued weed control for optimum tree growth.

It is apparent that the control of weeds throughout each of the three growing seasons would enhance the production of higher quality grafted pecan trees and that less time would be required to obtain seedlings large enough to graft.

Many attempts to control weeds in pecan trees have met with failure due to lack of knowledge concerning the proper use of herbicides for this purpose.

The objectives of this experiment are to study several pre-emergence herbicides[1] and to determine their effect on:

(a) germination of pecan nuts in the treated soil,

(b) rate of emergence of pecan seedlings as affected by the various herbicide treatments,

(c) phytotoxicity to pecan seedlings, and

(d) persistent control of annual weeds.

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[1]The herbicides used in this study were selected on the basis of the known toxicity to annual weed species, primarily crabgrass (Digitaria spp.) and on speculation concerning the effects of the various herbicides on pecan seedlings.

CHAPTER II

REVIEW OF LITERATURE

Selective[1] weed control chemicals were given serious consideration as a practical agricultural innovation as early as 1908 when, according to Klingman (16), Bolley reported successful weed control in wheat using sodium chloride, iron sulfate and sodium arsenite. In Bolley's words:

> When the farming public has accepted this method (selective weed control) of attacking weeds ... the gain to the country at large will be much larger in monetary consideration than that which has been afforded by any other single piece of investigation applied to field work in agriculture.

During the 1920's, the predominant herbicides used were chlorates of calcium and sodium. The first work with these compounds was reported in 1925 at the Kansas Experiment Station and at Cornell University (22). Professor Pieper (22), in addressing the 35th Annual Meeting of the Illinois Farmers' Institute in 1930, pointed out that to be successful, chemicals for weed control must be inexpensive, must not retard the productivity of the soil and

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[1]Selectivity refers to a herbicide which is more toxic to one plant species than to another.

must be effective in small amounts. He recognized the need for more research with weed control chemicals since the chlorates did not fit these criteria.

Mr. A. G. Hirschi (14) reported, in the 37th Annual Report of the Northern Nut Growers Association, the use of a tree poison for removal of competing elm, hackberry and oak trees from native pecan groves. For poisoning, a mixture of two pounds of white arsenic and a pound of caustic soda mixed in one gallon of water was applied in a frill which completely encircled the tree. The poisoned trees were burned in place the following winter.

According to recent review articles by Audus (3) and Klingmann (16), most selective weed control research has evolved since 1935. The first major break-through in selective weed control is credited to Zimmerman when in 1935 he noted that synthetic compounds related to IAA (indole acetic acid) caused a number of physiological and morphological effects in plants (3). Later, in 1942, Zimmerman and Hitchcock reported 2, 4-D (2, 4-dichlorophenoxyacetic acid) to be a growth substance (16). In 1944, Marth and Mitchell are credited with establishing selectivity of 2, 4-D by successfully removing several broad-leaved weed species from a bluegrass lawn (16). During the same year, Hamner and Tukey used 2, 4-D successfully in selective field weed control (3).

Prior to 1945 most of the research in chemical weed control was with chemicals which either sterilized the soil and rendered it temporarily non-productive or with chemicals used in post-emergence[2] weed control as has been described with the use of 2, 4-D. In 1945, Templeman revolutionized chemical weed control techniques by establishing the pre-emergence[3] principle of soil treatment for selective weed control (3). Many chemicals have since been tested for pre-emergence weed control in fruit tree and ornamental plantings. Very limited research in the control of weeds in pecan trees has been reported, however, and most of this work has dealt with the control of existing perennial weed species (9, 14, 20).

Known cases of herbicide toxicity to bearing pecan trees have been observed when herbicides were used as soil sterilants at distances beyond the drip-line of mature native pecan trees (Hinrichs, unpublished).

Recent research in California has met with success in pre-emergence weed control of annual weeds in productive walnut orchards (18). Lange et al., (18) reported in 1967, that certain triazine and substituted urea herbicides (simazine and diuron) were equally effective in pre-emergence weed control in walnut trees but that there have been differences in response depending on the soil type, organic matter content of the soil, amount of rainfall,

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[2]Post-emergence treatments are those which are made after emergence of a specified crop or weed.

[3]Pre-emergence treatments are those made prior to emergence of a specified crop or weed.

and weed species present.

McKay and Berry (20), in 1958, reported excellent pre-emergence weed control in nursery plantings of chestnut seedlings. In their study, a dinitrophenol in the form of DNBP (4, 6 dinitro ortho secondary butyl phenol) was applied in solution directly after planting the seed. The spray was applied uniformly over the soil surface and the treated area was left undisturbed. The herbicide seemed to have little or no effect on the normal germination of the chestnut seed or phytotoxicity to the young seedlings.

Gordinier (9) has stated that the three most useful herbicides for use in nut tree plantings are dalapon (2, 2 dichloropropionic acid), amitrol (3 amino-1, 2, 4 triazole), and simazine (2, chloro-4, 6-bis ethylamino-s-triazine). He suggested the use of dalapon as a pre-plant treatment, amitrol for post-emergence weed control, and simazine for pre-emergence weed control in existing and recently transplanted nut trees. Gordinier (9) added one cautionary note by stating that simazine may damage nut trees if a substantial amount leaches into the root zone. He pointed out that damage is more likely to occur to newly planted trees than to deep rooted established trees.

Amizine (a combination of amitrol and simazine) applied at seven pounds per acre was reported to have given excellent weed control throughout the growing season and well into the succeeding growing season without appreciable damage to nut trees (9). Hewetson (11) observed similar effects when simazine and amitrol-T were applied together for pre-emergence weed control around young apple trees. It appeared that these two materials were synergistic; i.e., one increased the efficiency of the other.

Ries et al., (23), in 1963, and Chappel (5), in 1964, reported increased vigor in young peach and apple trees when simazine plus amitrol-T was used. Ries et al., (23) noted an increase in leaf nitrogen resulted in trees growing in soils treated with the simazine-amitrol-T mix, but could offer no explanation for this phenomenon. They speculated that the increase in growth could have been caused by influencing nitrogen metabolism in the treated trees.

Holm, Gilbert, and Haltvick (15), in 1959, found that 10 pounds per acre of diuron [3-(3, 4 dichlorophenyl) 1, 1-dimethylurea] and 10 pounds per acre of monuron [3-(p-chlorophenyl)-1, 1-dimethylurea] gave complete control of vegetation around apple trees for two full seasons with no tree injury. However, herbicide toxicity in non-bearing apple trees was reported, in 1961, by Benson and Degman (4) when simazine and diuron were used at 10 pounds per acre in a sandy loam soil. When diuron was applied at five pounds per acre, 15 percent of the leaves exhibited herbicide injury symptoms but no reduction in stem diameter occurred. Simazine used at four and five pounds per acre on the same soil did not provide sufficient weed control. Due to weed competition, less tree growth resulted when comparisons were made with trees grown in cultivated plots which received no herbicide application (4).

Saidak and Rutherford (24) observed similar results in 1964 with diuron and simazine when the herbicides were used on seedling apple trees growing in sand culture. The growth of young apple trees was reduced by application of 24 pounds per acre of either simazine or diuron when applied over a two-year period.

Saidak and Rutherford (24), in a greenhouse study, described simazine and diuron toxicity symptoms in young apple trees. Occasionally, leaves of trees growing in plots treated with eight pounds per acre of simazine initially developed a pale green color and had a more netted appearance than leaves of control trees. Trees in plots which had received 16 pounds per acre of simazine showed interveinal chlorosis and necrosis and were prematurely defoliated.

Diuron toxicity was characterized by veinal chlorosis which was followed by an interveinal and marginal leaf necrosis and by premature leaf drop (24).

Larsen and Ries (19), using simazine at 16 pounds per acre, reported interveinal chlorosis in young and mature peach and cherry trees. However, chlorosis was not observed at rates lower than 16 pounds per acre. Commercially acceptable weed control was not obtained at rates lower than eight pounds per acre.

Gilbert, Holm and Rake (7) reported only slight chlorosis in newly-planted red tart cherry trees which received a total of 160 pounds simazine over a four-year period. Trees which received 80 pounds simazine per acre over the same period gave no evidence of injury. No mention was made of soil type in this study.

Welker (30), on the basis of a preliminary herbicide screening study, suggested the use of several herbicides for pre-emergence annual weed control in established peach and apple trees. Trifluralin [a, a, a-trifluoro-2, 6-dinitro-N, N, dipropyl-p-toluidine] and EPTC [ethyl N, N-dipropylthiolcarbamate] were found to be ineffective for pre-emergence weed control if left non-incorporated but provided excellent, persistent weed control when incorporation followed herbicide application.

Klingman et al., (17) emphasized the importance of incorporating EPTC and noted that method of incorporation also influenced herbicidal effectiveness. A power driven rotary hoe was found to be most effective.

Upchurch (29) reported in 1966 that incorporation of trifluralin and EPTC maintained herbicidal effectiveness of these herbicides due to their volatility. In addition to this, trifluralin and EPTC are decomposed by light and, thus, should be incorporated to minimized photodecomposition.

Many herbicides have been tested for pre-emergence weed control in established woody ornamentals. Several herbicides have been cleared for this use and are currently recommended (1, 2, 6, 17, 25, 26, 28).

Successful pre-emergence weed control in deciduous orchards has been reported by several researchers, but generally, certain limitations are stressed with the consistent use of each herbicide tested (2, 7, 9, 13, 27, 30).

Other herbicides (1, 28) reported to be promising for weed control in nursery plantings include: (1) benefin (N-butyl-N-ethyl-aaa-trifluoro-2,6-dinitro-p-toluidine); (2) diphenamid (NN-dimethyl-aa-diphenylacetamide); (3) DCPA (Dimethyl tetrachloro-terephthalate); (4) Atrazine (2-chloro-4 (ethylamino)-6-(Isopropyl amino)-s-triazine); (5) Sesone (Sodium 2,4-dichlorophenoxyethyl sulfate); (6) CIPC (isopropyl N-(3 chlorophenyl) carbamate); (7) NPA (n-1 Naphthyl Phthalamic acid); (8) Amiben (3-amino-2, 5-dichlorobenzoic acid); and (9) CDEC (2-chlorallyl diethyldithio carbamate).

CHAPTER III

METHODS AND MATERIALS

Experiments were conducted to compare the effects of pre-emergence herbicides on Western pecan seedlings grown in nursery rows for propagational purposes.

Field Test

A field test was conducted to determine the comparative value of 14 herbicides, five of which were used at two different rates, on pecan seedling emergence, phytotoxicity, growth, and control of annual weeds. Also, comparisons were made between herbicide treated plots in which the middles of the rows were either cultivated or not cultivated.

The study was conducted on a Teller fine sandy loam soil at the Perkins Horticultural Research Station. Heavy infestations of weeds, primarily crabgrass (*Digitaria spp.*), had been known to have matured in the experimental area the previous year. This provided reasonable assurance of adequate weed populations in the area selected for study.

No herbicides were known to have been used in this particular area in the past.

The moisture content of the soil at time of treatment was at, or slightly below, field capacity; and the soil was in a friable condition suitable for planting pecan nuts.

A randomized block design with 44 plots was used in the study. The rows were oriented east and west and had three-foot alleyways north and south at twenty-foot intervals across the rows with the rows spaced four feet apart. There was a total of 80 square feet of treated area in each plot.

Treatments used in the study were assigned at random to each of the 44 plots. There were 19 herbicide treatments replicated twice and six check plots.

Three of the herbicides used, trifluralin, benefin, and EPTC, were recommended to be used as soil incorporated herbicides. These herbicides were sprayed on the surface of the designated plot and on March 14, 1966, incorporated with the soil to an approximate depth of four inches by means of a gasoline powered garden rotary tiller.

To facilitate rapid germination, the pecan seeds were soaked in water for five days and held at approximately 75° F. in sphagnum peat moss for three weeks prior to planting. Shells had split on some of the pecans, and in some cases, radicles had emerged one-fourth to one-half inch from the shell.

On March 15, 100 Western pecan seeds were planted approximately four inches deep and two and one-half inches apart in a row in the center of each of the plots. This provided a treated area of two feet on each side of the row. The remainder of the herbicide treatments were made immediately after planting the nuts.

The treatment rates and the herbicides used are expressed in pounds of active ingredient per acre.

1.	Trifluralin (Treflan), 1 Lb/A	Incorporated prior to planting
2.	Trifluralin (Treflan), 3/4 Lb/A	Incorporated prior to planting
3.	Benefin (Balan), 3/4 Lb/A	Incorporated prior to planting
4.	Diphenamid (Dymid), 2 Lbs/A	Not incorporated
5.	Diphenamid (Dymid), 1 Lb/A	Not incorporated
6.	DCPA (Dacthal), 12 Lbs/A	Not incorporated
7.	DCPA (Dacthal), 8 Lbs/A	Not incorporated
8.	DNBP (Dow General), 4 Lbs/A	Not incorporated
9.	Simazine, 2 Lbs/A	Not incorporated
10.	Atrazine, 2 Lbs/A	Not incorporated
11.	Sesone, 4 Lbs/A	Not incorporated
12.	Sesone, 2 Lbs/A	Not incorporated
13.	Diuron, 2 Lbs/A	Not incorporated
14.	Diuron, 1 Lb/A	Not incorporated
15.	CIPC, 6 Lbs/A	Not incorporated

16. NPA (Alanap), 2 Lbs/A Not incorporated
17. Amiben, 2 Lbs/A Not incorporated
18. EPTC (Eptam), 2 Lbs/A Incorporated prior to planting
19. CDEC (Vegedex), 4 Lbs/A Not incorporated

On May 7, 1966, one-half of the area containing one replicate of each herbicide treatment was cultivated with a rotary tiller. This provided 38 herbicide treatments with no replication and both cultivated and non-cultivated checks, each of which were replicated three times.

Two additional cultivations were provided utilizing a tractor mounted sweep type cultivator during the summer.

Purpose of cultivation was to obtain information concerning the use of the various herbicides in conjunction with cultivation as compared to the use of the same herbicides when no cultivation was used.

Pecan seedling emergence data were taken at seven- to ten-day intervals beginning April 27, 1966, and ending May 31, 1966. Final emergence data were collected on date of harvest, September 18, 1966. This provided six dates for comparisons of the effects of the treatments on pecan seedling emergence. Emergence data were used as an index for an assumed germination percentage in the various treatments.

Weed emergence data were collected June 8, 1966, to determine and compare the residual properties of the various herbicides. Weed counts were made in five areas, each one square foot, taken at random in each of the 44 plots. Weed counts were taken only within the rows in the cultivated area. A weed count calculation was made and expressed as number per square foot per treatment. Photographs were taken June 22, 1966, to illustrate the residual properties of the herbicides 100 days after treatment.

The pecan seedlings were harvested September 18, 1966, by cutting them off at soil level with a knife. After harvesting, they were brought into the laboratory for analysis. Seedlings were measured individually for each treatment. The total number of inches of seedling length per treatment was divided by the number of seedlings harvested to arrive at the average seedling length for that treatment. In the instance of seedling weight, one weight was recorded per treatment. Average seedling weight was calculated from this total.

In addition to yield data, the number of abnormal[1] seedlings in each treatment was recorded at time of harvest. This was done in order to provide a basis for determining the phytotoxic effects of the various herbicides on the pecan seedlings.

Seedlings were placed in four different groups

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[1]An abnormal seedling was considered to be any seedling, which if allowed to reach a graftable size, could not be used due to a morphological or physiological disorder of any nature.

according to growth characteristics exhibited by the seedlings. The four classes were (1) normal seedlings, (2) seedlings which had multiple stems, (3) seedlings with curled stems, and (4) seedlings with curled stems and latent buds forced. All types of abnormal seedlings were totaled and the percentages of normal and abnormal seedlings calculated for each treatment.

Rainfall data were collected at the Horticulture Research Station, Perkins, Oklahoma, from March 12, 1966, to September 16, 1966. Sprinkler irrigation was used April 6, at which time 1.44 inches of water was applied. Total monthly precipitation plus irrigation was as follows: March 12-31, 1.16 inches; April, 3.53 inches; May, 2.50 inches; June, 3.23 inches; July, 6.71 inches; August, 3.16 inches; and September 1-16, 1.53 inches.

Greenhouse Study

A greenhouse study was designed for further testing of three herbicides which appeared to be most promising for pre-emergence weed control in pecan seedlings. Criteria for decision on which herbicides would be used was based on their performance in the field test. Herbicides selected for further study were: trifluralin, DCPA, and simazine.

The objective was to determine the effect of the three herbicides on Western pecan seedling emergence and also on post-emergence phytotoxicity at different growth stages when the herbicides were applied as directed and non-directed sprays.

The greenhouse study consisted of six sections which were as follows:

A. Pre-emergence applications of trifluralin, DCPA, and simazine on Western pecan seedling emergence;

B. Post-emergence applications of trifluralin, DCPA, and simazine applied at two different growth stage ranges either as directed or non-directed sprays;

C. Topical sprays of trifluralin, DCPA, and simazine applied to Western pecan seedlings (6 to 12 inches tall);

D. Topical sprays of trifluralin applied to emerging Western pecan seedlings;

E. The effect of trifluralin on lateral root development of Western pecan seedlings; and

F. Bioassay tests to determine the movement and persistence of trifluralin, DCPA, and simazine in the soil under greenhouse conditions.

Part A - This portion of the experiment was initiated November 8, 1966. One hundred and seventy soil cylinders were constructed by rolling asphalt building felt into cylinders 24 inches in length by 7.5 inches in diameter.

The asphalt cylinders were fit into number 10 cans and tied with wire at the top of the cylinder and half-way between the top wire and the top of the can. This provided a container with sufficient depth to permit unobstructed root growth throughout the study. All cylinders were filled with a Port clay loam soil. Soil was not sterilized since simulated field soil conditions were desired. Trifluralin was applied at the rate of one pound per acre to ten cylinders and incorporated with the top three inches of soil prior to planting nuts. One Western pecan seed was planted in each of the 170 cylinders. Ten cylinders were treated with DCPA, applied at twelve pounds per acre, and ten cylinders treated with simazine, applied at two pounds per acre. These materials were sprayed on the soil surface immediately following planting and left undisturbed. The remaining cylinders were used in post-emergence treatments.

Rancid pecans were planted November 8, 1966, with the result that no germination occurred. On December 18, 1966, the cylinders were replanted with viable Western pecan seeds, but received no additional chemical treatment.

Part B - This portion of the study was established to determine the necessity of preventing the herbicide spray materials from coming in contact with the pecan seedlings at different growth stages. Treatments were made on March 20, 1967, as follows:

	Herbicide	Rate	Pecan Seedling Growth Stage Range	Method of Application
1.	Trifluralin	1 Lb/A	Emergence to 4 Inches	Directed Spray
2.	Trifluralin	1 Lb/A	Emergence to 4 Inches	Non-Directed Spray
3.	Trifluralin	1 Lb/A	4 Inches to 10 Inches	Directed Spray
4.	Trifluralin	1 Lb/A	4 Inches to 10 Inches	Non-Directed Spray
5.	DCPA	12 Lbs/A	Emergence to 4 Inches	Directed Spray
6.	DCPA	12 Lbs/A	Emergence to 4 Inches	Non-Directed Spray
7.	DCPA	12 Lb/A	4 Inches to 10 Inches	Directed Spray
8.	DCPA	12 Lbs/A	4 Inches to 10 Inches	Non-Directed Spray
9.	Simazine	2 Lbs/A	Emergence to 4 Inches	Directed Spray
10.	Simazine	2 Lbs/A	Emergence to 4 Inches	Non-Directed Spray
11.	Simazine	2 Lbs/A	4 Inches to 10 Inches	Directed Spray
12.	Simazine	2 Lbs/A	4 Inches to 10 Inches	Non-Directed Spray

An asphalt shield was used to keep the herbicides off pecan seedling stems and leaves while spraying the soil in the directed spray treatments. Pecan seedling stems, but not leaves, were purposely soaked with the herbicides in the non-directed treatments. Care was taken to prevent spray droplets from making foliage contact in both directed and non-directed treatments with an asphalt shield.

Soil incorporation followed each trifluralin treatment.

Part C - Topical sprays of trifluralin, DCPA, and simazine were applied directly to the growing points and foliage of Western pecan seedlings April 25, 1967. Each herbicide was applied at the same concentration used in the field and in the previous parts of the greenhouse study. Five seedlings, ranging from six to twelve inches in height, were selected for each herbicide treatment. This part of the experiment was initiated to determine the effects of the three herbicides on established pecan seedlings.

Part D - Indications of trifluralin toxicity to pecan seedlings, when applied at time of emergence, was apparent in Part B. Two pecan seedlings died following an application of trifluralin to the shoots of very young pecan seedlings soon after they had emerged from the soil. Additional pecan seed were planted April 15, 1967, to determine if the trifluralin was actually responsible for the dead seedlings or whether death may have been due to other causes. Trifluralin was applied at the one pound per acre rate directly to the growing points of eight seedlings soon after they had emerged through the soil. Date of the first treatment was May 8, 1967, and the last treatment was May 15, 1967. This treatment is designated as "C" in Figure 33.

Part E - This portion of the experiment was initiated due to numerous unpublished reports of lateral root inhibition of trifluralin on tolerant crop species.

Ten Western pecan seed were planted in each of three containers on May 15, 1967. The treatments in Part E were as follows:

A. Ten Western pecan seed planted in a two-inch layer of soil treated with trifluralin at one pound per acre;

B. Ten Western pecan seed planted two inches above a trifluralin treated layer of soil; and

Check. Ten Western pecan seed planted in soil containing no trifluralin.

Part F - This portion of the experiment was a bioassay test initiated April 25, 1967. The purposes of the bioassay were twofold: (1) to indicate if there was movement of herbicides in the soil, and (2) to indicate the persistence of the herbicides as influenced by the conditions of the experiment.

Four soil cylinders were selected at random from each of the trifluralin, DCPA, and simazine post-emergence treatments and one cylinder from each pre-emergence treatment. Four soil samples were collected from each cylinder, beginning with (A) the top two inches; (B) the six to eight inch level; (C) the 12 to 14 inch level; and (D) the 18 to 20 inch level. Soil samples taken from the cylinders were placed in four-inch plastic pots and labeled with respect to the herbicide treatment and the soil depth from which the samples were taken.

Soil in pots designated as checks were treated with trifluralin, DCPA, and simazine immediately prior to or following seedling. Soil used in the checks was taken from cylinders which had received no previous herbicide treatment. The purposes of the checks were to provide comparison of herbicidal persistence and movement differences between these herbicides when recently applied and when applied at two- and six-month intervals prior to date of bioassay tests.

Each pot was seeded with a given volume (approximately one hundred) of crabgrass (Digitaria spp.) seeds. Crabgrass was selected for bioassay since it was known to be sensitive to all three herbicides being studied. After seeding, the pots were placed under continuous fluorescent light for germination and growth.

CHAPTER IV

EXPERIMENTAL RESULTS

Fourteen herbicides, five of which were used at two rates, were applied as pre-emergence treatments to Western pecan seedlings at the Horticulture Research Station, Perkins, Oklahoma. Each herbicide treatment was replicated twice, and six check plots were added which gave a total of 44. Seven weeks after planting, one replicate plot of each treatment was cultivated.

Yield data were analyzed, and comparisons were made between plots receiving cultivation and those which were not cultivated. Additional data were collected to determine the effect of the herbicide treatments on pecan seedling emergence, phytotoxicity to pecan seedlings and soil persistence of the herbicides.

Tests were also conducted in the horticulture greenhouses at Oklahoma State University to study the effects of three herbicides on Western pecan seedlings.

Additional greenhouse studies were initiated when what appeared to be trifluralin toxicity occurred on emerging pecan seedlings. Further soil treatments were conducted to determine the effect of trifluralin on Western pecan seedling lateral root development.

A bioassay test was conducted to determine movement in the soil and the persistence of three herbicides as influenced by the conditions of the study.

Research Conducted at the Horticulture Research Station, Perkins, Oklahoma

1. Pecan Seedling Emergence

Table I shows the effect of the various herbicides on Western pecan seedling emergence. Numbers in Table I represent percent emergence at six time intervals beginning April 27 and ending September 18, 1966.

The results of this portion of the experiment indicated that cultivation did not enhance emergence of pecan seedlings in the herbicide treatments selected for study.

It is reasonable to assume that cultivations were made too infrequently for an accurate estimate of the effects of herbicides used with cultivation on pecan seedling emergence. A comparison of emergence in the check treatments would seem to substantiate this observation, since there were lower emergence percentages in each check receiving cultivation than in the checks which were not cultivated. Weed population and soil crusting within the rows may have been causal factors in delaying emergence and this effect was expressed regardless of whether cultivation was or was not used. Also, blowing sand during the summer may have caused shoot death in the

TABLE I

THE EFFECT OF PRE-EMERGENCE HERBICIDES AND CULTIVATION ON RATE OF EMERGENCE AND TOTAL NUMBER OF WESTERN PECAN SEEDLINGS

Treatment		April 27	May 7	May 14	May 21	May 31	Sept. 18[1]
Trifluralin	No Cultivation	0	9	16	42	70	84
(1 Lb/A)	Cultivated	0	2	11	48	61	87
Trifluralin	No Cultivation	0	16	20	31	42	100
(3/4 Lb/A)	Cultivated	0	9	16	45	66	100
Benefin	No Cultivation	18	58	58	74	78	92
(3/4 Lb/A)	Cultivated	15	33	40	74	75	97
Diphenamid	No Cultivation	30	65	69	79	89	97
(2 Lbs/A)	Cultivated	16	35	43	64	74	82
Diphenamid	No Cultivation	30	55	59	69	81	86
(1 Lb/A)	Cultivated	16	28	35	60	82	84
DCPA	No Cultivation	9	40	62	74	74	85
(12 Lbs/A)	Cultivated	10	29	38	58	58	97
DCPA	No Cultivation	11	59	75	79	79	86
(8 Lbs/A)	Cultivated	12	19	22	41	62	90
DNBP	No Cultivation	9	41	52	52	82	95
(4 Lbs/A)	Cultivated	10	25	25	61	70	78

TABLE I (CONTINUED)

Treatment		April 27	May 7	May 14	May 21	May 31	Sept. 18[1]
Simazine	No Cultivation	21	63	66	81	81	99
(2 Lbs/A)	Cultivated	32	48	59	73	81	92
Atrazine	No Cultivation	11	66	71	84	88	84
(2 Lbs/A)	Cultivated	14	31	45	69	71	97
Sesone	No Cultivation	0	9	24	52	63	84
(4 Lbs/A)	Cultivated	0	18	26	47	55	78
Sesone	No Cultivation	4	19	26	60	66	83
(2 Lbs/A)	Cultivated	10	31	45	69	82	86
Diuron	No Cultivation	35	77	77	84	84	94
(2 Lbs/A)	Cultivated	26	37	47	68	70	85
Diuron	No Cultivation	21	52	66	77	86	100
(1 Lb/A)	Cultivated	25	39	45	61	72	90
CIPC	No Cultivation	0	1	7	2	8	89
(6 Lbs/A)	Cultivated	10	12	12	30	44	85
NPA	No Cultivation	28	79	77	89	89	93
(2 Lbs/A)	Cultivated	11	20	60	47	66	77
Amiben	No Cultivation	19	75	75	81	91	93
(2 Lbs/A)	Cultivated	16	30	38	65	72	84

TABLE I (CONTINUED)

Treatment		April 27	May 7	May 14	May 21	May 31	Sept. 18[1]
EPTC	No Cultivation	30	71	75	76	82	78
(2 Lbs/A)	Cultivated	23	31	46	65	75	92
CDEC	No Cultivation	38	66	72	86	92	98
(4 Lbs/A)	Cultivated	27	43	61	82	89	91
Check	No Cultivation	25	61	61	83	90	96
	Cultivated	12	13	15	58	58	86
Check	No Cultivation	43	80	81	91	91	95
	Cultivated	5	8	17	43	64	86
Check	No Cultivation	22	59	59	81	88	87
	Cultivated	30	63	55	85	85	87

[1]Total number of seedlings emerged.

cultivated checks. This might account for the lower numbers of seedlings harvested September 18, 1966, in the cultivated checks.

Trifluralin, used at both three-fourths of a pound and one pound per acre appeared to be responsible for delaying pecan seedling emergence. This effect was observed in the cultivated plots as well as in the plots receiving no cultivation. This also appeared to be true in plots receiving sesone at four pounds per acre and CIPC at six pounds per acre. In the instance of CIPC, this was the situation only in the non-cultivated plot. When cultivation was used with CIPC there was a substantial increase in pecan seedling emergence.

Emergence was quite variable, apparently due to factors other than herbicide treatment. This observation is especially evident when emergence data between the check treatments are analyzed. Except for possibly the delayed effect on germination by the herbicides, it appears that the herbicide treatments had little, if any, effects on Western pecan seedling emergence.

2. Weed Control

Weed emergence data, as shown in Table II, were collected on June 6, 1966, approximately 11 weeks after treatment. These data are indicative of soil persistence of the various herbicides as influenced by the edaphic and climatic factors associated with the study.

TABLE II

THE EFFECT OF PRE-EMERGENCE HERBICIDES ON WEED EMERGENCE AT THE PERKINS RESEARCH STATION, JUNE 6, 1966

Treatment	Average Weeds Per Square Foot	
	Cultivation[1]	No Cultivation[2]
Trifluralin, 1 Lb/A	4.6	6.2
Trifluralin, 3/4 Lb/A	.8	.4
Benefin, 3/4 Lb/A	10.4	19.0
Diphenamid, 2 Lbs/A	16.8	6.2
Diphenamid, 1 Lb/A	32.2	31.6
DCPA, 12 Lbs/A	2.2	3.0
DCPA, 8 Lbs/A	3.0	3.2
DNBP, 4 Lbs/A	3.2	26.6
Simazine, 2 Lbs/A	19.0	.4
Atrazine, 2 Lbs/A	2.6	2.0
Sesone, 4 Lbs/A	29.8	29.4
Sesone, 2 Lbs/A	2.8	15.2
Diuron, 2 lbs/A	3.2	2.2
Diuron, 1 Lb/A	5.8	15.6
CIPC, 6 lbs/A	6.8	2.6
NPA, 2 lbs/A	10.2	34.2
Amiben, 2 Lbs/A	18.0	3.8
EPTC, 2 Lbs/A	14.0	39.2
CDEC, 4 Lbs/A	8.2	7.8
Check	27.2	23.6
Check	8.2	4.6
Check	14.0	18.4

[1]Weed counts were made within the row in the cultivated area.

[2]Weed counts taken from within the treated area.

Data in the check treatments indicate wide variation in weed populations within the experimental area. This made statistical evaluation of weed control in the various treatments impractical. However, in some treatments, weed populations were very low 11 weeks following treatment which indicated herbicide persistence in these treatments. This was especially apparent in both cultivated and non-cultivated treatments in which trifluralin was applied at three-fourths of a pound per acre. In treatments receiving trifluralin at one pound per acre, it appears that persistence was decreased. It follows that an increase in concentration of this herbicide should have increased persistence, and, therefore, there is no readily available explanation for the results obtained in these treatments.

Apparently, cultivation reduced the herbicidal effectiveness of simazine and amiben when each were applied at two pounds per acre. In the cultivated simazine treatment weed counts indicated an average of 19 weeds per square foot. This compared to an average of .40 weeds per square foot when no cultivation was used. In the amiben treatment an average of 18 weeds per square foot was recorded when cultivation was used. This compared to an average of 3.8 weeds per square foot when no cultivation was used.

Other treatments which indicated residual weed control over the eleven-week period were: DCPA, eight and twelve pounds per acre, cultivated and non-cultivated; DNBP, four pounds per acre, cultivated; atrazine, two pounds per acre, cultivated and non-cultivated; sesone, two pounds per acre, cultivated; diuron, two pounds per acre, cultivated and non-cultivated; and CIPC, six pounds per acre, cultivated.

Photographs were taken June 22, 1966, to illustrate the residual weed control properties of the herbicides 100 days after treatment.

Figures 1, 2, and 3 are photographs which illustrate the effectiveness of the trifluralin, DCPA, and simazine treatments.

Figure 1 shows that trifluralin provided excellent crabgrass control in the cultivated plot as well as the plot which was not cultivated; however, as indicated in Figure 1, certain broad-leaf weed species were resistant to trifluralin and were not controlled. This same effect was expressed in the DCPA treatments and is shown in Figure 2.

Figure 3 and Table II show that cultivation reduced the herbicidal effectiveness of simazine.

3. Pecan Seedling Growth

The Western pecan seedlings were harvested on September 18, 1966, approximately six months from date of planting and treatment. The average height and weight and the number of seedlings harvested in each treatment are listed in Table III.

Figures 4, 5, 6, and 7 illustrate the data listed in

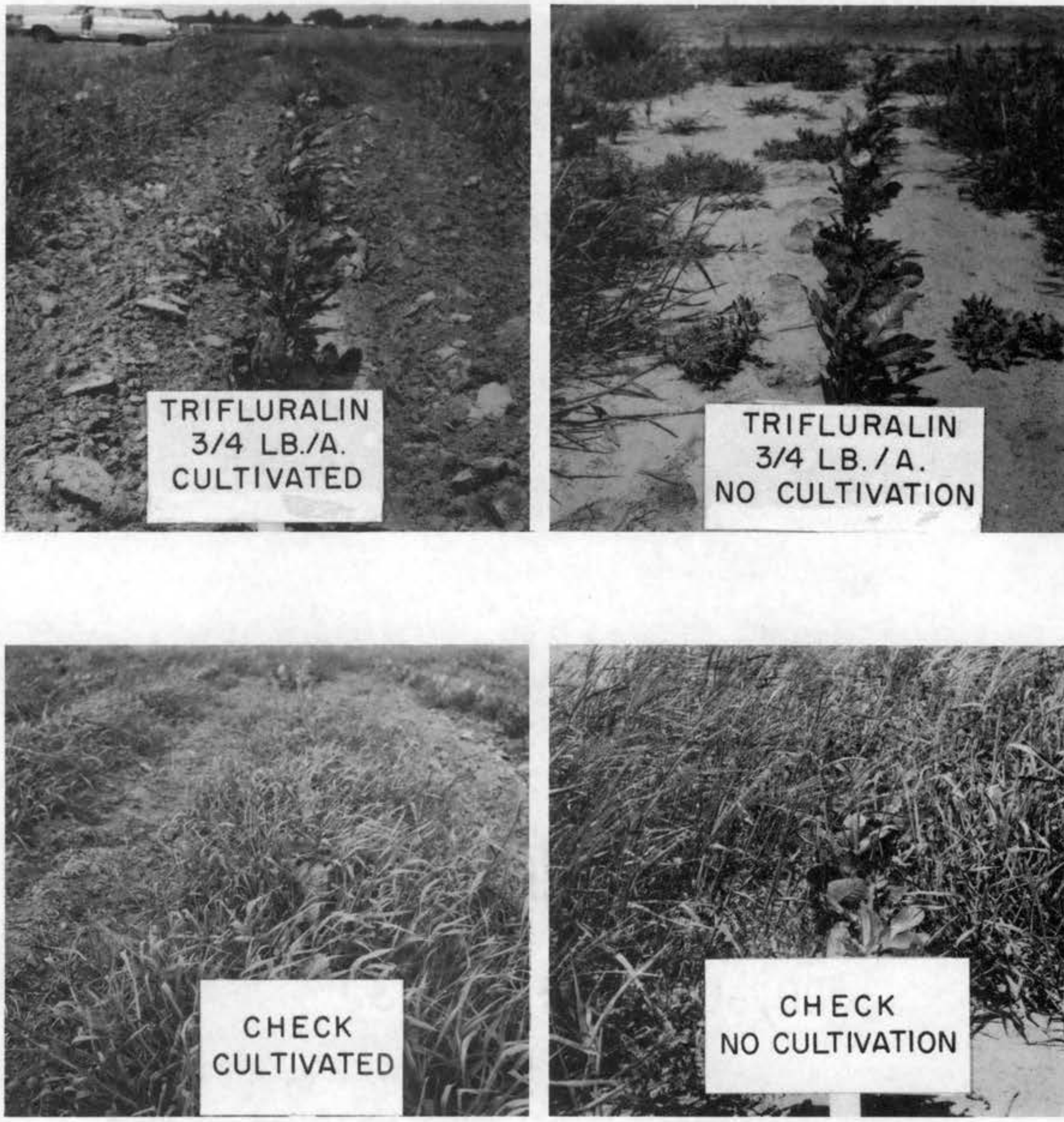

Figure 1. Residual Weed Control 100 Days After Treatment of Three-fourths of a Pound Per Acre Incorporated Trifluralin in a Teller Fine Sandy Loam Soil

Figure 2. Residual Weed Control 99 Days After Treatment of 12 Pounds Per Acre Non-incorporated DCPA in a Teller Fine Sandy Loam Soil

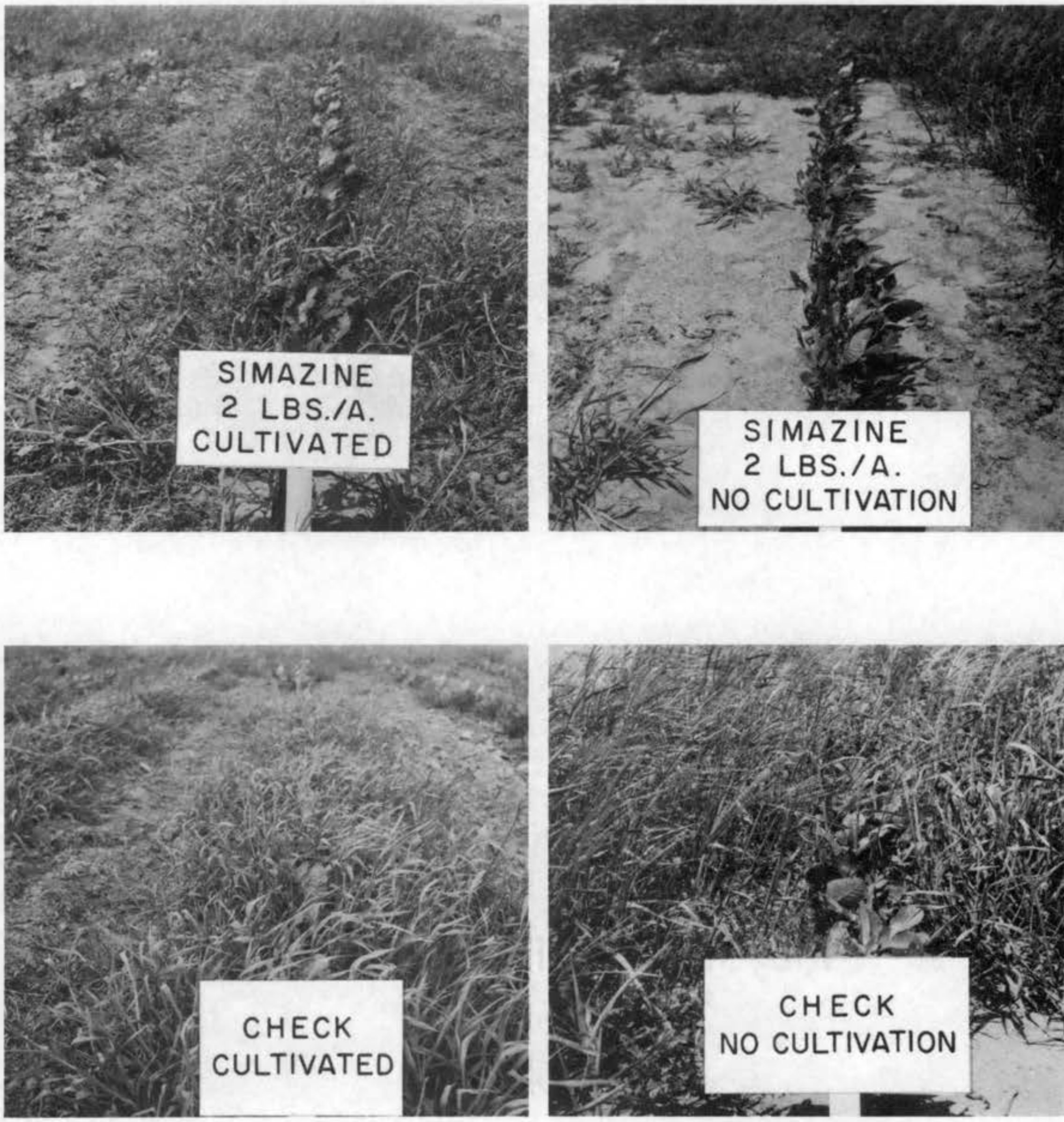

Figure 3. Residual Weed Control 99 Days After Treatment of Two Pounds Per Acre Non-incorporated Simazine in a Teller Fine Sandy Loam Soil

TABLE III

THE EFFECT OF PRE-EMERGENCE HERBICIDES ON GROWTH OF WESTERN PECAN SEEDLINGS, CULTIVATION VERSUS NO CULTIVATION

Treatment	No. of Seedlings Harvested		Av. Seedling Height (Inches)		Av. Seedling Weight (Grams)	
	Cult.	Non-cult.	Cult.	Non-cult.	Cult.	Non-cult.
Trifluralin, 1 Lb/A	87	84	7.39	6.57	7.51	2.86
Trifluralin, 3/4 Lb/A	100	100	6.10	6.78	8.02	5.63
Benefin, 3/4 Lb/A	97	92	7.87	8.08	6.55	4.59
Diphenamid, 2 Lbs/A	82	97	6.91	6.80	4.18	2.55
Diphenamid, 1 Lb/A	84	86	7.55	6.78	2.86	2.65
DCPA, 12 lbs/A	97	85	7.34	7.10	6.16	5.61
DCPA, 8 Lbs/A	90	86	8.78	6.71	7.77	4.57
DNBP, 4 Lbs/A	78	95	7.24	7.09	3.83	2.37
Simazine, 2 Lbs/A	92	99	6.94	7.74	3.09	5.43
Atrazine, 2 Lbs/A	97	84	6.11	7.12	3.99	3.57
Sesone, 4 Lbs/A	78	84	5.87	6.33	2.38	2.19
Sesone, 2 Lbs/A	86	83	6.56	5.73	3.90	2.43
Diuron, 2 Lbs/A	85	94	6.98	7.37	4.30	3.99
Diuron, 1 Lb/A	90	100	6.53	6.06	4.36	2.67
CIPC, 6 Lbs/A	85	89	7.86	5.35	3.66	2.40
NPA, 2 Lbs/A	77	93	5.51	6.91	2.31	2.40
Amiben, 2 lbs/A	84	93	6.43	7.35	3.02	2.82
EPTC, 2 Lbs/A	92	78	7.20	6.44	3.26	2.38

TABLE III (CONTINUED)

Treatment	No. of Seedlings Harvested		Av. Seedling Height (Inches)		Av. Seedling Weight (Grams)	
	Cult.	Non-cult.	Cult.	Non-cult.	Cult.	Non-cult.
CDEC, 4 Lbs/A	91	98	6.47	7.17	3.29	2.88
Check	86	96	6.19	6.83	2.00	2.73
Check	86	95	7.98	6.81	2.88	2.55
Check	87	87	6.46	6.21	3.10	2.94

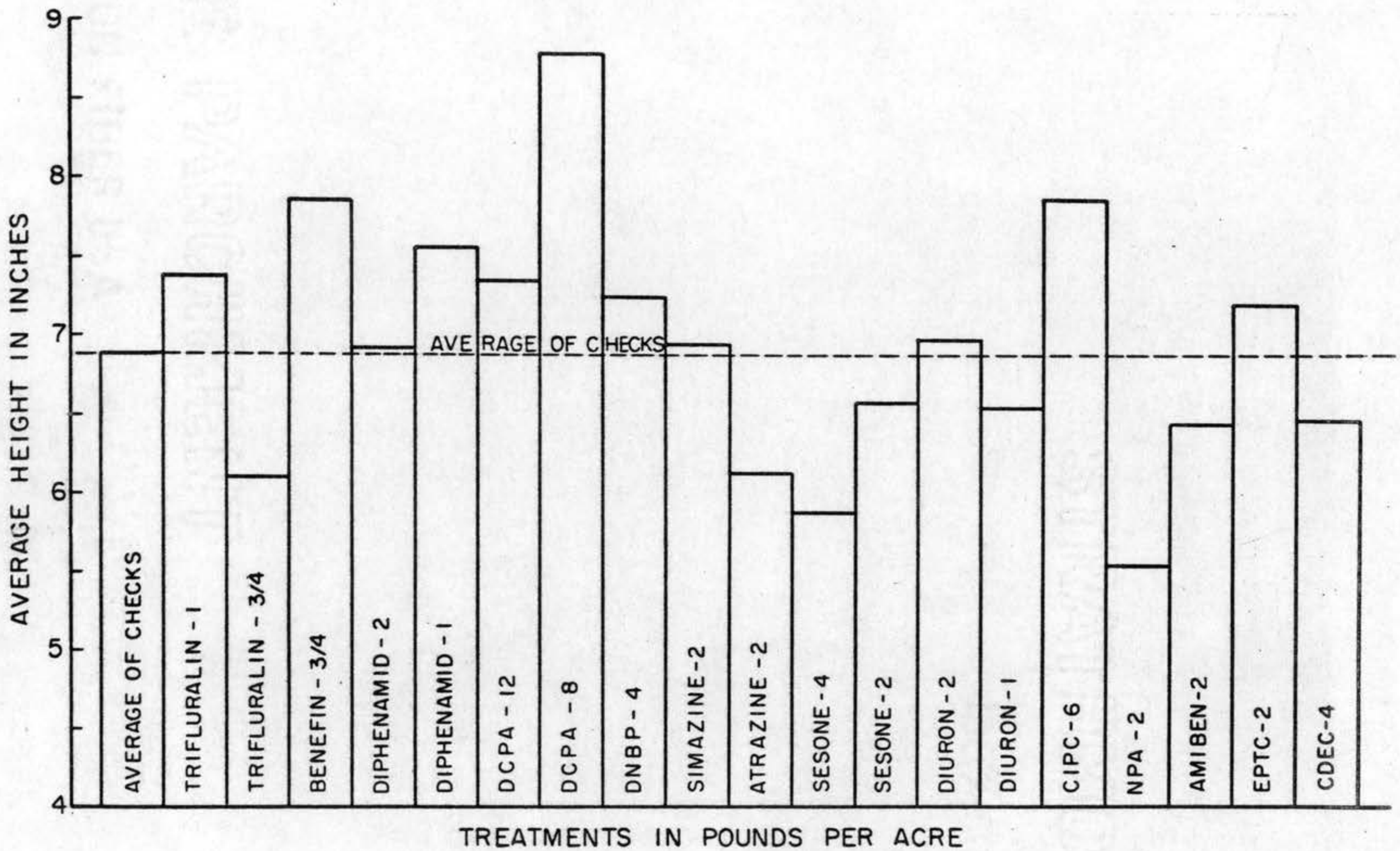

Figure 4. The Effect of Pre-emergence Herbicides and Cultivation on the Average Height of Western Pecan Seedlings

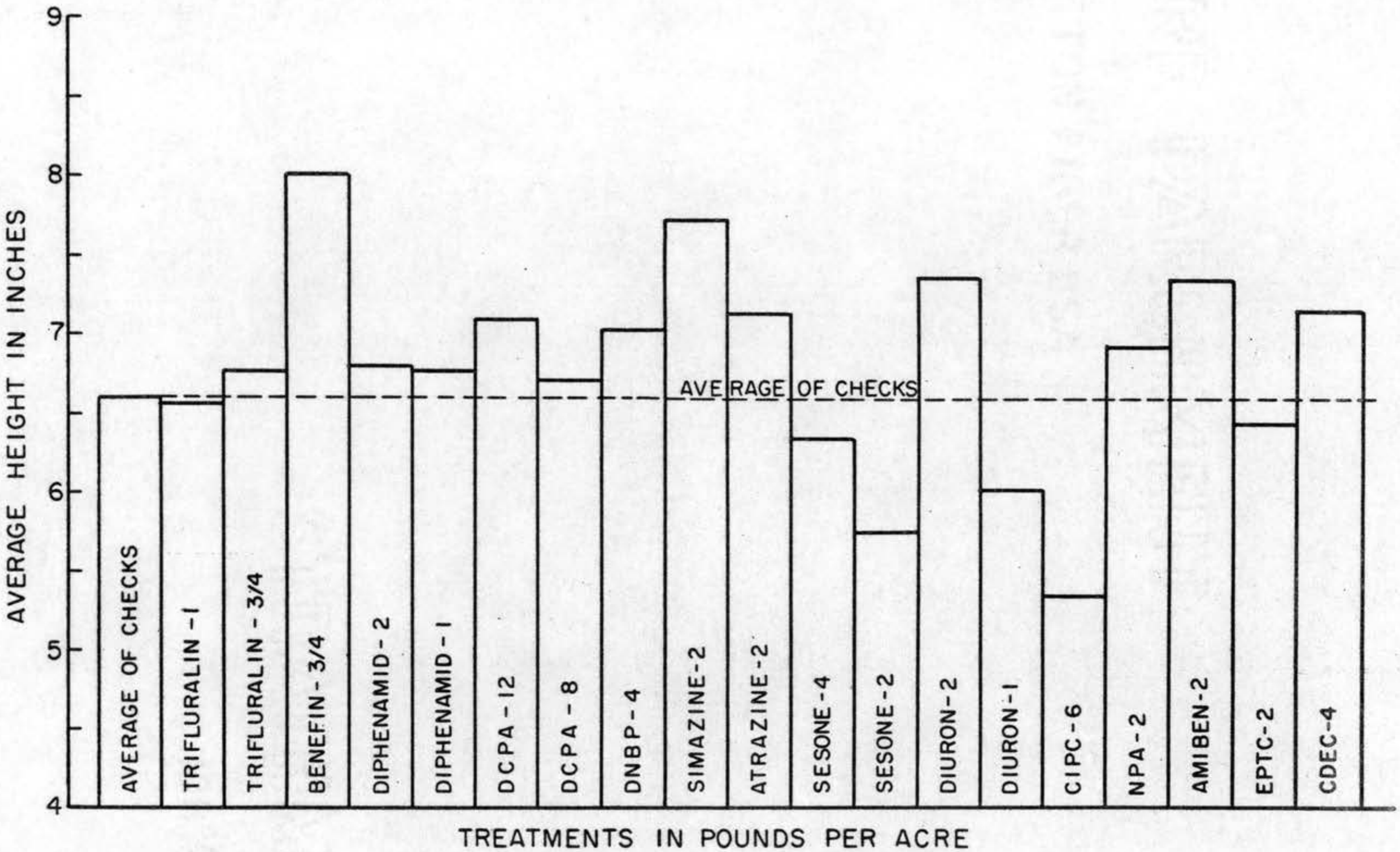

Figure 5. The Effect of Pre-emergence Herbicides and No Cultivation on the Average Height of Western Pecan Seedlings

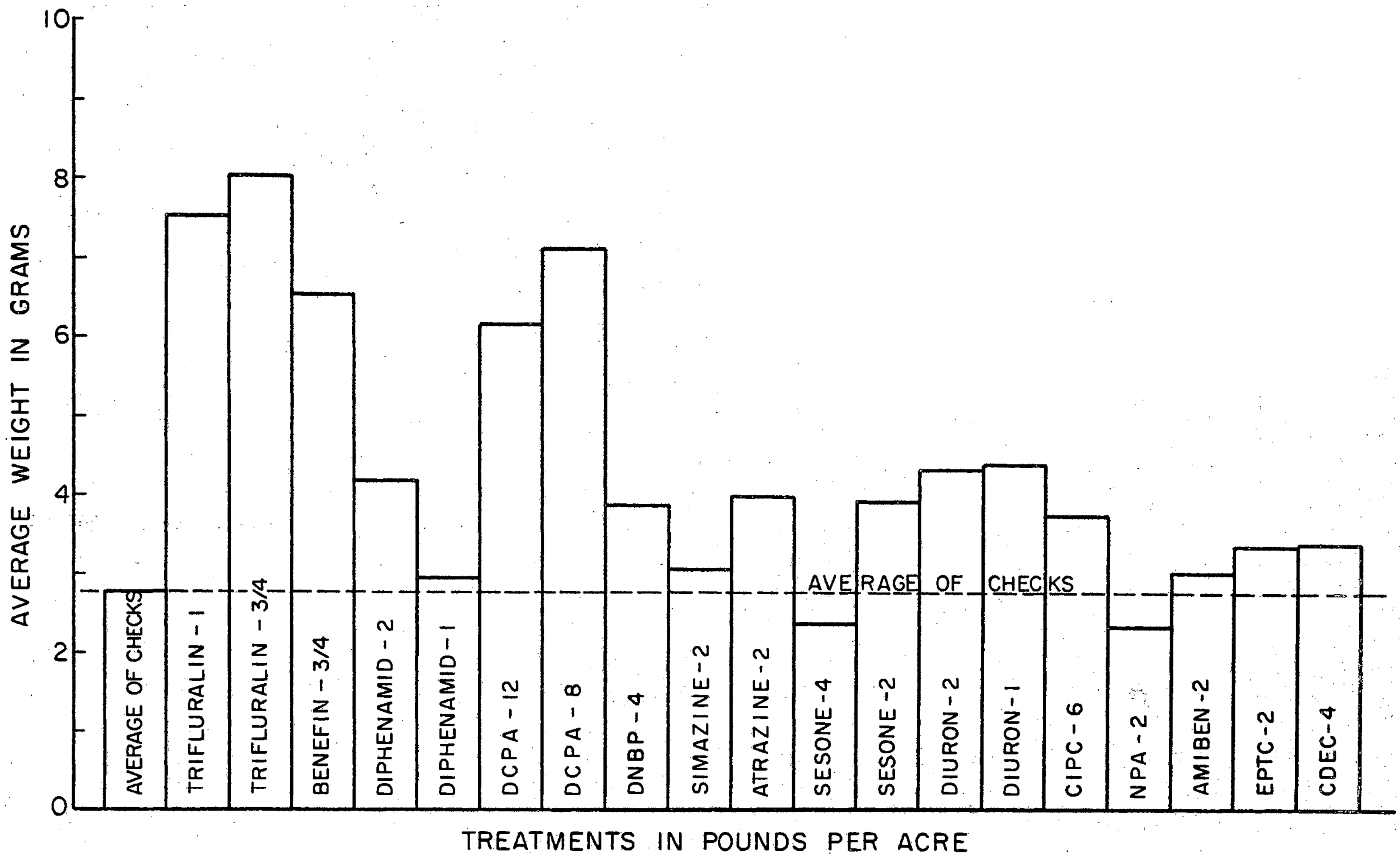

Figure 6. The Effect of Pre-emergence Herbicides and Cultivation on the Average Weight of Western Pecan Seedlings

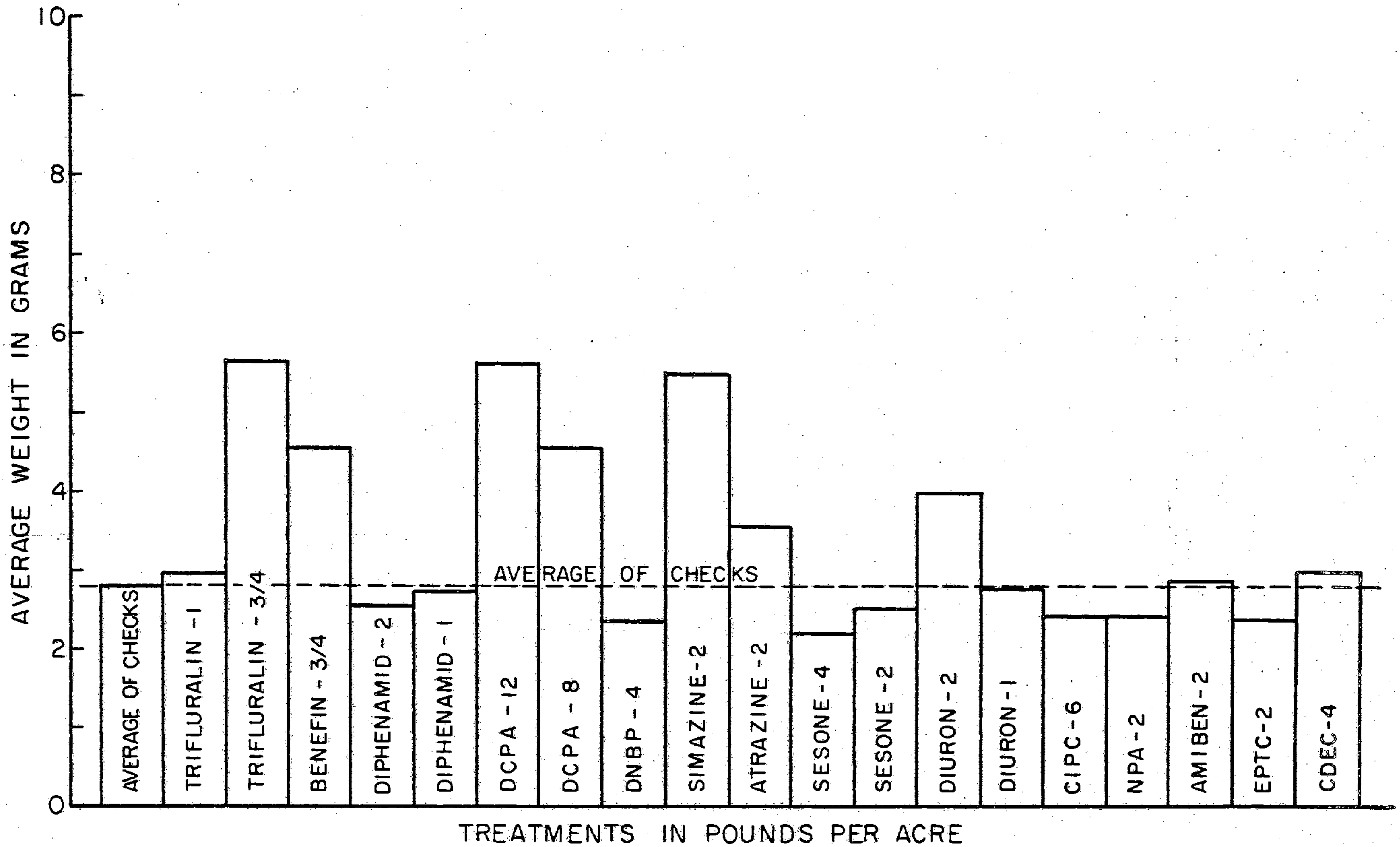

Figure 7. The Effect of Pre-emergence Herbicides and No Cultivation on the Average Weight of Western Pecan Seedlings

Table III. Figure 4 illustrates the average seedling height in each treatment and shows a comparison of the average seedling height in three check plots with the individual herbicide treatments when supplemental cultivation was used. Figure 5 shows the same comparisons but in plots where cultivation was not used.

Figure 6 illustrates the average seedling weight in each treatment and shows a comparison of the average seedling weight in three check plots with the individual herbicide treatments when supplemental cultivation was used. Figure 7 shows the same comparisons but in plots where cultivation was not used.

The greatest average seedling weights and the highest percentages of emergence were obtained in plots which received trifluralin at three-fourths of a pound per acre. This was apparent in the cultivated plot as well as in the plot receiving no supplemental cultivation. When trifluralin was applied at one pound per acre, average seedling weight and total number of seedlings harvested were lowered in both cultivated and non-cultivated plots. As was discussed previously, less weed control resulted when trifluralin was applied at one pound per acre than when it was applied at the lower rate. The competitive effect of the higher weed populations was probably responsible for reduced pecan seedling growth in plots receiving trifluralin at one pound per acre and not a direct effect of the herbicide.

There was a direct correlation between average seedling heights and average seedling weights in all treatments except the trifluralin treatments. In these treatments the average seedling weights exceeded the average seedling heights. Seedlings grown in the three-fourths pound per acre cultivated trifluralin plot had an average seedling weight of 8.02 grams and an average height of 6.10 inches.

In treatments receiving benefin at three-fourths of a pound per acre, the average seedling weights were 6.55 grams and 4.59 grams, respectively, in the cultivated and non-cultivated plots. These average weights were higher than those obtained in the checks but not as high as was obtained in treatments receiving trifluralin at three-fourths of a pound per acre. Since benefin is very closely related chemically to trifluralin, one might expect similar effects from the two herbicides. The differences were not considered to be sufficient enough to suggest that either herbicide was better than the other.

Average seedling weights and heights considerably higher than were obtained in the checks were recorded in six of the herbicide treatments. These were in plots treated with trifluralin at one pound per acre, trifluralin at three-fourths of a pound per acre, benefin at three-fourths of a pound per acre, DCPA at eight and twelve pounds per acre, and simazine at two pounds per acre.

Figure 4 shows that when cultivation was used, there were 11 herbicide treatments that yielded average seedling heights greater that the average of three checks. DCPA applied at eight pounds per acre was the treatment in which the tallest average seedling height was obtained.

Figure 5 shows that when no cultivation was used, 13 herbicide treatments produced seedlings taller than the average of the three checks. The treatment receiving benefin, applied at three-fourths of a pound per acre produced the tallest average seedling height.

The data in Figures 6 and 7 illustrate that seedling weight was not always directly correlated with seedling height. This observation is especially apparent when average seedling height in the trifluralin treatments are compared with the average seedling weight obtained in the same treatment. Although Figure 4 shows the average seedling height in the trifluralin (three-fourths of a pound per acre) treatment to be less than that obtained in the checks, Figure 7 shows that the largest average seedling weight was obtained in this treatment.

Comparisons of the effect of cultivation and no cultivation were made individually for each herbicide treatment. Figures 8 through 26 provide an account of individual seedling heights in each herbicide treatment. Seedlings are listed in growth range classes of one inch increments beginning with seedlings three inches or less in height and ending with seedlings twelve inches or more

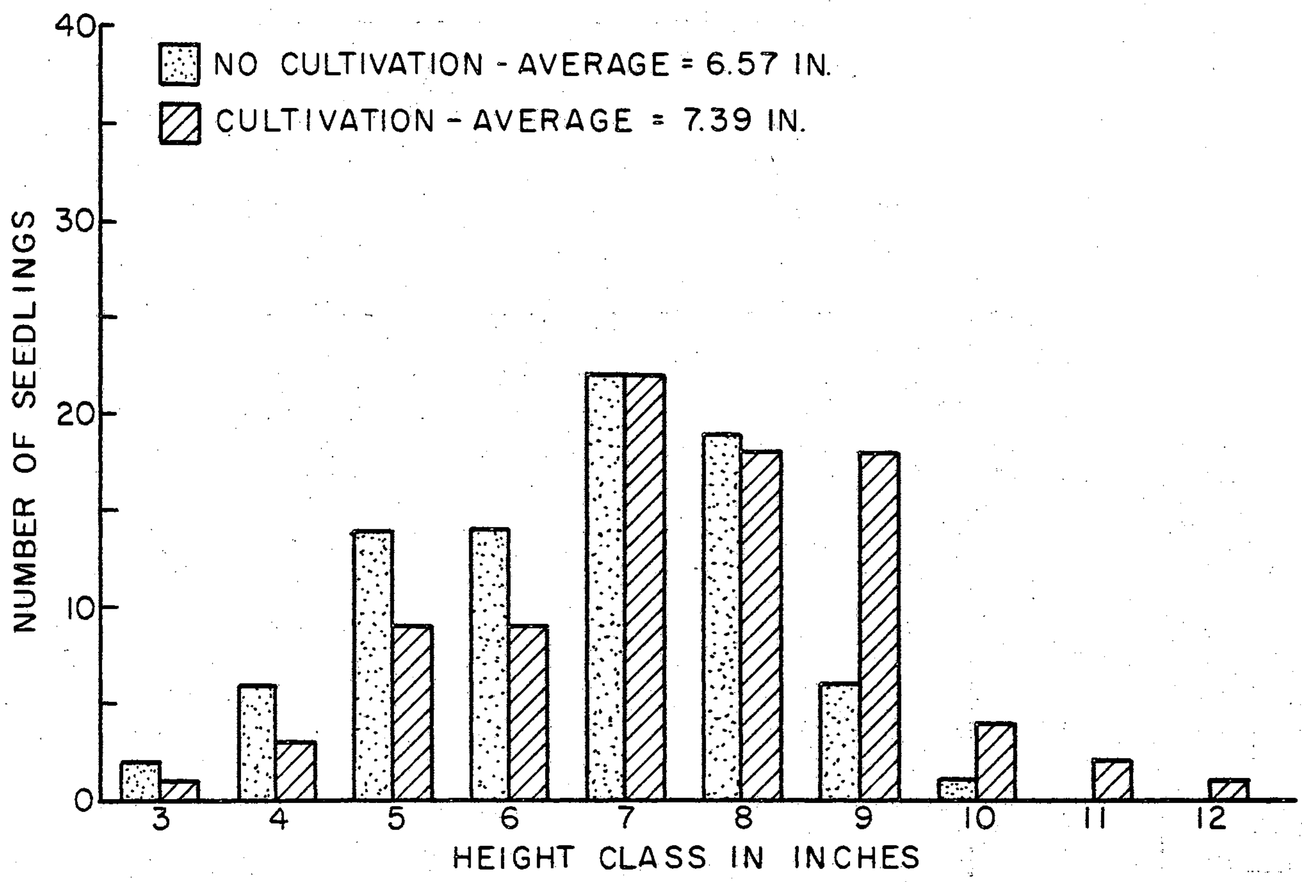

Figure 8. The Effect of Cultivation Versus no Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With One Pound Per Acre of Incorporated Trifluralin

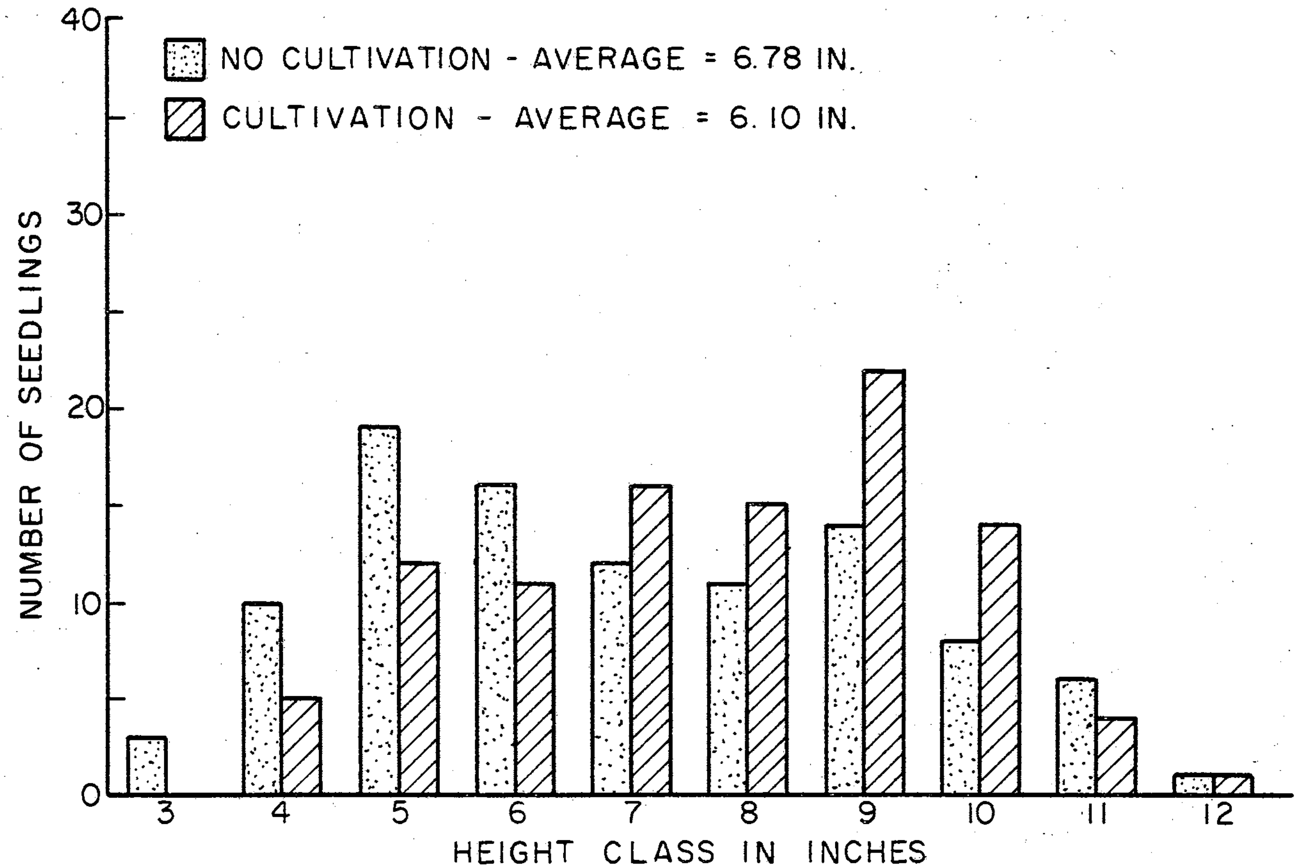

Figure 9. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Three-fourths of a Pound Per Acre of Incorporated Trifluralin

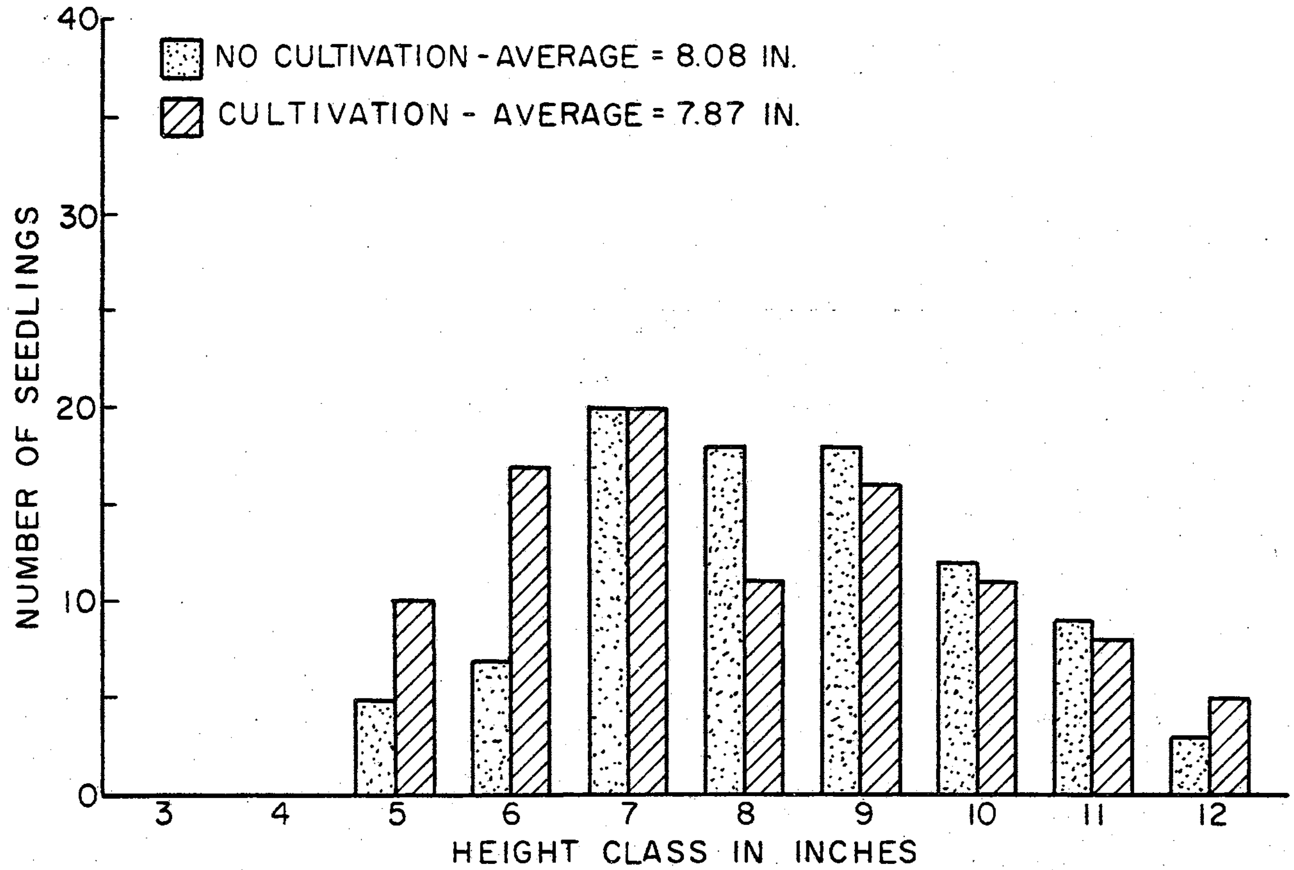

Figure 10. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Three-fourths of a Pound Per Acre of Incorporated Benefin

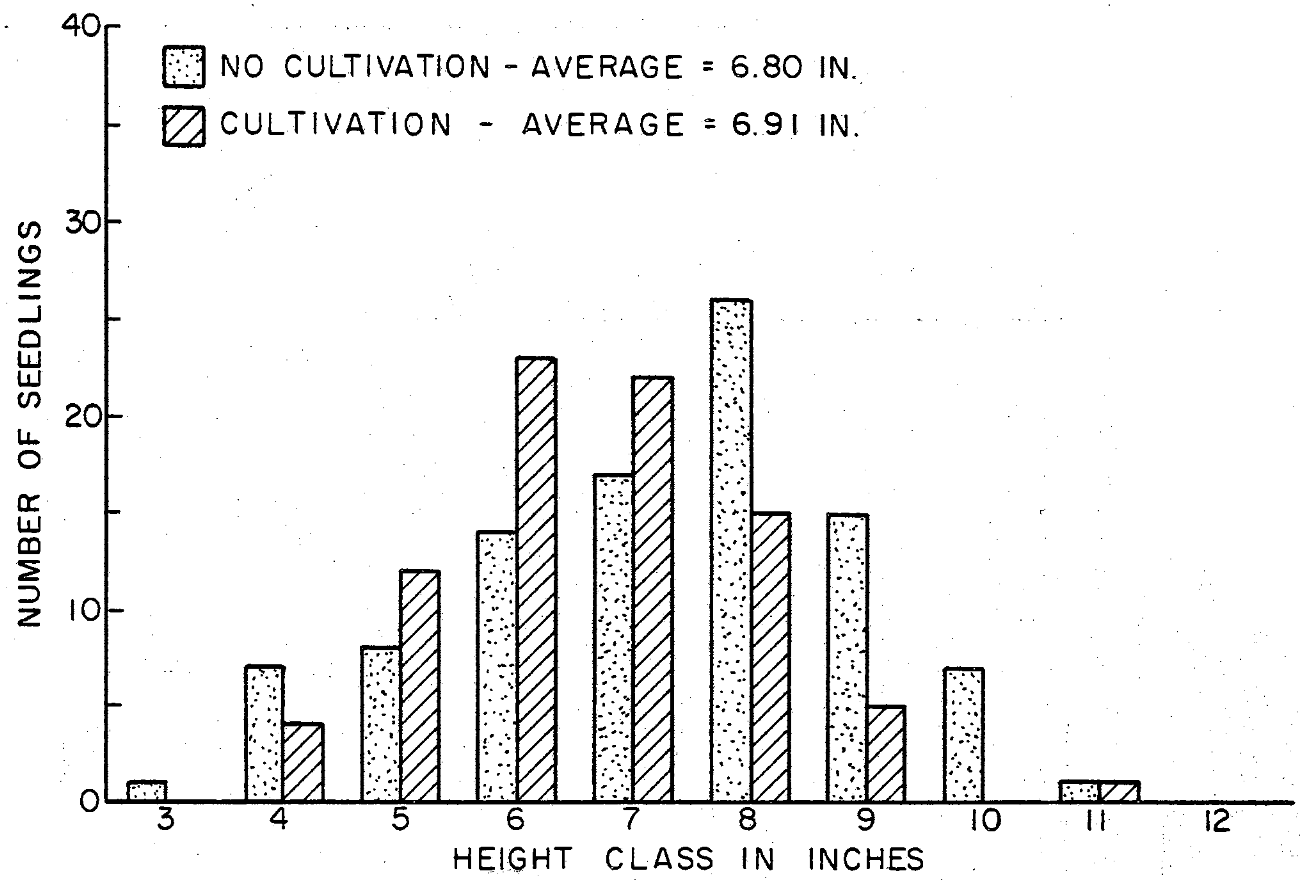

Figure 11. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Two Pounds Per Acre of Non-incorporated Diphenamid.

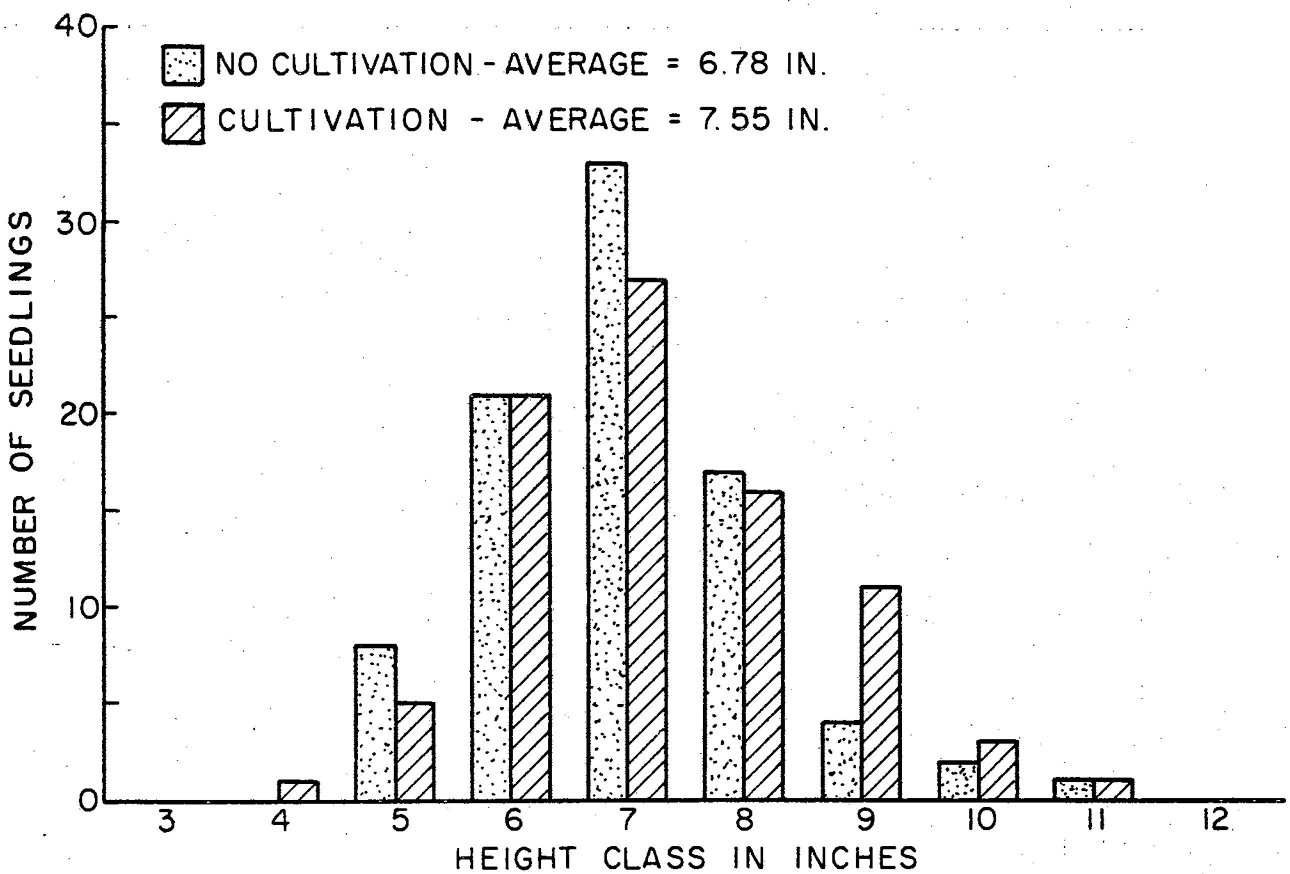

Figure 12. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With One Pound Per Acre of Non-incorporated Diphenamid

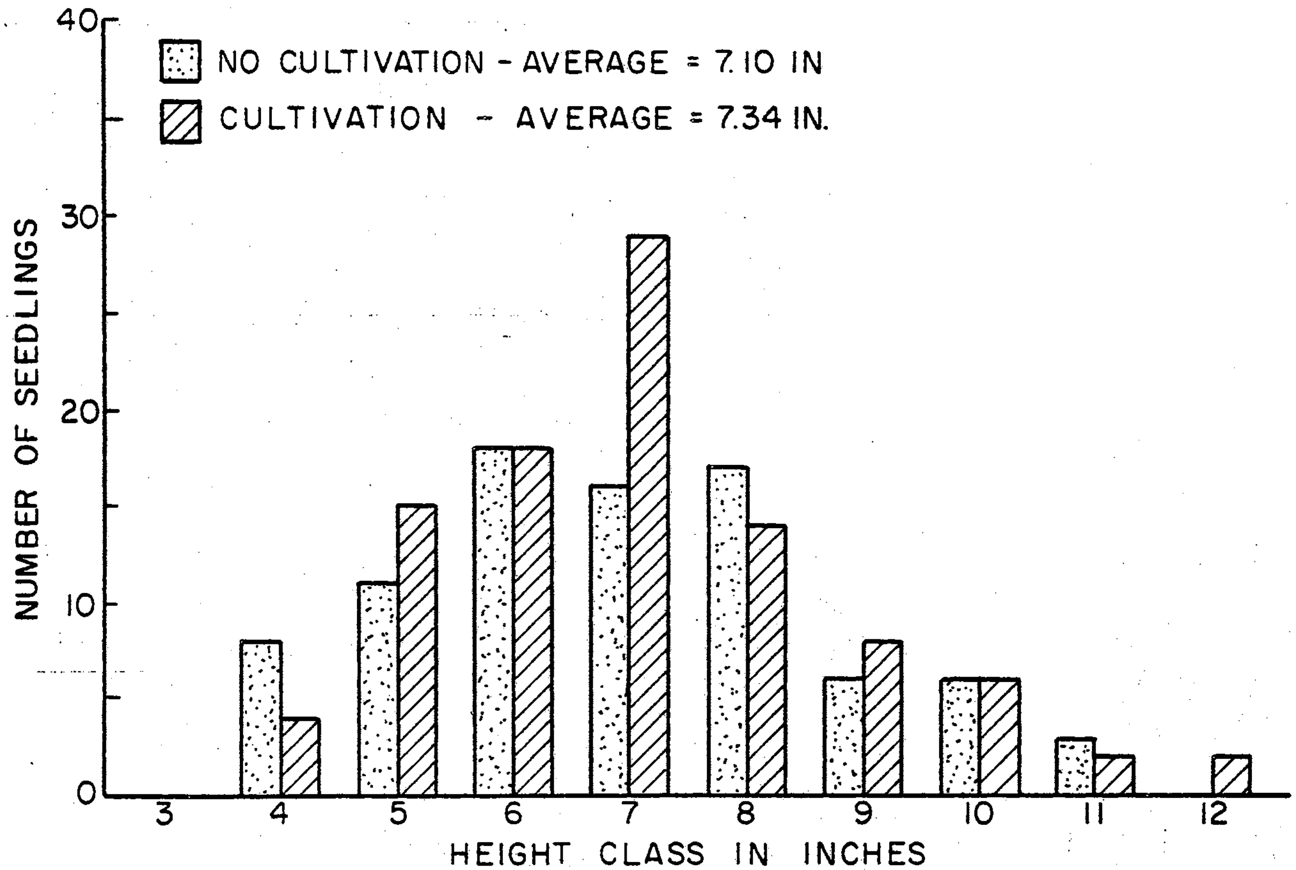

Figure 13. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With 12 Pounds Per Acre of Non-incorporated DCPA

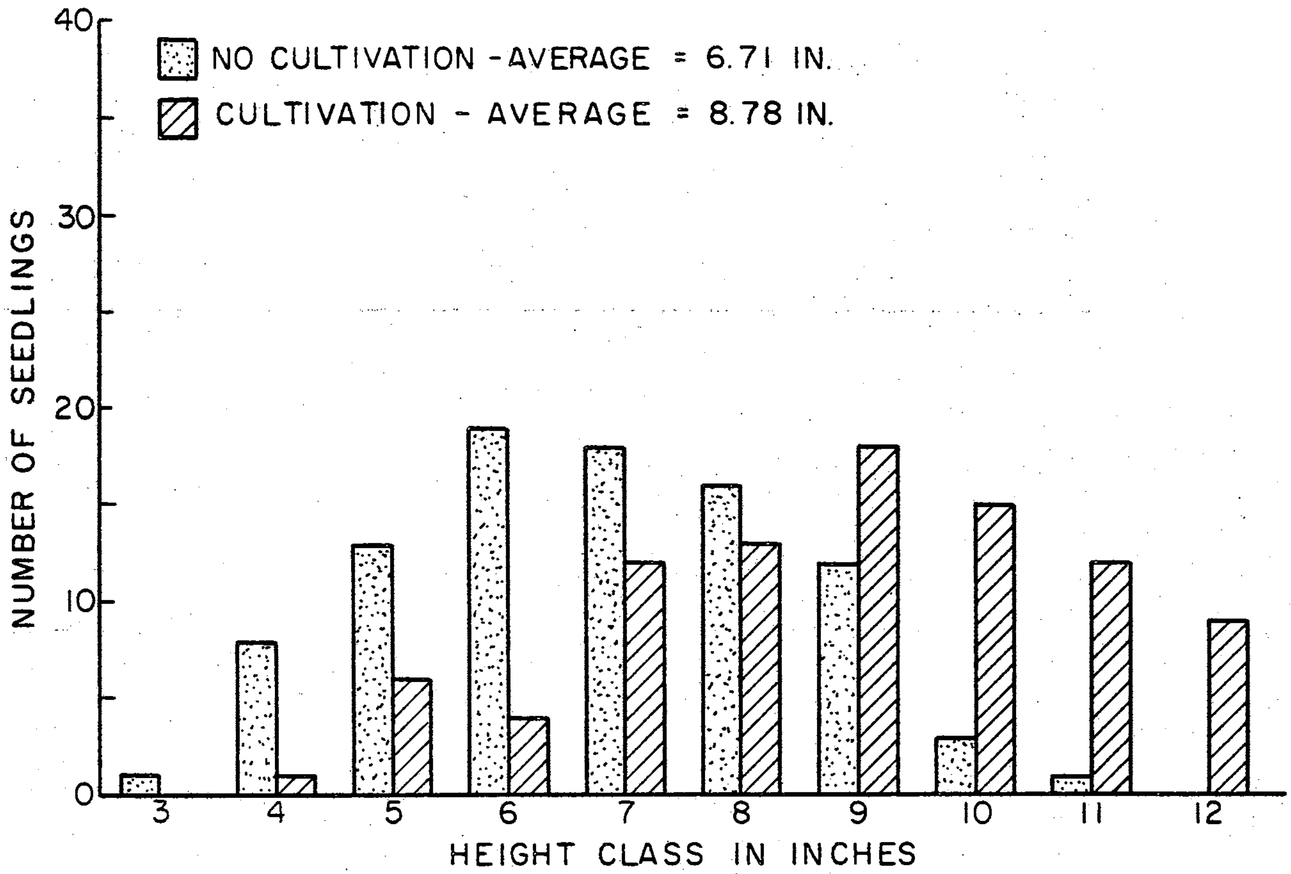

Figure 14. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Eight Pounds Per Acre of Non-incorporated DCPA.

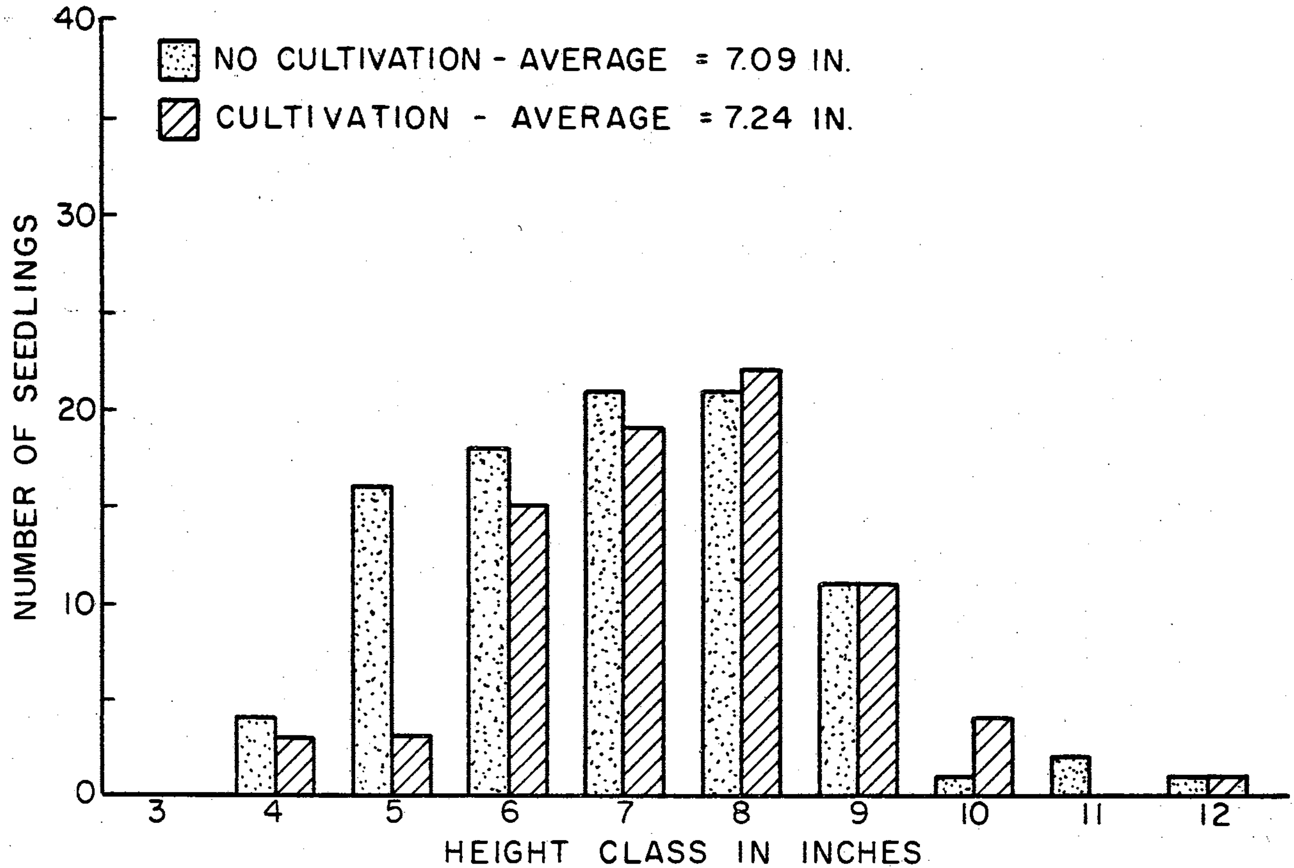

Figure 15. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Four Pounds Per Acre of Non-incorporated DNBP

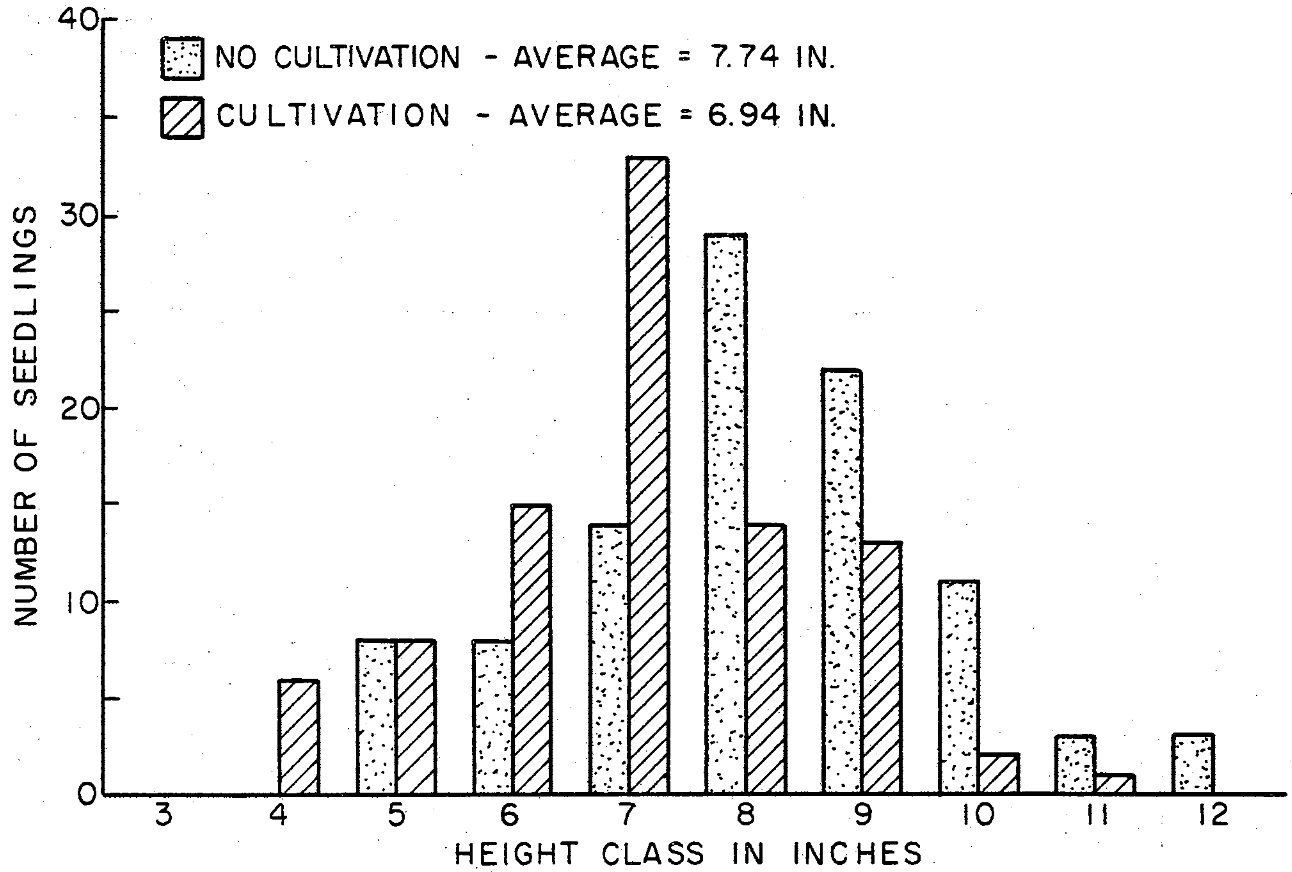

Figure 16. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Two Pounds Per Acre of Non-incorporated Simazine

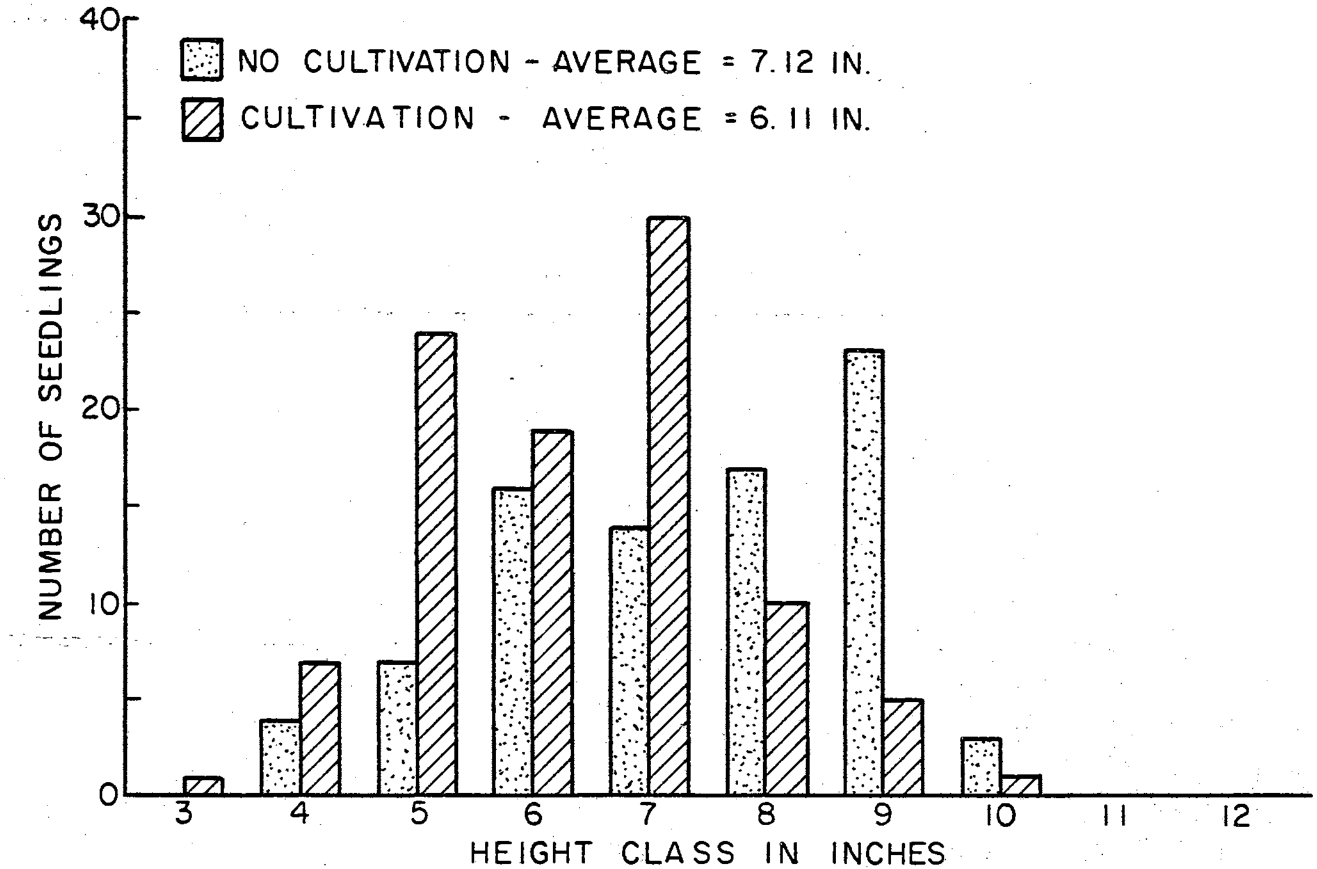

Figure 17. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Two Pounds per Acre of Non-incorporated Atrazine

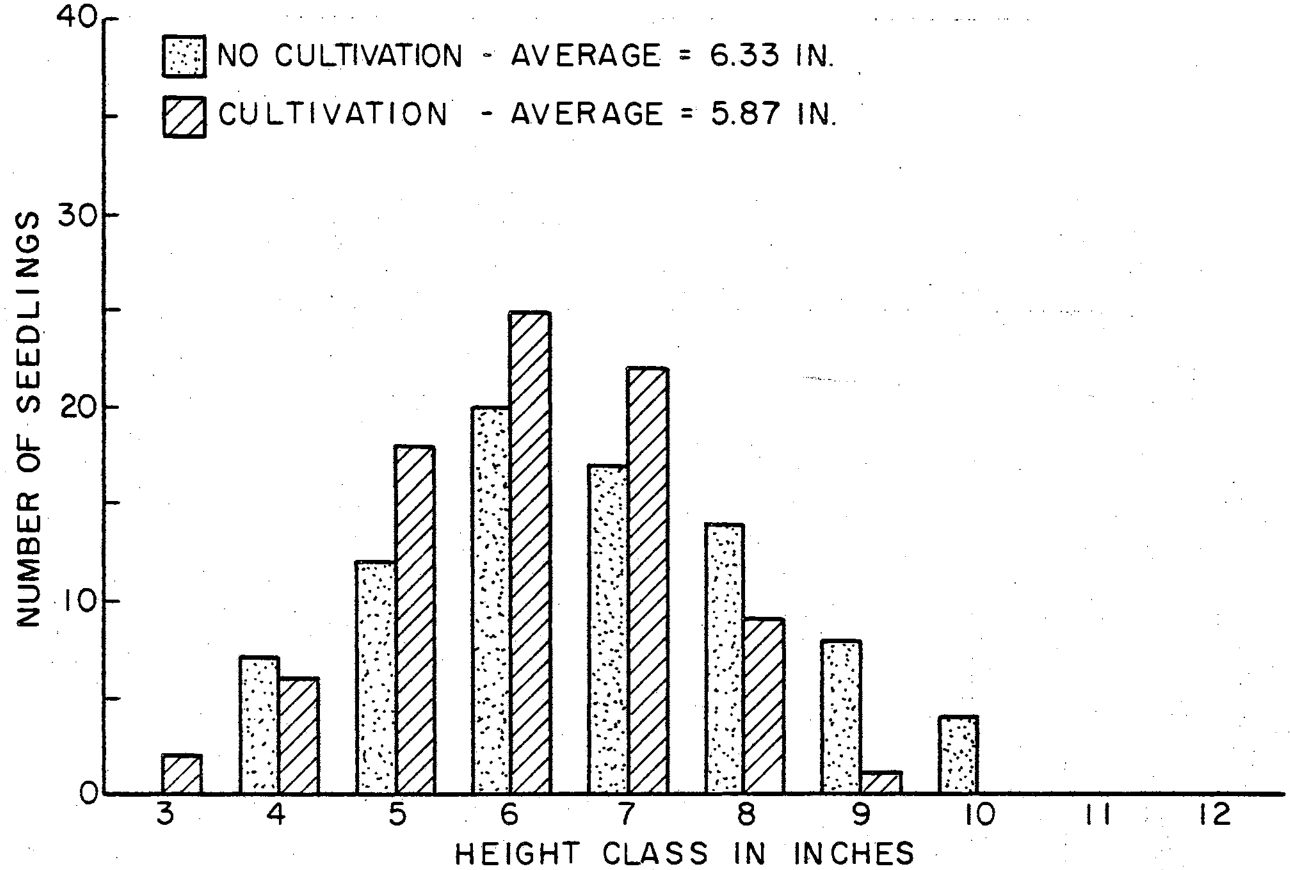

Figure 18. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Four Pounds Per Acre of Non-incorporated Sesone

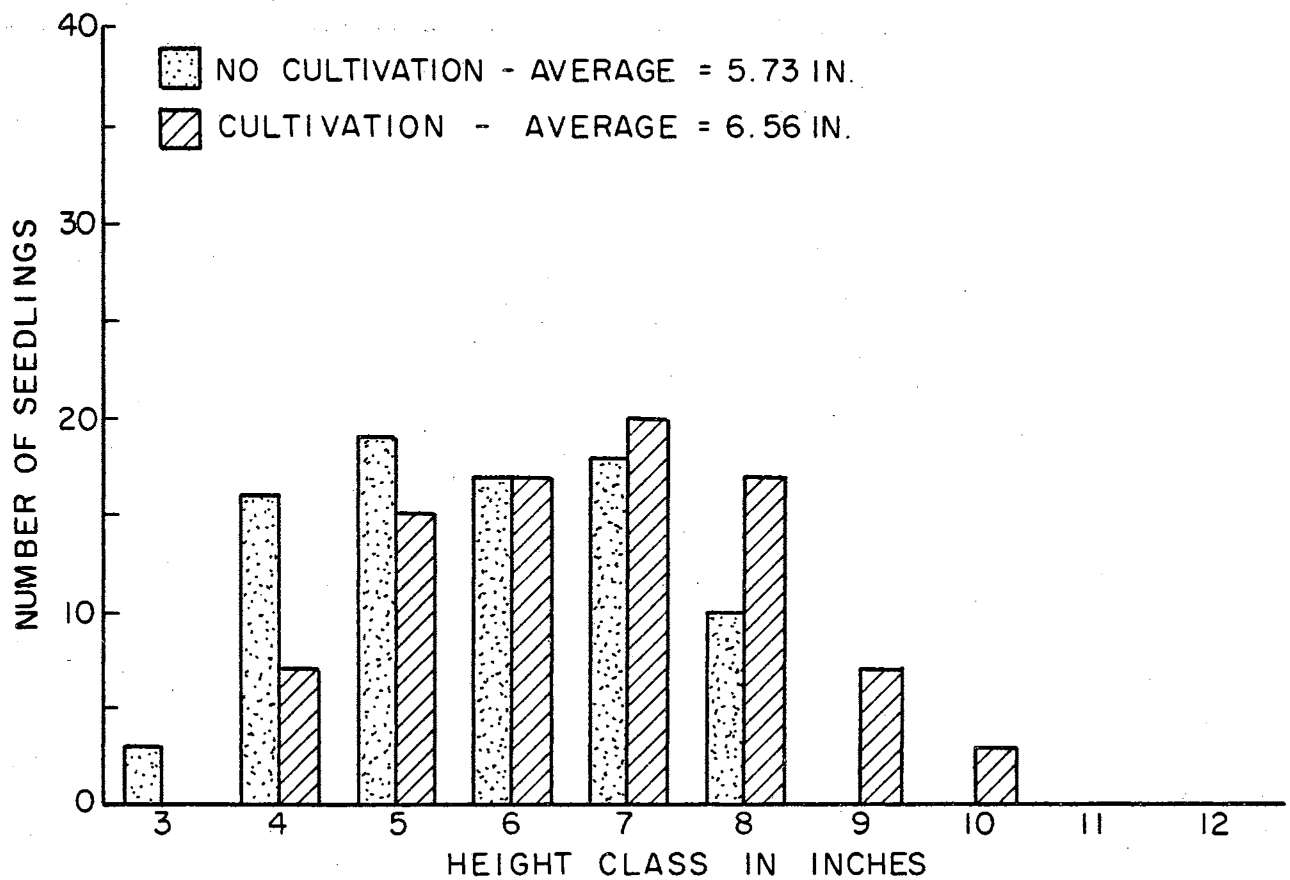

Figure 19. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Two Pounds Per Acre of Non-incorporated Sesone

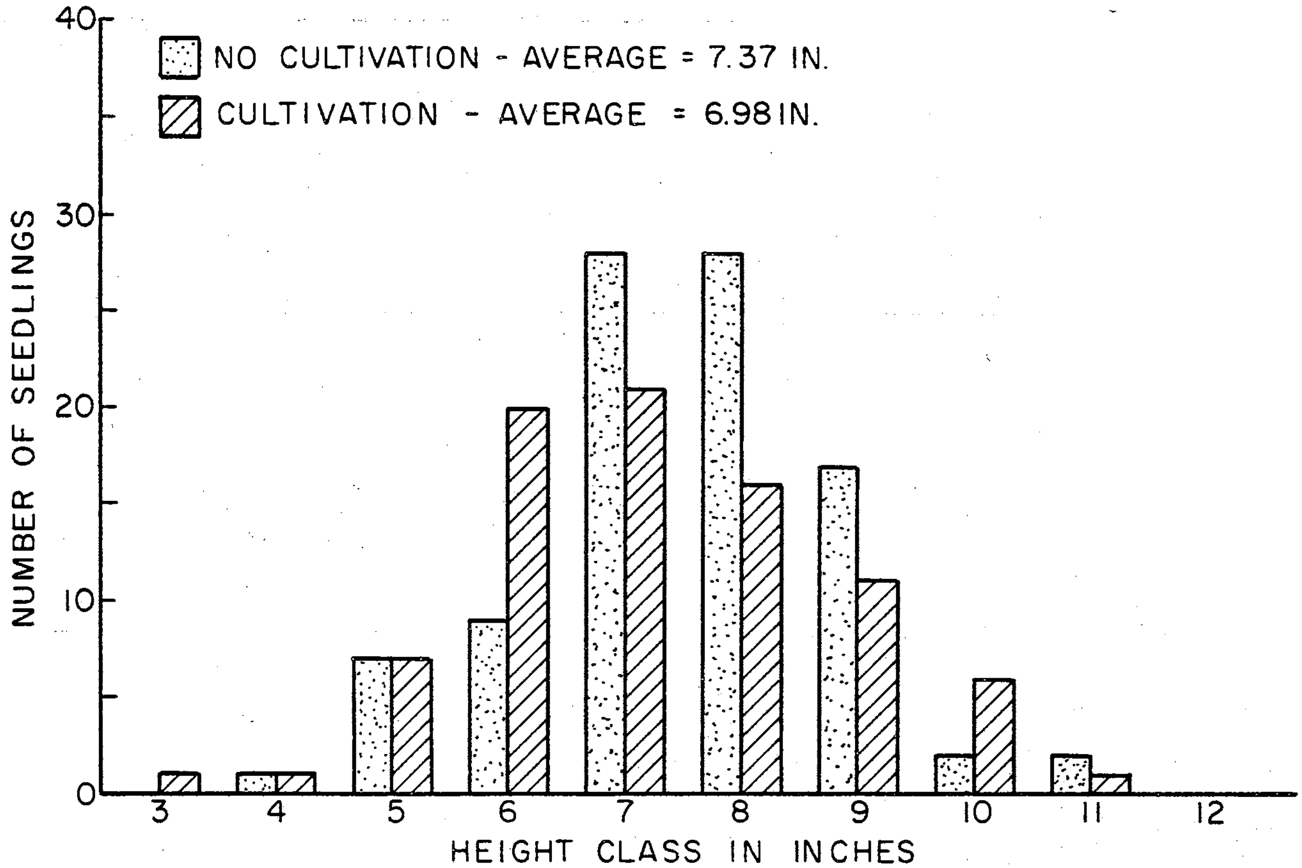

Figure 20. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Two Pounds Per Acre of Non-incorporated Diuron

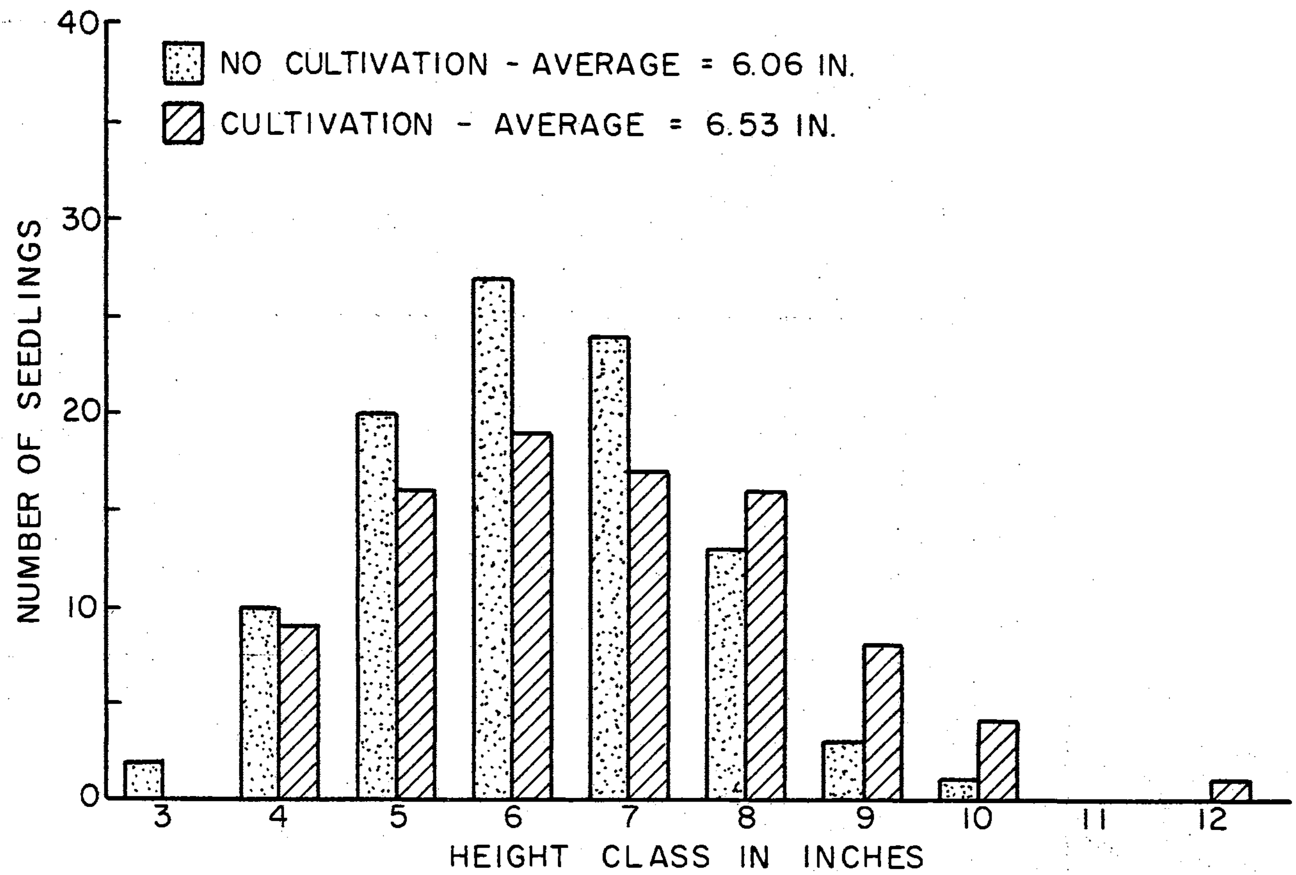

Figure 21. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With One Pound Per Acre of Non-incorporated Diuron

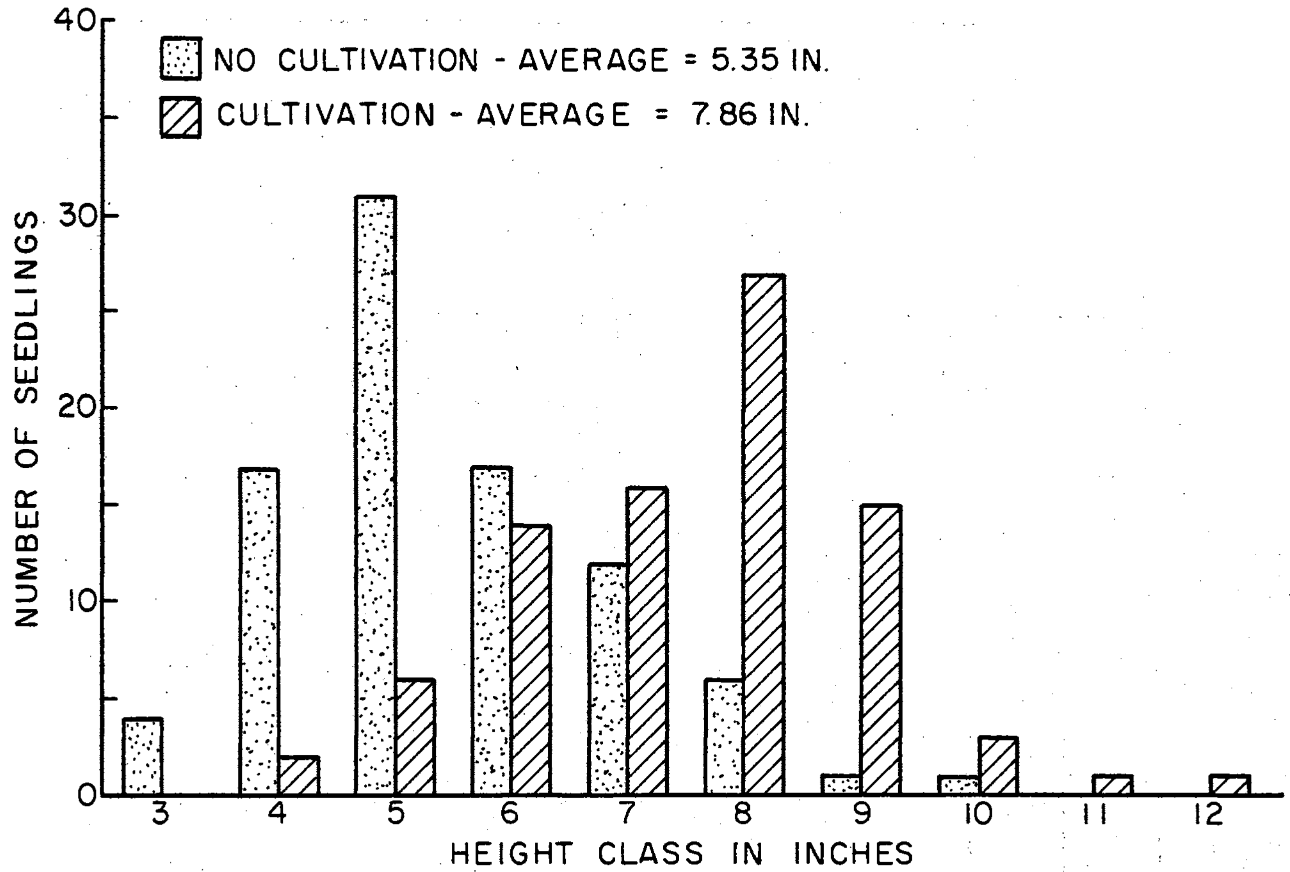

Figure 22. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Six Pounds Per Acre of Non-incorporated CIPC

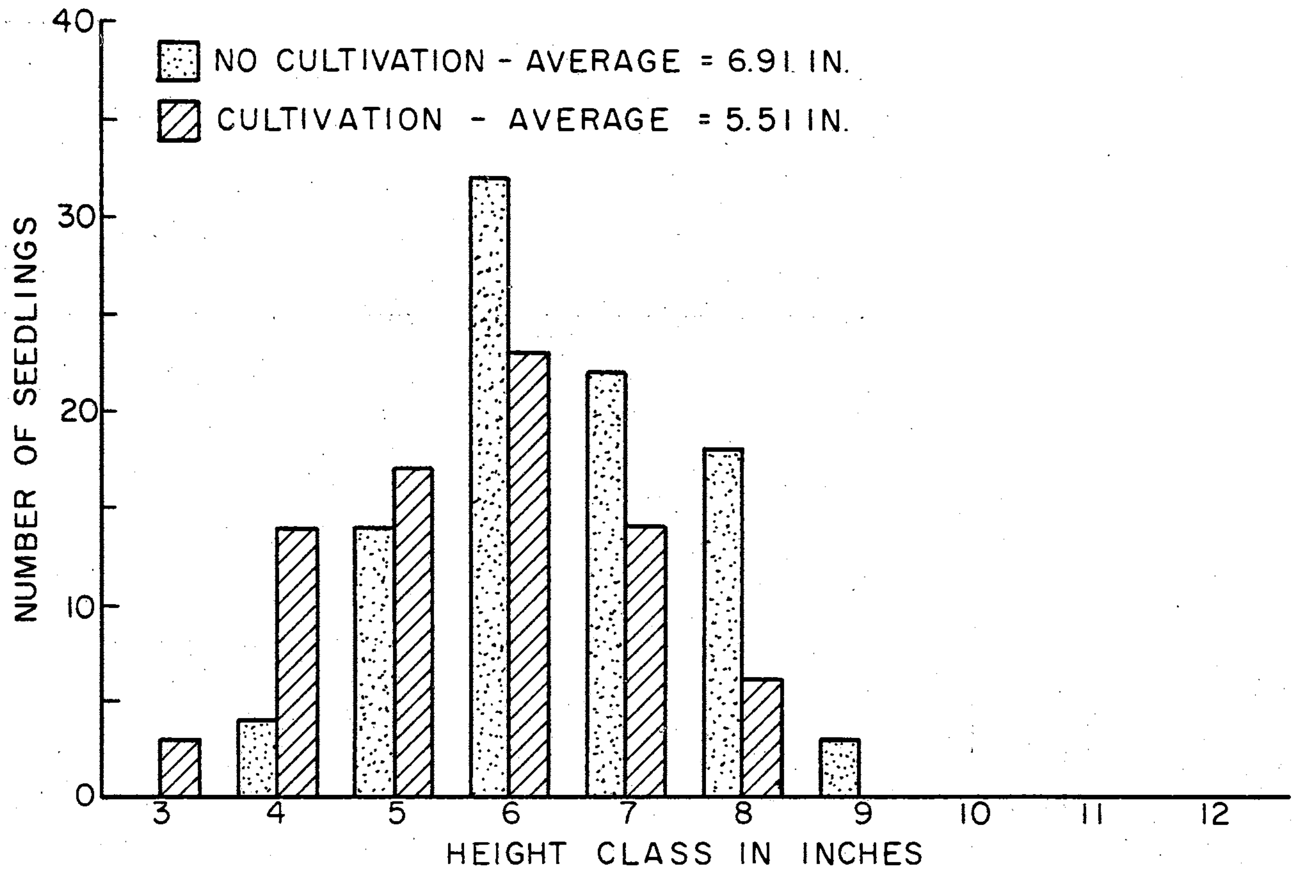

Figure 23. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Two Pounds Per Acre of Non-incorporated NPA

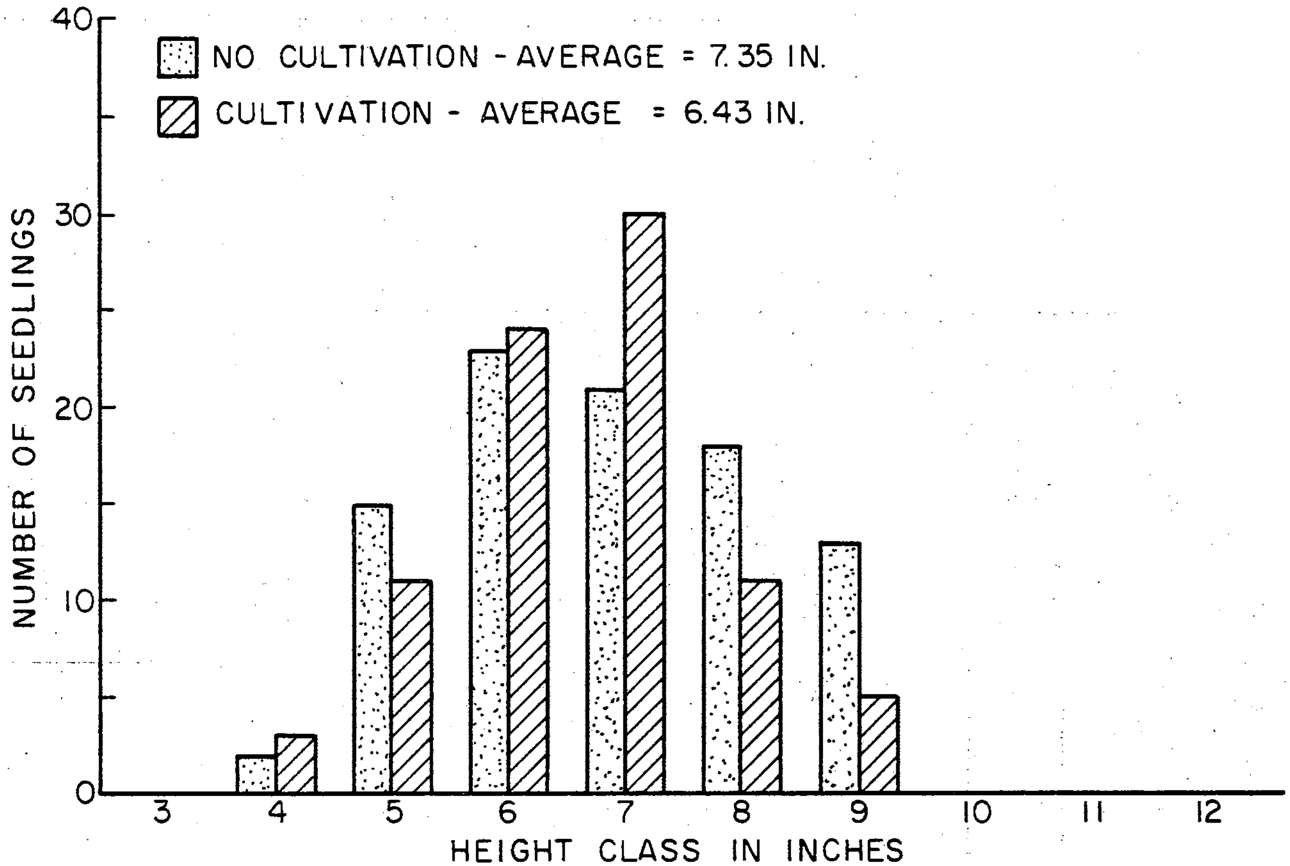

Figure 24. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Two Pounds Per Acre of Non-incorporated Amiben

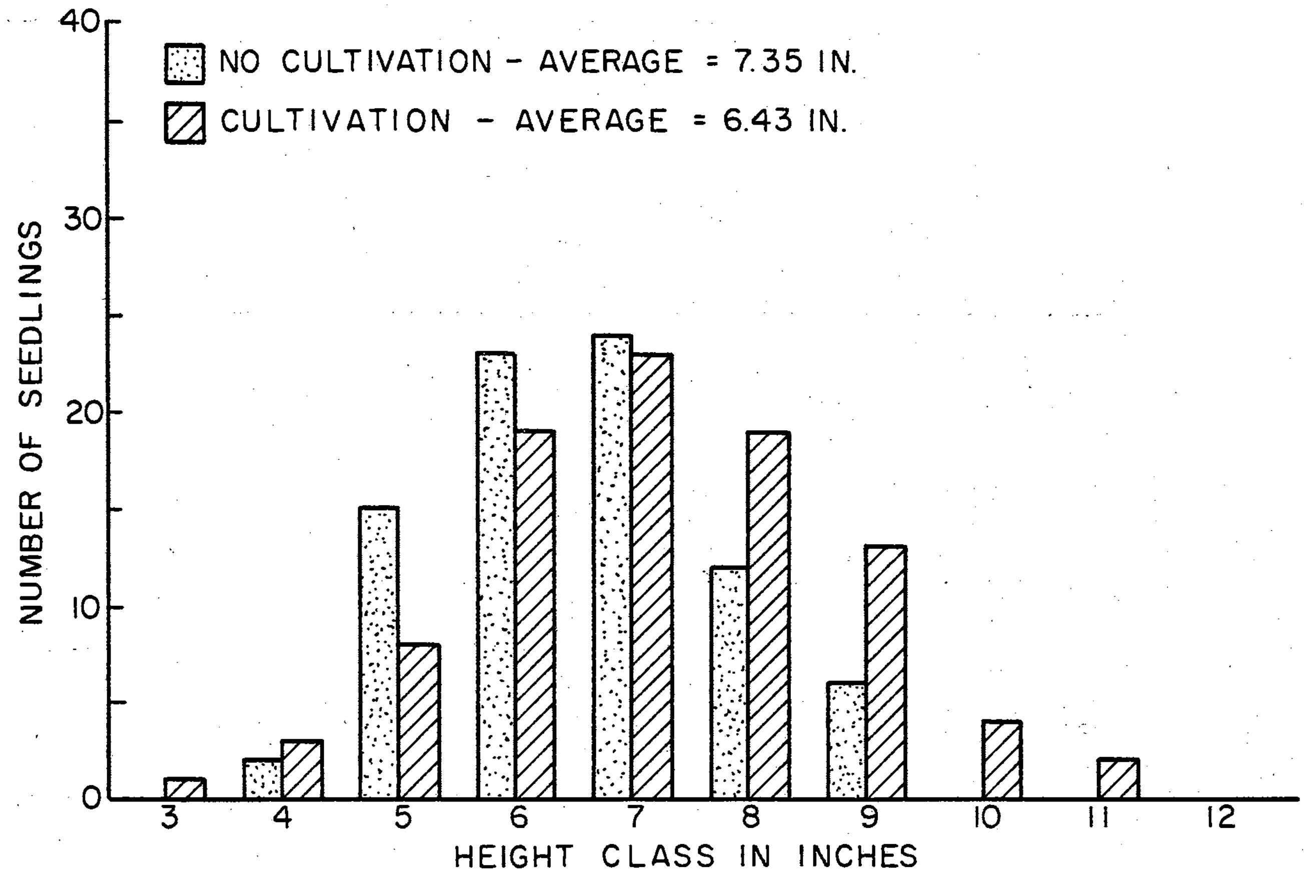

Figure 25. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Two Pounds Per Acre of Incorporated EPTC

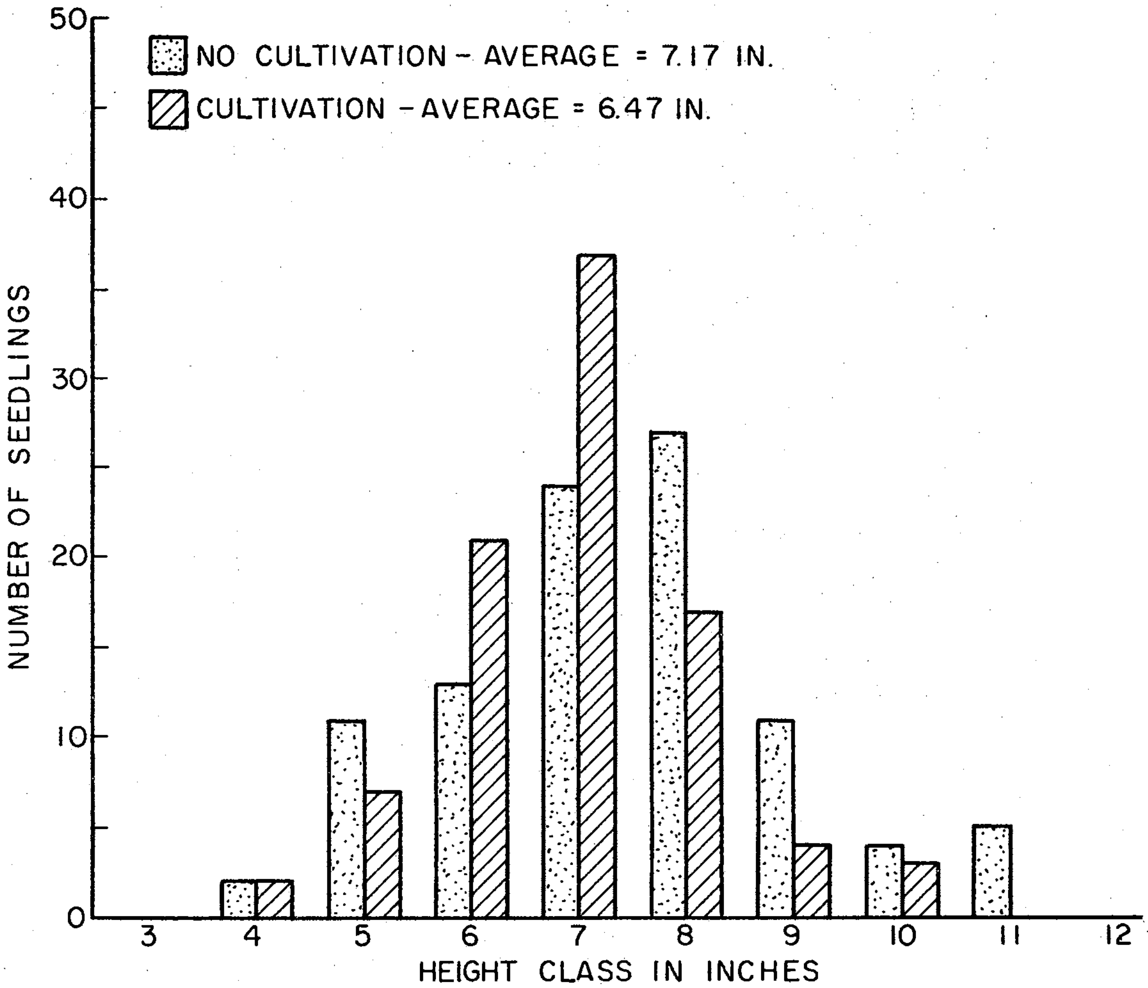

Figure 26. The Effect of Cultivation Versus No Cultivation on the Height Distribution Pattern of Western Pecan Seedlings Treated With Four Pounds Per Acre of Non-incorporated CDEC

in height. Each figure represents one herbicide but two treatments since both cultivated and non-cultivated plots are shown in the same figure.

Figure 8 shows that there were greater numbers of tall pecan seedlings grown in the treatment receiving trifluralin at one pound per acre when cultivation was used than when it was not used. Three seedlings were 11 inches or taller when cultivation was used for supplemental weed control. The tallest seedling produced when no cultivation was used was only 10 inches in height.

Figure 9 shows two peaks in pecan seedling heights relative to the effect of cultivation and no cultivation. The five-inch growth range contained the largest number of seedlings in the treatment in which no cultivation was used. When cultivation was used, there were more seedlings nine inches in height than in any of the other growth classes. This same effect is shown in Figures 13, 14, 15, 19, 22, and 24. Figures 11, 17, 20, and 26 show the opposite effect; i.e., more seedlings in the taller growth range classes when no cultivation was used. The treatments illustrated in Figures 8, 12, 16, 18, 21, 23, and 25 show the largest number of seedlings for each respective treatment to be in the same growth range class.

4. Phytotoxicity

As was previously mentioned, the relative percentage of abnormal seedlings harvested in each treatment was used as an index for determining the degree of phytotoxicity exhibited in each of the various treatments. Pecan seedling abnormalities were expressed in three categories as is shown in Tables IV and V. Pecan seedlings which had multiple stems, ones which had curled stems, or ones which had curled stems with latent buds forced were considered abnormal and were listed separately. Data listed in Table IV represents the pecan seedlings harvested in the cultivated plots. Table V lists the data taken from plots receiving no cultivation.

Multiple stems was used as an indication of shoot injury occurring to pecan seedlings either before or after emergence. The fact was recognized that the cause of all multiple stemmed seedlings could not be attributed directly to herbicide injury. However, in treatments where large numbers of multiple stemmed seedlings occurred speculation of phytotoxicity seemed plausible. Seedlings with curled stems indicated either soil crusting or high weed populations in a given treatment and not phytotoxicity.

Due to considerable variation in the three checks listed in Table IV, it appears that there would be no significant differences between the herbicide treatments in the cultivated plots. In one check, 24 percent of the seedlings had multiple stems. Since no herbicides were applied in the checks, cause of seedling injury was

TABLE IV

THE EFFECT OF PRE-EMERGENCE HERBICIDES AND CULTIVATION ON NUMBERS AND PERCENT OF ABNORMAL WESTERN PECAN SEEDLINGS

Treatment	Total Seedlings	Multiple Stems	Curled Stems	Curled Stems With Latent Buds Forced	Total Abnormal Seedlings	Percent Abnormal Seedlings
Trifluralin, 1 Lb/A	87	16	1	3	20	22.98
Trifluralin, 3/4 Lb/A	100	9	1	0	10	10.00
Benefin, 3/4 Lb/A	97	14	1	2	17	17.52
Diphenamid, 2 Lbs/A	82	18	0	1	19	23.17
Diphenamid, 1 Lb/A	84	24	0	4	28	33.33
DCPA, 12 Lbs/A	97	14	0	0	14	14.43
DCPA, 8 Lbs/A	80	18	1	1	20	22.22
DNBP, 4 Lbs/A	78	17	1	6	24	30.76
Simazine, 2 Lbs/A	92	18	2	4	24	26.09
Atrazine, 2 Lbs/A	97	16	2	6	24	24.74
Sesone, 4 Lbs/A	78	29	0	4	33	42.31
Sesone, 2 Lbs/A	86	15	1	2	18	20.93
Diuron, 2 Lbs/A	85	17	0	5	22	25.88
Diuron, 1 Lb/A	90	4	1	4	9	10.00
CIPC, 6 Lbs/A	85	10	0	4	14	16.47
NPA, 2 Lbs/A	77	17	1	3	21	27.27
Amiben, 2 Lbs/A	84	20	2	2	24	28.57
EPTC, 2 Lbs/A	92	23	3	1	27	29.35

TABLE IV (CONTINUED)

Treatment	Total Seedlings	Multiple Stems	Curled Stems	Curled Stems With Latent Buds Forced	Total Abnormal Seedlings	Percent Abnormal Seedlings
CDEC, 4 Lbs/A	91	23	1	3	27	29.67
Check	86	14	0	5	19	22.09
Check	86	18	0	3	21	24.42
Check	87	24	0	3	27	31.03

TABLE V

THE EFFECT OF PRE-EMERGENCE HERBICIDES AND NO CULTIVATION ON NUMBERS AND PERCENT OF ABNORMAL WESTERN PECAN SEEDLINGS

Treatment	Total Seedlings	Multiple Stems	Curled Stems	Curled Stems With Latent Buds Forced	Total Abnormal Seedlings	Percent Abnormal Seedlings
Trifluralin, 1 Lb/A	84	10	1	0	11	13.10
Trifluralin, 3/4 Lb/A	100	11	1	1	13	13.00
Benefin, 3/4 Lb/A	92	27	1	3	31	33.70
Diphenamid, 2 Lbs/A	97	15	7	8	30	30.92
Diphenamid, 1 Lb/A	86	56	2	3	61	70.93
DCPA, 12 Lbs/A	85	27	1	1	29	34.12
DCPA, 8 Lbs/A	86	29	2	2	33	38.37
DNBP, 4 Lbs/A	95	57	0	0	57	60.00
Simazine, 2 Lbs/A	99	21	1	2	24	24.24
Atrazine, 2 Lbs/A	84	27	0	3	30	35.71
Sesone, 4 Lbs/A	84	25	1	3	29	34.53
Sesone, 2 Lbs/A	83	24	0	0	24	28.91
Diuron, 2 Lbs/A	94	21	1	4	26	27.66
Diuron, 1 Lb/A	100	31	0	6	37	37.00
CIPC, 6 Lbs/A	89	8	0	1	9	10.01
NPA, 2 Lbs/A	93	59	1	3	63	67.74
Amiben, 2 Lbs/A	93	32	1	5	38	40.86
EPTC, 2 Lbs/A	78	57	1	2	60	76.92

TABLE V (CONTINUED)

Treatment	Total Seedlings	Multiple Stems	Curled Stems	Curled Stems With Latent Buds Forced	Total Abnormal Seedlings	Percent Abnormal Seedlings
CDEC, 4 Lbs/A	98	28	2	1	31	31.63
Check	96	21	0	2	23	23.96
Check	95	32	1	3	36	37.89
Check	87	23	2	4	29	33.33

necessarily attributed to factors other than herbicide toxicity.

When no cultivation was used with the herbicide treatments, as is shown in Table V, four treatments had very high percentages of multiple stemmed seedlings. In the treatment where diphenamid was applied at one pound per acre there was a higher percentage (56%) of multiple stemmed seedlings than when the same herbicide was applied at two pounds per acre (15%). Other treatments yielding high percentages of multiple stemmed seedlings were: DNBP, applied at four pounds per acre; NPA, applied at two pounds per acre; and EPTC, applied at two pounds per acre. Their percentages of multiple stemmed seedlings were 57%, 59%, and 57%, respectively.

The numbers of normal and abnormal pecan seedlings and the percentages of abnormal pecan seedlings for each treatment are listed in Table VI.

In some treatments there were extremely high percentages of abnormal seedlings. This was especially evident in the treatments receiving no supplemental cultivation. In the non-cultivated EPTC treatment, 76.92 percent of the pecan seedlings were abnormal. Other non-cultivated treatments producing high percentages of abnormal seedlings were: diphenamid, applied at one pound per acre (70.93%); DNBP, applied at four pounds per acre (60.00%); NPA, applied at four pounds per acre (67.74%); and amiben applied at two pounds per acre (40.86%).

TABLE VI

THE NUMBER OF NORMAL AND ABNORMAL WESTERN PECAN SEEDLINGS AND THE PERCENTAGES OF ABNORMAL PECAN SEEDLINGS IN THE VARIOUS HERBICIDE TREATMENTS

Treatment	Normal		Abnormal		% Abnormal	
	Cult.	Non-cult.	Cult.	Non-cult.	Cult.	Non-cult.
Trifluralin, 1 Lb/A	67	73	20	11	22.98	13.10
Trifluralin, 3/4 Lb/A	90	87	10	13	10.00	13.00
Benefin, 3/4 Lb/A	80	67	17	31	17.52	33.70
Diphenamid, 2 Lbs/A	63	67	19	30	23.17	30.92
Diphenamid, 1 Lb/A	56	25	28	61	33.33	79.93
DCPA, 12 Lbs/A	83	56	14	29	14.42	34.12
DCPA, 8 Lbs/A	70	53	20	33	22.22	38.37
DNBP, 4 Lbs/A	54	38	24	57	30.76	60.00
Simazine, 2 Lbs/A	68	75	24	24	26.09	24.24
Atrazine, 2 Lbs/A	73	54	24	30	24.74	35.71
Sesone, 4 Lbs/A	45	55	33	29	42.31	34.53
Sesone, 2 Lbs/A	68	59	18	24	20.93	28.91
Diuron, 2 Lbs/A	63	68	22	26	25.88	27.66
Diuron, 1 Lb/A	81	63	9	37	10.00	37.00
CIPC, 6 Lbs/A	71	80	14	9	16.47	10.01
NPA, 2 Lbs/A	56	30	21	63	27.27	67.74
Amiben, 2 Lbs/A	60	55	24	38	28.57	40.86
EPTC, 2 Lbs/A	65	18	27	60	29.35	76.92

TABLE VI (CONTINUED)

Treatment	Normal Cult.	Normal Non-cult.	Abnormal Cult.	Abnormal Non-cult.	% Abnormal Cult.	% Abnormal Non-cult.
CDEC, 4 Lbs/A	64	67	27	31	29.67	31.63
Check	67	73	19	23	22.09	23.96
Check	65	59	21	36	24.42	37.89
Check	60	58	27	29	31.03	33.33

In some plots there were considerably fewer abnormal seedlings than in the checks. In the cultivated plots, the treatment which received trifluralin at three-fourths of a pound per acre had only 10 percent abnormal seedlings. This was true also in the plot receiving diuron at one pound per acre. Other cultivated treatments that had relatively low percentages of abnormal seedlings were: benefin, applied at three-fourths of a pound per acre (17.52%); DCPA, applied at twelve pounds per acre (14.42%); and CIPC, applied at six pounds per acre (16.47%).

In the plots receiving no supplemental cultivation, the treatment in which CIPC was applied at six pounds per acre yielded the lowest percentage of abnormal seedlings (10%). Other treatments which yielded relatively low percentages of abnormal seedlings in the non-cultivated area were: trifluralin, applied at one pound per acre (13.10%); and trifluralin, applied at three-fourths of a pound per acre (13.00%).

Greenhouse Study

A. The following is a report of the effect of three herbicides on Western pecan seedlings grown in the horticulture greenhouses, Oklahoma State University.

Treatments consisted of both pre-emergence and post-emergence applications of trifluralin, DCPA and simazine to Western pecan seedlings at different stages of development. Pre-emergence treatments were made on November 8,

1966. Post-emergence treatments were made on March 20, 1967. Date of analysis was April 25, 1967.

1. Pre-Emergence Treatments

A count was made of the number of pecan seedlings which had emerged by March 18, 1967. The results were as follows: trifluralin, 30% emergence; DCPA, 70% emergence; and simazine, 60% emergence. These figures compared to 64% emergence for 140 cylinders which had received no herbicide treatment. It appears that trifluralin may have retarded germination in the pre-emergence treatments, but, on date of analysis, no apparent harmful effect was detected in seedlings which emerged in these treatments. Pecan seedling emergence in the DCPA and simazine treatments did not appear to be affected by the herbicides. Also, as was observed in the trifluralin treatments, no noticeable herbicide damage was apparent on seedlings which had emerged.

2. Post-Emergence Treatments

The results obtained in post-emergence treatments are discussed separately for each herbicide as follows:

(a) Trifluralin - Pecan seedlings which had fully expanded leaves were not affected by any treatment in which trifluralin was applied at one pound per acre. However, when trifluralin was applied directly to the growing points of emerging seedlings, two seedlings were killed. More work, which is discussed later, was initiated to determine whether the cause of death was actually attributable to trifluralin or whether other factors may have caused death.

(b) DCPA - DCPA appears to be safe for use around pecan seedlings regardless of method of application used or stage of growth when applied. No visual differences were observed in pecan seedlings treated with DCPA at 12 pounds per acre and those from the checks.

(c) Simazine - Interveinal chlorosis developed in one pecan seedling which was treated with simazine at two pounds per acre. These symptoms seemed to be much like those described by Saidak and Rutherford (24) in seedling apple trees. Since interveinal chlorosis was exhibited in only one of the seedlings receiving this treatment, it was assumed that the chlorosis developed due to causes other than simazine phytotoxicity. No visual differences were detected in any of the other treatments receiving simazine when comparisons were made with the non-treated checks.

B. The following is a report on results obtained in bioassay tests conducted for purposes of determining movement and persistence of trifluralin (one pound per acre), DCPA (twelve pounds per acre), and simazine (two pounds per acre) when applied to soil in cylinders and influenced by a Port clay loam soil and greenhouse growing conditions.

1. Pre-Emergence Treatments

Each pre-emergence treatment was made November 8, 1966, over six months prior to photographing results of the bioassay. Photographs were taken May 19, 1967.

The results obtained in pre-emergence treatments are discussed separately for each herbicide as follows:

(a) Trifluralin - Figure 27 shows that trifluralin did not maintain its herbicidal effectiveness throughout the period of the study. Approximately equal crabgrass growth resulted in soil samples taken from each level of the trifluralin treated cylinders.

(b) DCPA - Figure 28 indicates the same effect in DCPA treated cylinders as was discussed in treatments receiving trifluralin. It appears that due to leaching, dilution, or structural breakdown, DCPA, as well as trifluralin, loses its herbicidal

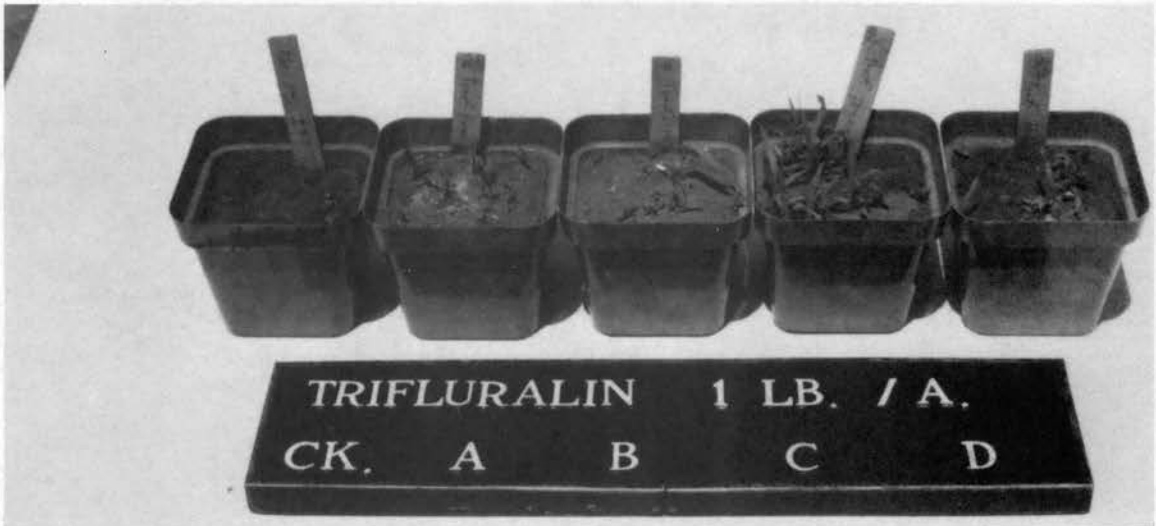

Figure 27. Results of a Bioassay Test to Determine the Soil Persistence and Movement of Trifluralin Six Months Following Date of Application. (A description of treatments is found on page 22.)

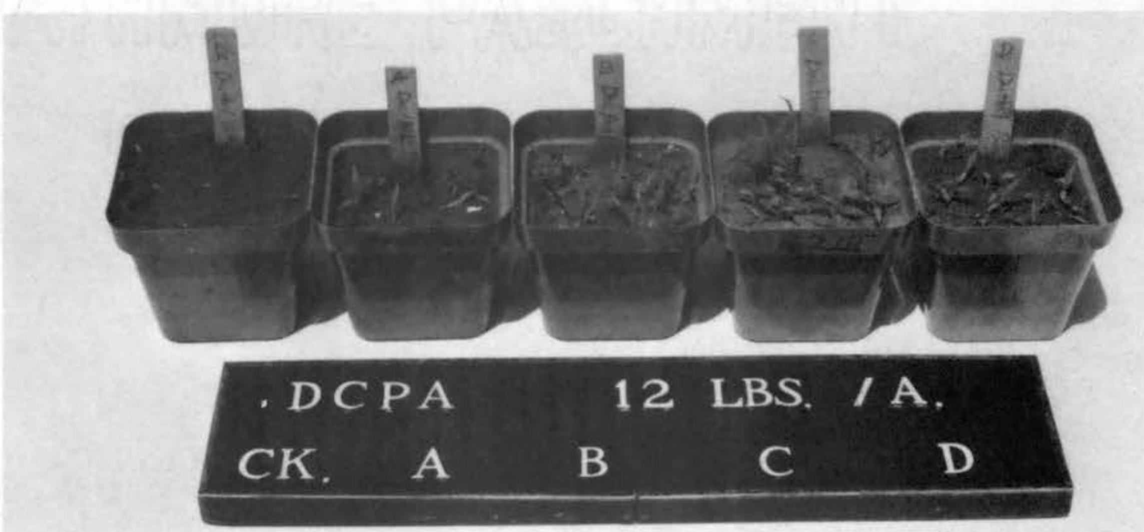

Figure 28. Results of a Bioassay Test to Determine the Soil Persistence and Movement of DCPA Six Months Following Date of Application. (A description of treatments is found on page 22.)

effectiveness when subjected to the conditions previously described in the study.

(c) Simazine - Figure 29 illustrates that simazine was quite active throughout the duration of the study. However, it is apparent that simazine was leached from the surface area and into the pecan seedling root zone. Apparently, this had no adverse effect on pecan seedling growth since there was no noticeable injury to any seedling receiving this treatment.

2. Post-Emergence Treatments

Post-emergence treatments were made March 20, 1967, two months prior to photographing the results of the bioassay.

The results obtained in post-emergence treatments are discussed separately for each herbicide as follows:

(a) Trifluralin - Figure 30 shows that trifluralin was not readily leached and that it exhibited residual weed control throughout the two-month period. As indicated by bioassay, the highest concentration of trifluralin was in the top two inches of soil. Progressively less trifluralin was detected at the three lower sampling depths.

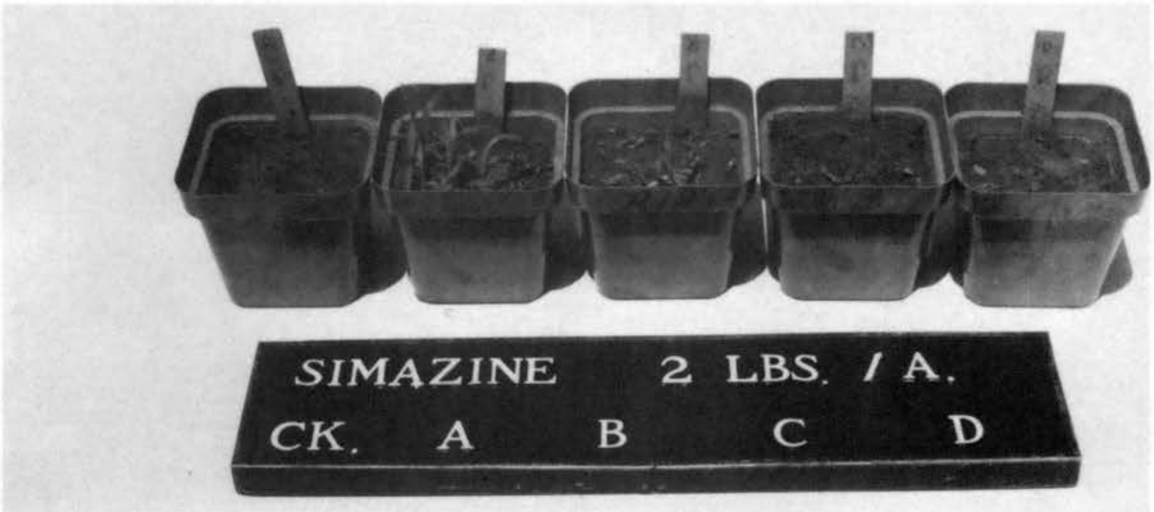

Figure 29. Results of a Bioassay Test to Determine the Soil Persistence and Movement of Simazine Six Months Following Date of Application. (A description of treatments is found on page 22.)

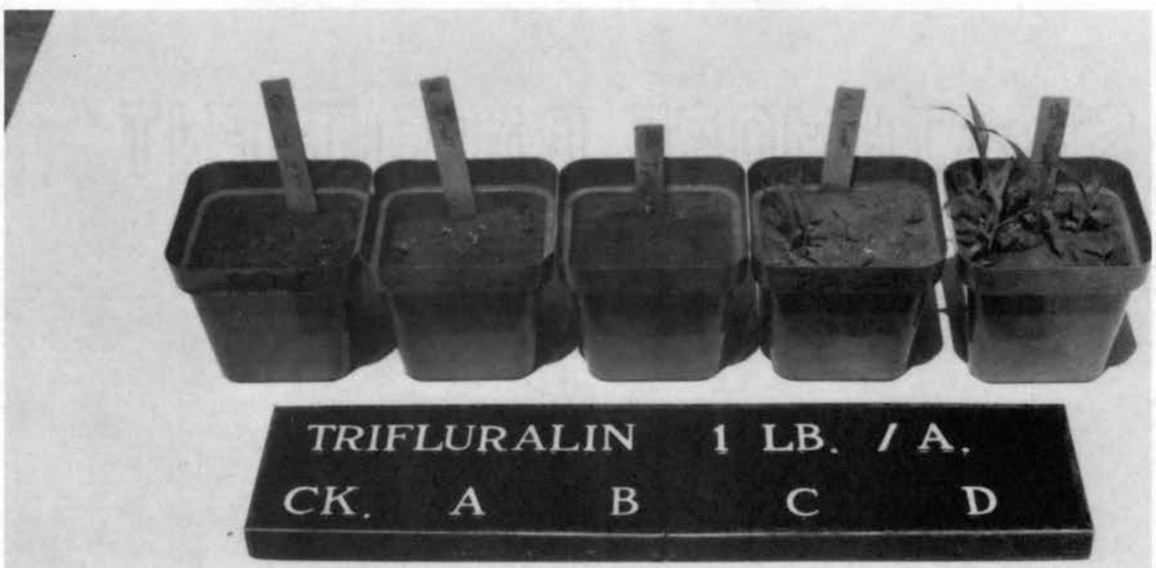

Figure 30. Results of a Bioassay Test to Determine the Soil Persistence and Movement of Trifluralin Two Months Following Date of Application. (A description of treatments is found on page 22.)

(b) DCPA - Figure 31 illustrates an apparent loss of DCPA activity over the two-month period. Equal crabgrass growth was obtained in each soil sample regardless of depth. This indicated that the herbicide was either leached out of the soil cylinders or decomposed and was no longer herbicidal.

(c) Simazine - Apparently, simazine was still active two months following treatment. As in the pre-emergence simazine treatments, it was evident that leaching had occurred in the post-emergence treatments. Figure 32 illustrates that no crabgrass was grown in soil samples taken from the bottom two inches of cylinders receiving simazine. Progressively less crabgrass growth resulted in soil samples taken at lower sampling depths.

C. The following is a report on the effect of trifluralin (one pound per acre) applied directly to the growing points of Western pecan seedlings when applied on date of emergence.

Analysis of this portion of the study was made May 20, 1967, twelve days after first treatment.

It was apparent that trifluralin is phytotoxic to emerging Western pecan seedlings when applied directly to

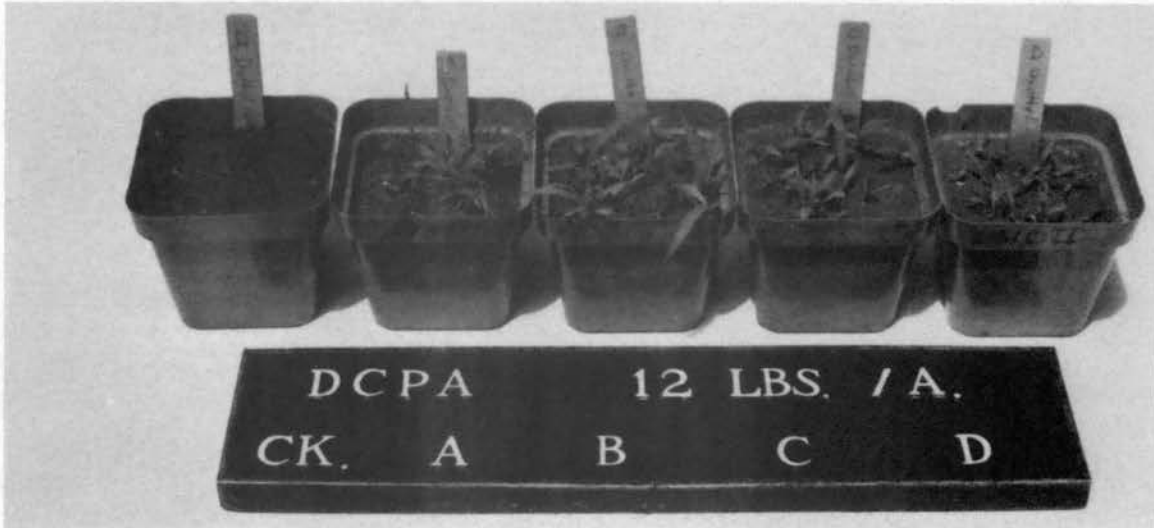

Figure 31. Results of a Bioassay Test to Determine the Soil Persistence and Movement of DCPA Two Months Following Date of Application. (A description of treatments is found on page 22.)

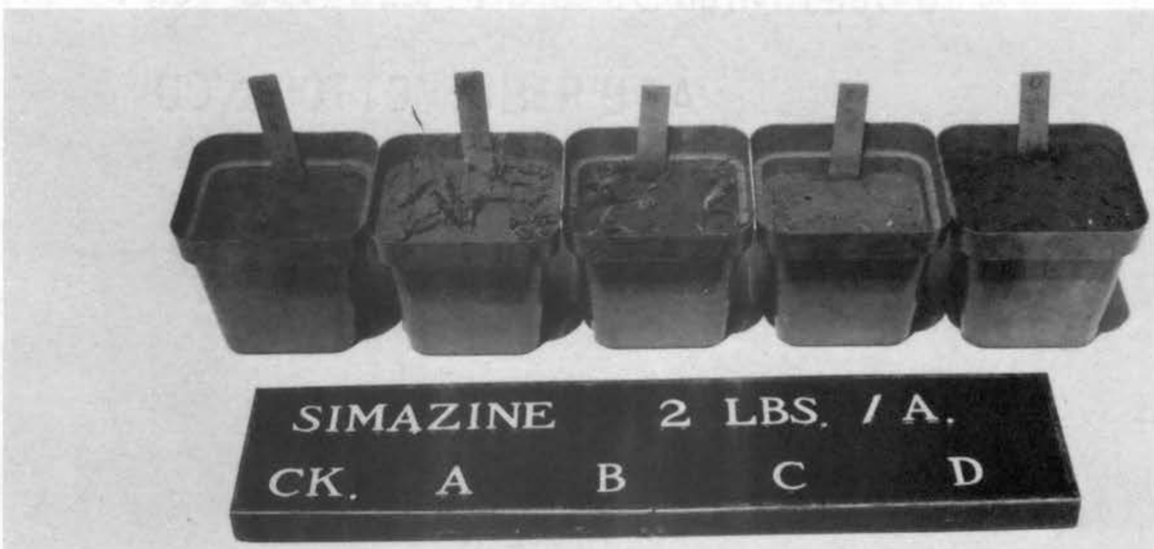

Figure 32. Results of a Bioassay Test to Determine the Soil Persistence and Movement of Simazine Two Months Following Date of Application. (A description of treatments is found on page 22.)

the seedlings at dosages of one pound per acre. No seedling death had occurred 12 days after treatment. However, all seedling shoots analyzed were very brittle, stunted, and water-soaked in appearance. It appeared that shoot death would occur if the seedlings were permitted to grow over an extended period of time. Pecan seedlings which had emerged on the same dates, but received no trifluralin treatment were, in contrast, normal in appearance and several times taller than the trifluralin treated seedlings. Table VII and Figure 33 show the effects of this portion of the study.

D. The following is a report on the effect of trifluralin, applied at one pound per acre, on Western pecan seedling lateral root development.

Analysis of this portion of the study was made May 20, 1967, 35 days after date of treatment.

Inadvertently, it was discovered that trifluralin not only affected pecan seedling lateral root development but also inhibited shoot emergence and tap root development.

Restricted development of radicles and plumules was observed in all pecans planted in a two-inch soil layer treated with trifluralin. Radicles were short, thick, very brittle, and void of lateral roots.

Trifluralin apparently inhibited normal elongation of plumules since no shoots emerged through the soil surface during the period of treatment. This compared to 100 percent shoot emergence in the non-treated checks.

TABLE VII

THE INFLUENCE OF THE POSITION OF PLACEMENT OF TRIFLURALIN WITH RESPECT TO WESTERN PECAN SEED AND EMERGING SEEDLINGS ON SHOOT AND ROOT GROWTH OF THE DEVELOPING SEEDLINGS

Treatment	Western Pecan Seedlings Avg. Shoot Height* (Inches)	Avg. Root Length* (Inches)
Trifluralin - 1 Lb/A		
Seeds Planted in 2" Incorporated Layer	.37	.78
Seeds Planted 2" Above a 2" Incorporated Layer	1.44	2.25
Seedlings Sprayed at Time of Emergence	2.11	11.44
No Trifluralin		
Check	5.35	9.20

*Average of 8 to 10 seedlings.

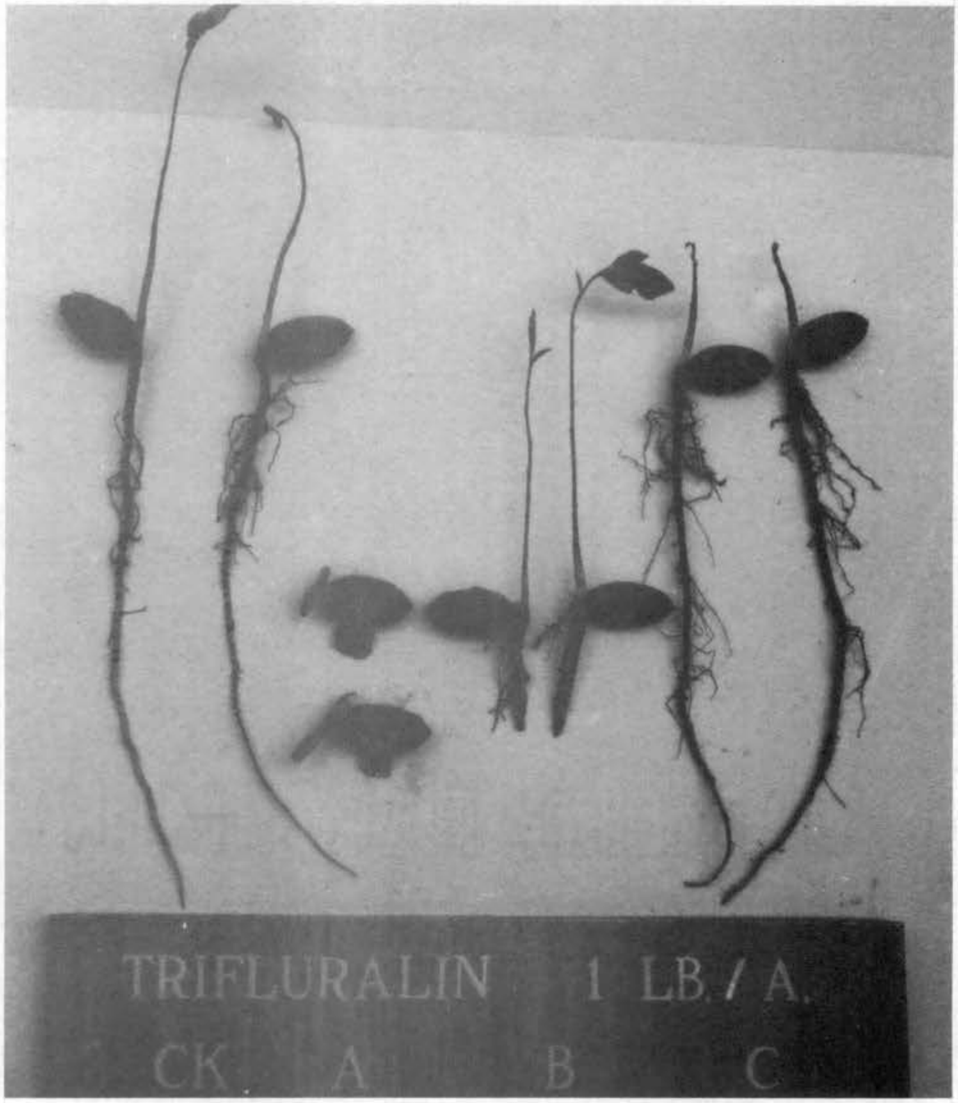

Figure 33. The Influence of Position of Placement of Trifluralin With Respect to Western Pecan Seed and Seedlings and Subsequent Shoot and Root Growth of the Developing Seedlings. (A description of treatments is found on page 21 and 22.)

Seedlings which had received no herbicide treatment developed normal, healthy root systems. Results of this portion of the study are shown in Table VII and Figure 33.

Pecan seedlings planted two inches above a trifluralin treated layer of soil developed seemingly normal root systems down to the treated layer of soil. Beyond this point, no lateral roots developed and tap roots ceased to develop further. This effect is shown in Table VII and Figure 33.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Weed control is essential for optimal growing conditions in pecan tree nurseries. Weeds compete with pecan seedlings for space, light, nutrients, and moisture and should be eliminated for maximum pecan tree growth. Herbicides acceptable for this purpose would benefit the nurseryman by saving him time and unnecessary expense.

The purpose of this study was to determine which of 19 herbicide treatments, used with and without supplemental cultivation, would provide maximum weed control with little or no phytotoxicity to pecan seedlings throughout the growing season. Criteria for determining the effectiveness of each treatment were based on: (1) the effect of the herbicides on pecan seedling emergence, (2) the effect of the herbicides on pecan seedling growth, (3) the phytotoxicity of the herbicide to pecan seedlings, and (4) the residual weed control obtained from use of the various herbicides. Trifluralin, DCPA, and simazine were selected for additional study on the basis of their performance relative to these criteria. Reasons for selecting these herbicides are discussed separately.

Trifluralin - Trifluralin appears to repress (but not inhibit) pecan seedling emergence. The apparent delayed emergence caused by trifluralin is shown in Table I. Table I shows also that emergence was only temporarily delayed since 100 pecan seedlings were harvested in each treatment receiving trifluralin at three-fourths of a pound per acre.

Data in Table I shows that trifluralin applied at one pound per acre reduced plant stands and seedling weights more than when used at three-fourths of a pound per acre.

Soil type should be considered in relation to herbicide application rates. The soil in which these treatments were made was a Teller fine sandy loam. Soils having higher percentages of clay and/or organic matter would require increased application rates. In the greenhouse experiment Port clay loam soils were used; therefore, application rates were increased to one pound per acre.

Cultivation was found to increase pecan seedling weights when trifluralin was applied at both three-fourths and one pound per acre. This is shown in Table III and Figures 6 and 7.

Larger numbers of tall pecan seedlings were obtained when cultivation was used with trifluralin at both rates of application. This information is given in Figures 8 and 9. This was found to be true even though when cultivation was used with trifluralin applied at one pound per acre, the average seedling height for the treatment was less than when no cultivation was used.

In treatments receiving trifluralin at one pound per acre, more abnormal seedlings were harvested than in treatments where trifluralin was applied at three-fourths of a pound per acre. This effect was observed in cultivated treatments as well as in treatments receiving no cultivation. This might tend to suggest that the higher application rate caused the increase in damaged seedlings due to the coarse textured soil in which the herbicide was applied. However, it should be pointed out that in the checks which received no herbicide applications higher percentages of abnormal seedlings were harvested than in the treatments in which trifluralin was applied at one pound per acre. On the basis of these data, it would have to be concluded that factors other than trifluralin phytotoxicity were instrumental in causing the abnormal seedlings. These data are presented in Tables IV, V, and VI.

Weed emergence data collected 11 weeks after treatment indicated that trifluralin, applied at three-fourths of a pound per acre, provided the best weed control when comparisons were made with all other treatments, except possibly in the non-cultivated simazine plot. In this treatment, weed control was equal to the trifluralin treatment. Weed emergence data are shown in Table II.

DCPA - Data listed in Table I indicates that DCPA does not inhibit Western pecan seedling emergence. Eleven ɜeks following treatment, plots in which DCPA was applied ; 12 pounds per acre had 74 percent emergence in the cul- .vated area and 58 percent emergence in the area receiv- ıg no cultivation. When DCPA application rates were ɜduced to eight pounds per acre, a slight increase in ıergence was noted. However, when comparisons are made ɜtween the checks it became obvious that due to variabil- ;y, no significant herbicidal effect as related to emer- ɜnce can be attributed to the differences obtained in the ;PA treatments.

Table III and Figure 4 show that pecan seedlings ırvested in the cultivated DCPA, eight pounds per acre, ;eatment were of taller average height than seedlings ırvested in any other treatment.

No definite conclusive statements can be made regard- ıg the residual weed control exhibited in the DCPA treat- ɜnts 11 weeks following application. Very little .fference between the DCPA treatments was evident regard- ɜss of rate of application or whether supplemental culti- ıtion was or was not used. It is apparent, however, that ɜrbicidal activity was more persistent in these treat- ɜnts than in several of the other treatments. Treatments ıbstantiating this observation are: both diphenamid, one ɔund per acre treatments, and the EPTC, two pounds per ;re treatment that received no cultivation. Weed emer- ɜnce data, 11 weeks after treatment, are listed in Table [.

<u>Simazine</u> - Table I shows that Western pecan seedling emergence was not reduced by simazine, applied at two pounds per acre, in a Teller fine sandy loam soil. This observation is apparent in both cultivated and non-cultivated treatments.

Table III shows that when cultivation was used with simazine, the pecan seedlings harvested were of lower average weight than when no cultivation was used. There was very little difference in average pecan seedling height. This indicates that cultivation with the use of simazine reduces pecan seedling growth. The adverse effect caused by cultivation was probably due to the fact that cultivation reduced the herbicidal effectiveness of simazine, and that less growth resulted due to weed competition.

Table II shows that cultivation greatly reduced the effectiveness of simazine in this study.

Greenhouse studies revealed that, with certain limitations, each of the three herbicides could be used successfully for weed control in pecan seedlings.

As indicated in Figure 30, trifluralin is not readily leached in Port clay loam soils. This would be a point favoring the use of trifluralin in preference to simazine since the latter was readily leached from the weed control zone.

Time and method of application appear to be important when trifluralin is used for weed control in pecan seedlings. Table VII and Figure 33 show that trifluralin inhibits normal root development of pecan seedlings. In view of this fact, planting nuts prior to trifluralin application may be more feasible than pre-plant applications of trifluralin. However, nuts would have to be planted deep enough to permit shallow herbicide incorporation and this may lessen the practicability of the suggestion.

Trifluralin was found to be phytotoxic to pecan seedlings if applied on date of seedling emergence. However, when trifluralin was applied directly to pecan seedlings which were six to twelve inches tall, no noticeable phytotoxicity occurred. Therefore, it appears that band treatments of trifluralin can be made directly over pecan seedlings after they have attained sufficient height but not at time of emergence.

Apparently, trifluralin, applied at one pound per acre, provides sufficient soil persistence for full season weed control.

Both field and greenhouse studies indicated that trifluralin delays pecan seedling emergence. This was shown to be only a temporary effect in the field study, however, and it is possible that the temporary effect would have been expressed in the greenhouse study also if time of harvesting seedlings had been extended to a later date.

DCPA appears to be safe for weed control in pecan seedlings regardless of time or method of applications.

No noticeable phytotoxicity was evident on seedlings which had been sprayed to the run-off stage with DCPA applied at 12 pounds per acre.

Apparently, DCPA, applied at 12 pounds per acre, is decomposed more rapidly than either simazine, applied at two pounds per acre, or trifluralin, applied at one pound per acre. This may limit its use for full season annual weed control in pecan seedlings. Figure 31 shows that DCPA was inactive two months following treatment.

DCPA apparently had no effect on Western pecan seedling emergence.

Simazine was found to be safe for weed control in Western pecan seedlings. However, what appeared to be simazine toxicity symptoms was observed on one pecan seedling receiving this treatment. Since these symptoms appeared in only one seedling, factors other than simazine toxicity were attributed to the cause. As shown in Figure 29, simazine, applied at two pounds per acre, exhibited residual weed control for a period exceeding six months. This was longer than in either the trifluralin treatments or the DCPA treatments. It was evident that simazine, in amounts sufficient to be toxic to crabgrass, was in the pecan seedling root zone on date of examination. It was concluded that simazine, applied at two pounds per acre in a Port clay loam soil, is not phytotoxic to Western pecan seedlings.

Simazine did not delay Western pecan seedling emergence or root development during the period of the study.

CHAPTER VI

SUMMARY

The objectives of this study were to determine the effect of 19 herbicide treatments, used with and without cultivation, on Western pecan seedling growth and phytotoxicity, and control of annual weeds.

Further tests of the three most promising herbicides were conducted under controlled greenhouse conditions.

Results of these studies indicate:

1. With certain limitations, trifluralin, DCPA, and simazine all appear to be suitable for use in pecan seedlings.
2. Cultivation reduced the herbicidal effectiveness of simazine.
3. Cultivation did not reduce the herbicidal effectiveness of trifluralin.
4. Trifluralin delayed Western pecan seedling emergence.
5. Trifluralin inhibits normal Western pecan seedling root development when pecans are germinated in, or above, the treated soil layer.
6. Topical applications of trifluralin

are phytotoxic to emerging pecan seedlings.

7. Topical applications of trifluralin, DCPA, and simazine are not phytotoxic to pecan seedlings when leaves are fully expanded and may be applied as non-directed sprays post-emergence to the pecan seedlings.
8. Simazine, but not trifluralin, is readily leached in Port clay loam soils and may be leached out of the weed germination zone.
9. Simazine, applied at two pounds per acre, is more persistent in a Port clay loam soil than trifluralin, applied at one pound per acre, or DCPA, applied at twelve pounds per acre.
10. The relatively short soil persistence of DCPA would limit its use for full season annual weed control in pecan seedlings.
11. Herbicides which merit further consideration in future studies include: (1) benefin, (2) atrazine, and (3) amiben.

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