THE EFFECTS OF TRIFLURALIN AND DIURON ON STAND AND YIELD OF COTTON

by

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ABSTRACT

This study was conducted in 1972 and 1973 to determine the effects of trifluralin (a,a,a-dinitro-N,N-dipropyl-p-toluidine) and diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] on the stand and yield of cotton (Gossypium hirsutum L.).

Trifluralin and diuron were applied to the soil by two methods, (a) preplant incorporated broadcast before furrowing and (b) preplant incorporated broadcast over-the-bed after furrowing.

Trifluralin and diuron were applied alone and in combination at rates of: 0, 0.56, 0.84, and 1.1 kg/ha for trifluralin and at 0, 1.1, 1.7, and 2.2 kg/ha for diuron.

Stunting of cotton seedlings was observed in all plots treated with higher rates of trifluralin applied by either two methods of application. Recovery of stunting to normal growth occurred in 6 to 8 weeks.

When trifluralin was added to diuron a reduction of diuron symptoms in cotton was observed and also some protection of cotton seedlings from diuron was achieved.

Diuron at 2.2 kg/ha applied preplant incorporated broadcast before listing in combination with trifluralin reduced stands of cotton by over 50% regardless of the rate of trifluralin.

Trifluralin and (or) diuron applied broadcast before furrowing resulted in more stunting and loss of stand and yield as compared to treatments made broadcast over-the-bed after furrowing.

INTRODUCTION

Application of herbicides to the soil before planting has become an accepted practice in most cotton (<u>Gossypium</u> <u>hirsutum</u> L.) growing areas of the United States. Using herbicides in combination may have the advantages of lower costs, better weed control, increased safety, and less soil residue compared to the application of a single herbicide. Single tank mix combinations that include a herbicide that controls broadleaf weeds with one to control grassy weeds may broaden the spectrum of herbicide activity. Also, it is often possible to lower the rate of each herbicide without affecting weed control.

Trifluralin (<u>a</u>,<u>a</u>,<u>a</u>-dinitro-<u>N</u>,<u>N</u>-dipropyl-<u>p</u>-toluidine) is widely used as a preplant herbicide for control of many grasses and some broadleaf weeds in cotton in southwestern United States. Rates are critical. The spectrum of weeds controlled by trifluralin may be broadened by increasing the rate of application. However, this may result in crop injury and (or) loss of stand.

Diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] has also been used by cotton growers across the cotton belt for many years as a postemergence treatment for the control of broadleaf weeds and some grasses in cotton. Incorporated-preplant applications of diuron have frequently injured or killed cotton seedlings, especially when cotton seed is planted in the soil zone of diuron treatment.

Trifluralin inhibits lateral root growth of cotton seedlings in the treated soil zone (2, 5, 13, 22, 25, 29, 33, 42, 43, 46, 60). When diuron and trifluralin are used in combination, trifluralin inhibits the development of lateral roots. Consequently, uptake of diuron is reduced and severe injury to the cotton seedling is prevented (29).

The purpose of this study was to evaluate the effects of rates of trifluralin and diuron applied preplant singly and in combination on stands and yield of cotton.

LITERATURE REVIEW

This review will be oriented toward: (a) diuron and its effects on cotton and other plants, (b) trifluralin and its effects on cotton and other plants, (c) herbicide combinations, and (d) response of plants to pesticide combinations.

Effects of Diuron on Cotton and Other Plants

Diuron has been registered for many years to control weeds in cotton. Diuron has been used as a selective or non-selective soil or foliar-applied herbicide on many agronomic and horticulture crops and as a soil sterilant for non-cropland areas. Although it has been used primarily postemergence in the southwestern cotton growing area, it is often applied preplant and preemergence.

According to Hill (37) diuron is adsorbed on soil particles. The amount adsorbed is determined by soil properties such as clay content, types of clay, and organic matter content. Adsorption increases as the organic matter content and (or) clay content increases. Ashton (12) investigated the movement of diuron and other substituted urea herbicides by using simulated furrow irrigation conditions. The effectiveness of diuron was influenced by the amount of clay and organic matter in soils which adsorbed these herbicides so tenaciously that a portion of the applied material was biologically inactive. Diuron applied to the soil surface and subjected to furrow irrigation in the absence of rain or overhead irrigation remained close to the soil surface. Hance (31) studied competition for adsorption sites between diuron and water. He concluded there was competition between water and diuron for adsorption sites and diuron was a more effective competitor at soil organic matter surfaces. Organic matter was the most important site of adsorption of diuron by soils.

Upon application to soil surfaces, the effects of diuron are slight until moisture has moved the material into the root zone of plants. Movement of diuron will occur through translocation from roots upward through the plant in the xylem, although it can be taken up by stems and (or) leaves (14, 20, 24, 37). Diuron does not move downward in the plant to the roots through the phloem. The addition of a surfactant with diuron spray does not cause the material to move downward (14, 24).

One of the primary sites of action for diuron is in the leaves of green plants. Once in the leaves, diuron affects photosynthesis and affected leaves cannot synthesize and eventually die. Susceptible plants show chlorosis in leaves followed by necrosis, wilting, and death (18, 37).

According to Geissbuhler (24) diuron inhibits the evolution of oxygen in the presence of living chlorophyll which affects the photosynthetic mechanism in plants.

The primary mechanism for degradation of diuron in the soil is through activity of soil microorganisms which use diuron as a source of energy. Microbial activity and diuron degradation is dependent upon several factors such as temperature, good soil tilth, favorable soil moisture, and good farming practices (19, 37). Sheets and Crafts (54) indicated that microorganisms capable of inactivating diuron are probably present in most soils. Under conditions of the arid western states, breakdown of diuron could be greatly retarded by lack of sufficient moisture.

Weldon and Timmons (62) determined that irradiation on exposed diuron caused a progressive degradation of the material. Illumination of the chemical for a 28-hour period resulted in a 75% decrease in biological activity. However, under field conditions, diuron is generally partially protected from irradiation by incorporation into the soil and therefore, photodecomposition has not been demonstrated to be a major factor in its disappearance from the soil (39).

Hamilton et al. (30) reported that when diuron was applied and incorporated before furrowing for cotton preplant irrigation, stands were reduced. Stand reduction was most severe when cottonseed was planted within or above the layer of diuron-treated soil. Arle and Hamilton (10) concluded that diuron alone applied preplant and disked in at 1.7 to 2.2 kg/ha reduced cotton stands by 50%. Hamilton and Arle (28) found that preplanting application of diuron alone caused some chlorosis of cotton foliage about 10 days after cotton emergence. Cotton yields, fiber properties, and boll components were not affected.

Arle and Hamilton (9) found that over-the-top applications of diuron caused temporary chlorosis of cotton foliage. In a 3-year trial, diuron at 0.55 kg/ha and 1.1 kg/ha plus or minus surfactant in 374 liters/ha of water was applied over-the-top of cotton 2, 4, 6, and 8 weeks old. The higher rates caused more severe symptoms and stunting which was pronounced in younger plants. The addition of a surfactant increased toxicity of diuron and reduced yields of seed cotton by 8 to 12% compared to that of diuron alone.

Eshel (20) determined the tolerance of diuron to cotton by growing cotton in a solution and treating specific anatomical sections with the herbicide. Tests showed that diuron entered the plant via roots. No injury occurred to cotton when diuron was applied to the shoot zone only. Of all the compounds tested, diuron was most toxic to cotton when the entire root system was exposed to treated soil or solution. The detoxifying process of diuron by cotton foliage was not rapid enough to eliminate the accumulation of lethal concentrations.

Upchurch (58) reported the influence of soil moisture content on the response of cotton to diuron. He tested the response of cotton to diuron under varying soil moisture regimes. Soil mixed with diuron under all soil moisture levels produced plants having nearly equal amounts of green matter, dry matter, and plant height. The visual phytotoxic properties of diuron were more toxic under moist soil conditions than under dry conditions. Upchurch (59) also studied the factors influencing the phytotoxicity and plant selectivity of diuron. Cotton and ryegrass (*Secale cereals* L.) were grown on 12 soil types containing varying amounts of diuron to determine the effects of soil properties on the selectivity and phytotoxicity of diuron. Approximately 10 times as much diuron was required to produce a 50% reduction in dry shoot weight on some soils as on other soils. Organic matter content and cation exchange capacity were highly correlated with growth reduction. The type of colloids found in the soils did not influence the phytotoxicity of diuron. The selective herbicidal properties of diuron were not influenced by soil properties.

Research conducted in Arkansas (61) studied stand losses of cotton varieties caused by preemergence applications of herbicides. Diuron was applied at 1.1 kg/ha in 45 liters of water/ha. Diuron as a preemergence herbicide caused no stand reduction.

Porter et al. (50) applied diuron preemergence at 0.83 kg/ha in 374 liters of water/ha. There were no effects of diuron applied preemergence on either stands or yield of cotton.

Harris (32) reported that diuron when used preemergence or postemergence at 1.1 kg/ha was a superior treatment for weed control compared to other herbicides. Weeds were controlled and little or no reduction in cotton yield was observed in this experiment. Diuron did not accumulate in the soil at rates used.

Arle, Miller, and Sheets (11) demonstrated that seed cotton yields were generally not affected by annual applications of monuron [3-(*p*-chlorophenyl)-1,1-dimethylurea] and diuron. Diuron caused no adverse effect on cotton seedlings; however, the diuron residue affected the growth of oats (*Avena sativa* L.) and barley (*Hordeum vulgare* L.) planted 0 to 12 months after application.

Effects of Trifluralin on Cotton and Other Plants

Trifluralin is an organic herbicide belonging to the family of substituted dinitroanilines. It is a selective, preemergence, soil-incorporated herbicide which controls a wide variety of grasses and broadleaf weeds (7). It is used in many agronomic and horticulture crops. Trifluralin can be effectively applied as a preplant, preemergence, or postemergence herbicide to control weeds in cotton. Tests in all cotton-producing areas of the United States suggest it does not affect established weeds (36). Trifluralin is primarily used as a soil incorporated herbicide to control grassy weeds.

Ford and Massey (22) reported that due to low water solubility, susceptibility to ultra-violet light degradation, and volatilization from soil surface, trifluralin required soil-incorporation to insure maximum herbicidal activity. Soil-incorporation enhanced the performances of trifluralin in several ways: (a) soil incorporation eliminated need for rainfall or irrigation to move herbicide into the soil, (b) provided longer weed control than surface applications, and (c) less of the herbicide was required when soil-incorporated than when surface applied.

The mode of action of trifluralin is not understood. It will inhibit normal root growth by interfering with cell division and differentiation in root development (2, 5, 13, 22, 26, 34, 38, 43, 46, 47, 57, 60). Hacskaylo and Amato (26) found that trifluralin caused club-shaped radicles. They also found a disorganized nuclear division in cells behind the tip of treated roots. Cells of treated roots showed no mitosis and untreated roots showed all stages of mitosis. Oliver and Frans (47) studied the inhibition of cotton and soybean [Glycine max (L.) Merr.] roots from incorporating trifluralin in the soil. They reported that a compensation phenomena occurred with lateral roots in cotton. When the lateral roots were inhibited along the taproot exposed to trifluralin-treated soil, the number of lateral roots increased along that portion immediately below the untreated soils.

Vannoorbeeck (60) also reported that cotton seedlings reacted to trifluralin which was incorporated into the soil root zone by producing more secondary roots on the portion of the primary roots not in contact with the herbicide. He also reported that the threshold level for root inhibition was 0.55 kg of trifluralin per 2.5 cm of soil. The bioactivity of this concentration of trifluralin was influenced by the depth of incorporation.

Researchers (2, 60) have reported that lateral root growth of cotton was affected more by depth of incorporation than by dosage, though taproot growth was essentially unaffected. They (2) also reported that trifluralin applied to leaves did not affect growth. Stunting of plants can occur independent of the effects on root growth. When trifluralin was incorporated in the soil above the seed, stunting of the seedlings was observed, but lateral root growth was not affected. Apparently, the herbicide entered the emerging seedling through the hypocotyl, cotyledons and (or) a terminal bud. Trifluralin injury occurs primarily during the germination process and seedling stage of development. It has no effect on dormant seeds (22).

Anderson, Richards, and Whitworth (2) evaluated injury by incorporating four rates of trifluralin prior to planting within the zone of incorporation. Depth of incorporation had a greater influence on lateral root growth than dosage. Growth of the primary root was essentially unaffected and secondary root development was prevented only on that portion of root growing in treated soil.

Mallory (44) studied some morphological and anatomical differences between cotton and safflower (Carthamus tinctorius L.) treated with and without trifluralin. Eight hours after treatment the initial effect of trifluralin on the primary root of cotton and safflower was on the cells in the region of elongation. Cells became abnormally enlarged in the radical plane of the root. After prolonged treatment there was a gradual reduction in the region of active cell division--the apical meristem. After 120 hours, the root apex enlarged abnormally and caused the disorganization of the apical meristem and the loss of its meristematic properties. He agreed with other researchers that the mitotic process was affected by the herbicide. He also reported that cotton lateral root development was not complete, but safflower lateral roots developed normally.

Ketchersid, Boswell, and Merkle (41) studied the uptake and translocation of substituted aniline herbicides in peanut (Arachis hypogaea L.) seedlings. Greatest absorption of trifluralin occurred when seedlings were germinated in untreated soil and transplanted into treated soil than when germinated in treated soil for the same period. As the age of seedlings increased, absorption decreased. High concentrations of trifluralin were found in the treated area and the cotyledons of seedlings germinated in treated soil. Field studies indicated that peanut injury may occur when using trifluralin at a rate of 0.55 kg/ha or more. Symptoms of injury included stunted growth, shortened internodes, and lack of lateral root development. Usually symptoms disappeared after 2 to 3 weeks. They (41) also reported that similar symptoms of injury have been found in cotton. Recent experiments with cotton indicated that the effect produced by trifluralin may be due to uptake by hypocotyl, cotyledons, terminal buds, and roots.

Menges and Tamez (45) studied the movement and persistence of trifluralin in irrigated soil. Regardless of rainfall, trifluralin remained within the original soil zone of incorporation. Trifluralin persisted longer in soils as depth of incorporation increased. Trifluralin did not persist in appreciable amounts 12 months after treatment of 1.1 kg/ha. At this rate, significant residue of trifluralin was detected after 6 months only when tillage was restricted. Trifluralin was more rapidly degraded in lower soil depths or was moved upward in a vapor state during the period between bed preparation and soil sampling.

Probst et al. (51) studied the fate of trifluralin in soils and plants. They reported that crops tolerant to the herbicide include cotton, soybeans, snapbeans (*Phaseolus vulgaris* L.), lima beans (*Phaseolus lunatus* L.), safflower, carrots (*Daucus carota* L.) and several transplanted crops such as tomatoes (*Lycopersicon esculcentum* L.) and peppers (*Capsicum frutescens* L.). They reported that degradation studies on trifluralin in field soils showed a decrease to a concentration of 10 to 15% within 0.5 to 1 year. Extensive residue analysis of tolerant crops indicated that trifluralin was not readily absorbed from soil.

Savage and Barrentine (52) reported on the persistence of trifluralin as it was affected by depth of incorporation. The deeper the incorporation the greater the persistence of trifluralin. They also postulated that trifluralin volatilization decreased with an increase in depth of incorporation. Volatilization appeared to be an important mode of trifluralin dissipation from the soil.

Parka and Tepe (49) collected soil samples from 107 locations following the commercial applications of trifluralin for 1, 2, 3, or 4 consecutive years. Analysis of soil samples indicated that trifluralin did not accumulate with repeated annual applications and that a steady and continuous decline in the level of trifluralin present in the soil occurred. It was also reported (22) that trifluralin was strongly adsorbed by clay and organic matter.

The resistance to leaching supported the premise of strong binding to the soil. Parka and Tepe (49) also reported an increase in activity of trifluralin occurred when incorporated as compared to surface application. They suggested loss of trifluralin by either volatility or photodecomposition. Examination of soil samples showed no specific microorganism which caused trifluralin degradation. Temperature was directly related to rate of decomposition, the higher the temperature the greater the decomposition.

Gagnon (23) studied the persistence of seven dinitroanilines under irrigated and desert fallow conditions. The herbicides were incorporated immediately following treatment with a double disking to a 10 cm depth. Plots represented both irrigated and fallow conditions. The fallow plots received no irrigation. Per cent emergence of sorghum (*Sorghum vulgare* L.) was a sensitive indicator at 1 day and the 2- and 4-month intervals, but sensitivity was lost at the 8- and 12-month intervals. Persistence of trifluralin was strongly influenced by moisture. Herbicide loss was greatest in irrigated borders between 4 and 12 months.

Anderson, Richards, and Whitworth (3) studied leaching of three herbicides using soil columns. Using a clay loam soil, they reported that trifluralin leaching was minimal. Trifluralin, however, leached more than benefin (*N*-butyl-*N*-ethyl-*a*,*a*,*a*-trifluoro-2,6-dinitro-*p*-toluidine) but less than nitralin [4-(methylsulfonyl)-2,6-dinitro-N,N-dipropylaniline]. Gagnon (23) also reported that no leaching of trifluralin occurred below the zone of incorporation.

Ford and Massey (22) reported that trifluralin was strongly adsorbed on the soil and was extremely resistant to movement by water. Trifluralin did not leach and in furrow irrigation there was little, if any, lateral movement. They also found that trifluralin if not incorporated will volatilize and this can be an important source of herbicide loss.

Wright and Warren (63) studied photochemical decomposition of trifluralin by exposing glass and soil surfaces treated with trifluralin to sunlight and a mercury-vapor source. Glass treated with trifluralin and exposed to sunlight for 4 to 6 hours resulted in a loss of phytotoxicity. Soil surface exposure showed that photodegradation occurred, but at a much reduced rate than that of the glass surface.

Studying the effects of trifluralin on cotton seedlings, Anderson et al. (2) found reduced yields if dosages greater than those recommended were soil-incorporated below where the seed was planted. Stunting occurred at 1.1 kg/ha at all depths of incorporation.

Standifer, Sloane, and Wright (56) studied the effects of repeated trifluralin applications on the growth of cotton. Treatment of cotton plants with four times the recommended herbicide rate injured cotton. However, this did not affect ultimate plant height or yield. Trifluralin at 4.4 kg/ha applied at planting time had no effect on the cotton root system if the herbicide was not placed below seed depth.

Hamilton and Arle (28) demonstrated that trifluralin controlled weeds resulting in increased cotton production. Trifluralin applied at two rates at layby gave better grass control than broadleaf control and did not effect the development of cotton plants. Preplant application of 1.1 kg/ha of trifluralin caused temporary stunting of cotton seedlings for 4 to 5 weeks. They also reported that stands were reduced 15 to 25% when Rhizoctonia solani Kuehm occurred in plots receiving preplant trifluralin treatments. Agamalian (1) found that the addition of PCNB (Pentachloronitrobenzene) to R. solani and trifluralin treated soil significantly increased cotton emergence and fresh weight and significantly decreased hypocotyl infection at 23 C.

Chandler and Santelmann (16) investigated the interaction of four herbicides with R. solani on seedling cotton. Studies were conducted in growth chambers and field tests. Seedling diseases were caused under both conditions and interactions injurious to the cotton occurred between trifluralin and a low level of R. solani. This occurred only when the herbicide was used at a high rate.

Eslami (21) studied the effects of trifluralin and temperature on seedlings of three cotton varieties. All concentrations of trifluralin reduced top and root growth of the three cotton varieties. There was no significant interaction between temperature and concentration of trifluralin in their effects on cotton seedling growth.

Arle and Hamilton (7) found that cotton emergence was not affected by applications of trifluralin. Applications of trifluralin before furrowing temporarily retarded seedling growth; however, 6 weeks after emergence, growth differences of plants in treated or untreated plots were no longer evident. Significant increases in seed cotton yields were obtained with 1.1 kg/ha of trifluralin disked in before furrowing compared to the non-treated control.

Guse and Schwer (25) reported the effects of soil texture, rates, and application methods of trifluralin on cotton. Cotton seedlings were stunted when 1.7 and 3.3 kg/ha of trifluralin were used. Preplant, incorporated treatments were superior in their consistency of performance and gave longer duration of weed control. Cotton exhibited a high degree of tolerance to trifluralin with soybeans somewhat less tolerant. Surface spray treatments occasionally gave acceptable weed control. However, they were erratic and did not provide as good late season control as the incorporated treatments.

Schrader (53) evaluated 11 dinitroaniline herbicides on cotton, peanuts, and soybeans on soils with several organic matter levels. He observed no injury when trifluralin was applied preplant incorporated on sandy loam soil with 4% organic matter. Slight injury occurred with soils with 1.2% organic matter when trifluralin was applied at 0.55 and 1.1 kg/ha. At 1.1 kg/ha trifluralin maintained good grass control through midseason.

Research conducted in Tennessee (48) in 1972 compared trifluralin to newer anilines in their effect on weeds and phytotoxicity to crops. None of the newer dinitroanilines were superior to trifluralin in weed control or crop tolerance.

Buchanan et al. (15) evaluated the performance of dinitroaniline herbicides in peanuts. They agreed with Schrader (53) that preplant incorporation applications of 0.83 kg/ha controlled annual grass weeds. Preemergence applications were less effective than preplant incorporation applications. Weed control ratings of preplant incorporated treatments were superior to preemergence applications. Peanuts were generally tolerant to trifluralin with no foliage injury. Rates of 1.1 kg/ha or less did not reduce yield.

Herbicide Combinations

Some disadvantages of using herbicide combinations are: (a) some mixtures are incompatable, (b) dealing with two chemicals there will be more chance for human error in weighing and measuring correct amounts, and (c) difficult to obtain registration of herbicide combinations (17, 35, 55).

Kerr (40) reported that trifluralin plus fluometuron [1,1-dimethyl-3-(a,a,a-trifluoro-m-tolyl)urea] at 1.1 plus 0.83 kg/ha respectively when incorporated by disking controlled weeds just as well as when the fluometuron component was applied after planting at 1.9 kg/ha.

Arle and Hamilton (7) applied trifluralin and diuron preplant under several cultural practices. Applications were made before disking and furrowing prior to preplant irrigation, before furrowing prior to preplant irrigation, and after preplant irrigation before harrowing to prepare the seedbeds. Rates used were diuron at 1.1 to 2.2 kg/ha and trifluralin at 0.55 and 1.1 kg/ha. Emergence of cotton was not affected by preplant applications of the herbicide combinations. However, on plots treated with diuron before furrowing, many seedlings became chlorotic and remained stunted for several weeks.

Two tests were conducted in Arizona (8) in 1964 to evaluate combinations of two herbicides in one or two preplant applications for control of annual weeds on irrigated.

cotton. In one test, a single application of two herbicides was made immediately before furrowing for the preplant irrigation. Combinations used were 0.83 kg/ha of trifluralin with either 0.83 or 1.1 to 1.4 kg/ha of diuron. The second test, a prefurrowing application of 0.83 kg/ha of trifluralin, was followed with an application of 1.1 kg/ha of diuron after furrowing before the final harrowing of the seedbed. All preplant herbicide combinations which contained trifluralin stunted cotton for 2 to 3 months. Combinations which contained diuron caused temporary chlorosis of cotton foliage. Preplant herbicide combinations which contained trifluralin reduced cotton seedling stands 12% at emergence and 25% at thinning. Herbicide combinations gave 95 to 100% control of annual grasses until harvest. Broadleaf weed control was 77 to 96%. All herbicide combinations resulted in increased yields of cotton. There was no difference in weed control or response of cotton when the two herbicides were applied separately or combined in a single preplant application.

Andrews et al. (4) evaluated herbicidal combinations of alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide] in soybeans. The combining of alachlor with DNBP (2,4-dinitro-6-sec-butylphenol) and prometryn [2,4-bis(isopropylamino)-6-(methylthio)-s-triazine] increased activity on broadleaf species when compared to alachlor alone.

Response of Plants to Pesticide Combinations

Researchers in Texas (27) investigated the effect of diuron and monuron on growth of seedling cotton and their effect when applied jointly with phorate [O,O-diethyl S-(ethylthio)-methyl phosphorodithioate] and disulfoton [O,O-diethyl S-2-(ethylthio)ethyl phosphorodithioate]. Seed was treated with insecticides at different rates. Herbicides were applied preemergence on the soil surface. Combinations of either monuron or diuron with phorate or disulfoton reduced the margin of safety and increased phytotoxicity as compared with either chemical used alone.

Kirby and Santelmann (42) studied the compatibility of tank mixtures of herbicides and insecticides. They determined if interactions existed between tank mixes of selected herbicides and insecticides. These were evaluated as to physical compatibility and whether mixing influenced the herbicidal phytotoxicity. Solutions were mixed in either 47 or 374 l/ha diluent. Mixtures were then used in bioassay tests to evaluate for phytotoxicity interactions. Preplant mixtures were sprayed on the soil. Trifluralin mixed with furadan (2,3-Dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) or dasanit (0,0-Diethyl 0-[4-(methylsufinyl) phenyl] phosphorothioate) did not affect the activity of the herbicide regardless of the gallonage used in the mixture.

Arle (6) investigated the effects of trifluralin plus phorate and disulfoton insecticides on secondary root development of cotton seedlings. Trifluralin was applied and incorporated into the soil at the rate of 1.1 kg/ha alone or in combination with disulfoton or phorate at rates of 11, 22, and 44 kg/ha. Cotton seedling growth was increased when combinations of phorate and disulfoton with trifluralin were used as compared to trifluralin alone. Phorate was more effective than disulfoton in overcoming the inhibitory effect of trifluralin on secondary root development.

Hassawy (33) studied the effects of trifluralin alone and in combination with phorate on cotton root development in soil and culture solution. Soil applications of trifluralin, phorate, and trifluralin-phorate combinations did not affect cotton germination. Trifluralin-treated plants were shorter than phorate-treated plants. The total number of lateral roots was reduced by trifluralin treatments. Phorate-trifluralin combinations increased the number of lateral roots compared to trifluralin-treated plants. The mitotic process of the pericyclic cells was disturbed by trifluralin and trifluralin-phorate treatments. In some cells, divisions were observed but differentiation failed to occur.

METHODS AND MATERIALS

This research was conducted in 1972 and 1973. Varying rates of trifluralin and diuron were used alone, and in combinations, to determine the effect on cotton stands and yield. Four field tests were conducted on three cotton farms as follows:

1. Brown farm, Coolidge, Arizona, herbicides applied broadcast before furrowing, February, 1972.
2. Gilbert farm, Casa Grande, Arizona, herbicides applied broadcast over-the-bed, March, 1972.
3. Brown farm, Coolidge, Arizona, herbicides applied broadcast before furrowing, February, 1973.
4. Pate farm, Casa Grande, Arizona, herbicides applied broadcast over-the-bed, March, 1973.

Prior to herbicide application, soil samples were taken from each test to determine the sand, silt, clay, and organic matter content (Table 1).

Each test consisted of 16 treatments applied to plots 4 m wide by 12.2 m long. The experimental design was a randomized complete block with four replications.

Each year herbicides were applied by two methods: (a) broadcast and disked in 10 cm prior to furrowing for the preplant irrigation and (b) preplant incorporated

Table 1. Sand, silt, clay, and organic matter content of the soil in each location of herbicide test.

Location	Classification	Sand (%)	Silt (%)	Clay (%)	Organic matter (%)
Brown farm, 1972	loam	36	50	14	1
Gilbert farm, 1972	silty clay	5	50	45	1
Brown farm, 1973	sandy clay	63	29	8	2
Pate farm, 1973	sandy clay	61	33	6	2

over-the-bed after furrowing. Tops of beds were lowered several centimeters from peaked shape prior to herbicide application broadcast over-the-bed. The herbicides were then incorporated into the beds with a power-driven, rotary mulcher 10 cm deep.

Applications of trifluralin and diuron were made with a K5 flood nozzle operating at 2.8 kg/sq. cm. Trifluralin was applied at 0, 0.56, 0.84, and 1.1 kg/ha. Diuron was applied at 0, 1.1, 1.7, and 2.2 kg/ha. Trifluralin at 0.56, 0.84, and 1.1 kg/ha was applied in combination with diuron at 1.1, 1.7, and 2.2 kg/ha.

The cotton 'Deltapine 16' was planted in all tests. The cotton seed was planted in moist soil under a ridge of dry soil wich was later removed for emergence.

In the center of each plot, 3 meters of row were permanently staked and stand counts were made after the first, second, third, and fourth postemergence irrigations at all locations except at the Pate farm where three stand counts were made (Table 2).

Each test was irrigated according to the moisture needs of the entire field at each location. Yield determinations were made by harvesting the center two rows of each plot with an International picker on October 15 and 17, 1972, and October 22 and 23, 1973.

Table 2. Schedule of cotton stand counts at each location of herbicide test.

Location	Date of stand counts			
	After first irrigation	After second irrigation	After third irrigation	After fourth irrigation
Brown farm, 1972	April 20	April 27	May 4	June 17
Gilbert farm, 1972	April 18	April 25	May 2	May 25
Brown farm, 1973	May 14	May 30	June 19	July 10
Pate farm, 1973	May 31	June 22	July 12	

RESULTS AND DISCUSSION

Cotton Stands

Cotton stands were not affected by applying trifluralin or diuron or a combination of the herbicides over-the-top of beds and incorporating to a depth of 6 cm (Tables 3 and 4). The cotton seed was placed at or below the herbicide and cotton seedlings developed normally.

Trifluralin, although not readily absorbed in the plant (22, 60), prevents growth of lateral roots (5). Cotton seed planted in the treated soil must germinate and extend roots below herbicide-treated soil. When the herbicide-treated zone was deep and a high rate used, stunting and reduced root growth has been observed, as has increased susceptibility to seedling disease (16, 27). Diuron is translocated in the plant to the leaves where it interferes with photosynthetic processes (18, 37, 50). When these herbicides are applied over-the-bed and incorporated in the soil, the herbicide-treated area is determined by depth of incorporation. This information was used to avoid planting in the herbicide-treated zone which is likely the reason injury was avoided. Trifluralin is immobile and diuron has limited movement in the soil. Furrow irrigations generally do not move these herbicides and do not result in reduced stands. This method of application and incorporation

Table 3. Effects on cotton stands of diuron and (or) trifluralin applied broadcast over-the-bed in 1972.

Treatment		Date of stand counts[1]			
Trifluralin (kg/ha)	Diuron (kg/ha)	April 18	April 25	May 2	May 25
		(Plants per 3.1 m of row)			
0.0	0.0	17 a	17 a	15 a	15 a
0.0	1.1	17 a	17 a	16 a	16 a
0.0	1.7	22 a	22 a	22 a	21 a
0.0	2.2	24 a	23 a	22 a	20 a
0.56	0.0	21 a	20 a	19 a	18 a
0.56	1.1	21 a	20 a	19 a	17 a
0.56	1.7	16 a	18 a	17 a	16 a
0.56	2.2	22 a	22 a	20 a	20 a
0.84	0.0	18 a	19 a	17 a	17 a
0.84	1.1	18 a	18 a	16 a	15 a
0.84	1.7	21 a	21 a	20 a	18 a
0.84	2.2	20 a	19 a	17 a	16 a
1.1	0.0	17 a	17 a	16 a	16 a
1.1	1.1	16 a	15 a	15 a	14 a
1.1	1.7	22 a	23 a	23 a	20 a
1.1	2.2	19 a	19 a	19 a	17 a

[1] Values within a column followed by the same letter are not significantly different at the 5% level of Duncan's multiple range test.

Table 4. Effects on cotton stands of diuron and (or) trifluralin applied broadcast over-the-bed in 1973.

Treatment		Date of stand counts[1/]		
Trifluralin (kg/ha)	Diuron (kg/ha)	May 31	June 22	July 12
		(Plants per 3.1 m of row)		
0.0	0.0	16 a	16 a	16 a
0.0	1.1	19 a	20 a	19 a
0.0	1.7	15 a	14 a	14 a
0.0	2.2	14 a	14 a	14 a
0.56	0.0	13 a	13 a	13 a
0.56	1.1	16 a	16 a	16 a
0.56	1.7	18 a	17 a	17 a
0.56	2.2	18 a	18 a	17 a
0.84	0.0	15 a	16 a	15 a
0.84	1.1	15 a	17 a	17 a
0.84	1.7	17 a	18 a	18 a
0.84	2.2	15 a	15 a	14 a
1.1	0.0	21 a	20 a	13 a
1.1	1.1	17 a	17 a	16 a
1.1	1.7	16 a	15 a	16 a
1.1	2.2	13 a	14 a	13 a

[1/] Values within a column followed by the same letter are not significantly different at the 5% level of Duncan's multiple range test.

is one of the safest methods of application but generally does not provide the degree of weed control achieved by application of herbicides to the soil before furrowing out for the preplant irrigation.

In 1972, cotton stands were not reduced by trifluralin, but stands were reduced by certain diuron or trifluralin-diuron combinations applied to the soil and incorporated before furrowing out (Table 5). Diuron at 1.1, 1.7, and 2.2 kg/ha and combinations of 0.56 kg/ha of trifluralin with 1.7 and 2.2 kg/ha of diuron applied broadcast before furrowing reduced stands in June, 1972. In the same test, combinations of trifluralin at 0.84 kg/ha with 1.1 and 1.7 kg/ha of diuron significantly reduced final stand counts. Trifluralin at 1.1 kg/ha combined with 1.7 kg/ha of diuron reduced stands below that of the check. Surprisingly, trifluralin at 0.84 and 1.1 kg/ha combined with 2.2 kg/ha of diuron applied broadcast before furrowing did not reduce stands in 1972.

The effects of trifluralin and (or) diuron applied broadcast before furrowing in 1973 were more pronounced than applications in 1972 (Tables 5 and 6). Six to 10 days after emergence, seedlings in soil treated with diuron and trifluralin-diuron combinations became chlorotic and died. This could have been caused by the differences in irrigation dates, amount of water applied to plots, cooler temperatures, and other environmental factors. In 1973, cotton

Table 5. Effects on stands of diuron and (or) trifluralin applied broadcast before furrowing for preplanting irrigation in 1972.

Treatment		Date of stand counts[1/]			
Trifluralin (kg/ha)	Diuron (kg/ha)	April 20	April 27	May 4	June 17
		(Plants per 3.1 m of row)			
0.0	0.0	27 a	28 a	27 a	23 a
0.0	1.1	22 ab	19 ab	17 abc	14 bcd
0.0	1.7	19 b	14 b	11 bc	7 cd
0.0	2.2	24 ab	19 ab	15 bc	13 bcd
0.56	0.0	28 a	27 a	26 a	19 ab
0.56	1.1	26 ab	24 ab	24 a	20 a
0.56	1.7	22 ab	14 b	13 bc	11 bcd
0.56	2.2	22 ab	21 ab	20 ab	13 bcd
0.84	0.0	29 a	27 a	26 a	23 a
0.84	1.1	22 ab	19 ab	18 abc	14 bcd
0.84	1.7	24 ab	21 ab	16 bc	13 bcd
0.84	2.2	24 ab	20 ab	19 abc	15 abc
1.1	0.0	24 ab	25 a	21 a	15 abc
1.1	1.1	20 b	21 ab	19 abc	15 abc
1.1	1.7	21 b	12 b	10 c	6 d
1.1	2.2	27 a	24 a	25 a	20 a

[1/]Values within a column followed by the same letter are not significantly different at the 5% level of Duncan's multiple range test.

Table 6. Effects on cotton stands of diuron and (or) trifluralin applied broadcast before furrowing for preplanting irrigation in 1973.

Treatment		Date of stand counts[1/]			
Trifluralin (kg/ha)	Diuron (kg/ha)	May 14	May 30	June 19	July 10
		(Plants per 3.1 m of row)			
0.0	0.0	31 a	30 a	28 a	28 a
0.0	1.1	19 bc	17 bc	15 bc	15 bcd
0.0	1.7	9 de	6 d	5 d	4 e
0.0	2.2	7 e	3 d	2 d	2 e
0.56	0.0	17 bcd	13 c	12 bc	15 bc
0.56	1.1	25 ab	22 b	20 ab	18 b
0.56	1.7	20 bc	18 bc	16 bc	15 bcd
0.56	2.2	14 cde	12 c	10 cd	9 bcde
0.84	0.0	17 cd	14 c	13 bc	13 bcd
0.84	1.1	19 bc	17 bc	15 bc	16 bc
0.84	1.7	17 cd	15 c	15 bc	14 bcd
0.84	2.2	12 cde	5 d	9 cd	9 bcde
1.1	0.0	17 cd	15 c	13 bc	15 bcd
1.1	1.1	20 bc	15 c	13 bc	14 bcd
1.1	1.7	15 cde	12 c	9 cd	11 bcd
1.1	2.2	11 de	6 d	7 cd	7 cde

[1/] Values within a column followed by the same letter are not significantly different at the 5% level of Duncan's multiple range test.

stands were reduced by all rates of trifluralin and (or) diuron applied broadcast before furrowing (Table 6). Also, in 1973, stands of cotton were similar when diuron was applied broadcast before furrowing at 2.2 kg/ha with all rates of trifluralin compared to 1.7 and 2.2 kg/ha of diuron applied alone. Stunting of cotton seedlings was observed in all plots treated with 1.1 kg/ha of trifluralin applied broadcast before furrowing, but normal growth occurred in 6 to 8 weeks. It has been reported (5, 7) that the 1.1 to 2.2 kg/ha rates of diuron disked in before furrowing killed cotton seedlings and reduced stands. It has also been demonstrated (5) that trifluralin reduces lateral root growth in the zone of incorporation and, therefore, reduces the effect of diuron on plants.

In July, 1973, diuron applied alone before furrowing stunted cotton. Even though trifluralin reduced stands, the combinations of trifluralin at 0.56, 0.84, and 1.1 kg/ha and diuron at 1.1 and 1.7 kg/ha increased stands compared to diuron at 1.7 and 2.2 kg/ha (Table 6). The addition of trifluralin to diuron provided a margin of safety to the cotton plant except when trifluralin was used with 2.2 kg/ha of diuron.

Cotton Yields

In 1972, yield was not affected by trifluralin and (or) diuron applied broadcast over-the-bed (Table 7).

Table 7. Effects on cotton yield of diuron and (or) trifluralin applied broadcast over-the-bed in 1972-1973.

Treatment		Yield of seed cotton [1/]	
Trifluralin (kg/ha)	Diuron (kg/ha)	1972 (kg/ha)	1973 (kg/ha)
0.0	0.0	940 a	1990 c
0.0	1.1	1110 a	2790 b
0.0	1.7	1310 a	2620 b
0.0	2.2	1110 a	3160 ab
0.56	0.0	1200 a	2420 b
0.56	1.1	940 a	2990 ab
0.56	1.7	1110 a	3160 ab
0.56	2.2	1110 a	2990 ab
0.84	0.0	1110 a	3360 a
0.84	1.1	1110 a	3360 a
0.84	1.7	1110 a	3160 ab
0.84	2.2	940 a	3160 ab
1.1	0.0	740 a	3160 ab
1.1	1.1	940 a	2990 ab
1.1	1.7	1310 a	3360 a
1.1	2.2	1110 a	2620 b

[1/] Values within a column followed by the same letter are not significantly different at the 5% level of Duncan's multiple range test.

In 1973, all treatments of trifluralin and (or) diuron resulted in higher yields than the check (Table 7).

Trifluralin applied broadcast before furrowing, at 1.1 kg/ha in 1972, resulted in significantly greater yield than 1.7 kg/ha of diuron and the combination of trifluralin at 0.56 kg/ha with 2.2 kg/ha of diuron (Table 8). None of the herbicide treatments increased cotton yield compared to the check. In 1972, there was no significant difference in yield due to herbicide treatments applied broadcast before furrowing compared to the check.

In 1973, yields of plots treated with 0.56 and 0.84 kg/ha of trifluralin applied broadcast before furrowing were not significantly different from the check. All other treatments of trifluralin and (or) diuron applied in this manner yielded less than the check. Diuron at 1.7 and 2.2 kg/ha and combinations of trifluralin and 2.2 kg/ha of diuron caused the greatest yield reductions. There was a trend for the addition of trifluralin to diuron to reduce diuron's effect on yield. In 1973, diuron applied alone at 1.1 kg/ha yielded 1400 kg/ha of seed cotton as compared to 1670 kg/ha for the 0.56 kg/ha of trifluralin in combination with 1.1 kg/ha of diuron. Diuron applied alone at 2.2 kg/ha yielded 400 kg/ha of seed cotton as compared to the combination of trifluralin at 0.56 kg/ha with 2.2 kg/ha of diuron which yielded 1160 kg/ha (Table 8). This trend suggests that the trifluralin-diuron combinations resulted

Table 8. Effects on cotton yield of diuron and (or) trifluralin applied broadcast before furrowing for the preplanting irrigation in 1972-1973.

Treatment		Yield of seed cotton[1/]	
Trifluralin (kg/ha)	Diuron (kg/ha)	1972 (kg/ha)	1973 (kg/ha)
0.0	0.0	3530 abc	2320 a
0.0	1.1	3160 abc	1400 bcde
0.0	1.7	2420 c	890 e
0.0	2.2	2990 abc	400 e
0.56	0.0	3360 abc	1860 ab
0.56	1.1	3530 abc	1670 bc
0.56	1.7	3160 abc	1500 bcde
0.56	2.2	2620 bc	1160 cde
0.84	0.0	3530 abc	1730 abc
0.84	1.1	3360 abc	1620 bcd
0.84	1.7	2990 abc	1540 bcde
0.84	2.2	3160 abc	1000 e
1.1	0.0	3730 a	1310 bcde
1.1	1.1	3360 abc	1350 bcde
1.1	1.7	2990 abc	1200 cde
1.1	2.2	3530 abc	900 e

[1/] Values within a column followed by the same letter are not significantly different at the 5% level of Duncan's multiple range test.

in higher yields than the same rates of diuron alone. The reason for the higher yield is thought to be due to suppression of lateral root development by trifluralin which resulted in less diuron injury to young cotton seedlings. This reason can be further supported by stand counts (Table 6). In 1973, stands were reduced 93% by 2.2 kg/ha of diuron applied before furrowing. The same treatment yielded 80% less than the check (Table 8). In conclusion, data suggest that the severe stand reduction caused by high rates of diuron resulted in reduced yields. In some years, the addition of trifluralin to the preplant combinations of diuron could reduce the effects of diuron on seedling cotton.

SUMMARY

This study determined the effects of trifluralin and diuron applied preplant alone or in combination on stand and yield of cotton for 2 years. Cotton was planted in soil treated with varying rates of trifluralin and (or) diuron. The herbicides were applied by two methods: (a) preplant broadcast incorporated before furrowing, and (b) preplant broadcast incorporated over-the-bed.

1. Cotton seedling emergence was not affected by trifluralin and (or) diuron applied broadcast before furrowing or broadcast over-the-bed.
2. Applications of trifluralin and (or) diuron applied broadcast over-the-bed did not affect cotton stand.
3. Diuron applied alone broadcast before furrowing in 1972, at 1.1, 1.7, and 2.2 kg/ha significantly reduced cotton stands compared to the check. Cotton stands were not reduced by trifluralin, but were reduced by certain diuron or trifluralin-diuron combinations.
4. Cotton stands were reduced by all rates of trifluralin and (or) diuron applied broadcast before furrowing in 1973.

5. Yields were not affected by applications of trifluralin and (or) diuron applied broadcast over-the-bed in 1972.
6. In 1973, when herbicides were applied broadcast over-the-bed, yields were significantly higher than the check.
7. In 1972, there was no significant difference in yield due to herbicide treatments applied broadcast before furrowing compared to the check.
8. In 1973, diuron and (or) trifluralin applied broadcast before furrowing, except 0.56 and 0.84 kg/ha of trifluralin alone, reduced yield compared to check.
9. In 1973, a trend existed for the addition of trifluralin to diuron treatments to reduce diuron's effect on yield.

LITERATURE CITED

1. Agamalian, H. S. 1964. The effects of trifluralin and *Rhizoctonia solani* on cotton seedlings. M.S. Thesis, Agron. Dept., Univ. of Arizona (Univ. Library), 60 pp.

2. Anderson, P. W., A. B. Richards, and J. W. Whitworth. 1967. Trifluralin effects on cotton seedlings. Weeds 15:224-227.

3. Anderson, P. W., A. B. Richards, and J. W. Whitworth. 1968. Leaching of trifluralin, benefin, and nitralin in soil columns. Weed Sci. 16:165-169.

4. Andrews, O. N., Jr., C. W. Denting, D. F. Jones, and G. W. Selleck. 1971. An evaluation of alachlor herbicidal combinations in soybeans. Proc. S. Weed Sci. Soc. 24:63-66.

5. Arle, H. F. 1967. Increasing the tolerance of cotton seedlings to herbicides by soil application of trifluralin. Proc. West. Weed Contr. Conf. 21:36.

6. Arle, H. F. 1968. Trifluralin--systemic insecticide interactions on seedling cotton. Weed Sci. 16:430-432.

7. Arle, H. F., and K. C. Hamilton. 1964. Preplant applications of herbicides in cotton. Res. Prog. Rep. West. Weed Contr. Conf. pp. 80-81.

8. Arle, H. F., and K. C. Hamilton. 1965. Combinations of herbicides in one or two preplant applications in irrigated cotton. Res. Prog. Rep. West. Weed Contr. Conf. pp. 78-79.

9. Arle, H. F., and K. C. Hamilton. 1969. Foliar application of diuron in young cotton. Res. Prog. Rep. West. Soc. Weed Sci. p. 97.

10. Arle, H. F., and K. C. Hamilton. 1970. Preplanting applications of trifluralin to reduce diuron injury in cotton. Res. Prog. Rep. West. Soc. Weed Sci. pp. 86-87.

11. Arle, H. F., J. H. Miller, and T. J. Sheets. 1965. Disappearance of herbicides from irrigated soils. Weeds 13:56-60.

12. Ashton, F. M. 1961. Movement of herbicides in soil with simulated furrow irrigation. Weeds 9:612-619.

13. Barrentine, W. L., and G. F. Warren. 1971. Differential phytotoxicity of trifluralin and nitralin. Weed Sci. 19:31-37.

14. Bayer, D. E., and S. Yamaguchi. 1965. Absorption and distribution of diuron-14. Weeds 13:232-235.

15. Buchanan, G. A., R. D. McLaughlin, J. Bannon, and H. Ivy. 1973. Performance of dinitroaniline herbicides in peanuts. Proc. S. Weed Sci. Soc. 26: 95-98.

16. Chandler, J. M., and P. W. Santelmann. 1968. Interactions of four herbicides with Rhizoctonia solani on seedling cotton. Weed Sci. 16:454-456.

17. Colby, S. R., T. Wojtaszek, and G. F. Warren. 1965. Synergistic and antagonistic combinations for broadening herbicidal selectivity. Weeds 13:87-91.

18. Cooke, A. R. 1956. A possible mechanism of action of the urea type herbicides. Weeds 4:397-398.

19. Dalton, R. L., A. W. Evans, R. C. Rhodes, and E. I. DuPont de nemours & Co. 1965. Disappearance of diuron in cotton field soils. Proc. S. Weed Conf. 18:72-75.

20. Eshel, Y. 1969. Tolerance of cotton to diuron, fluometuron, norea and prometryne. Weed Sci. 17:492-496.

21. Eslami, K. 1965. Effects of trifluralin and temperature on cotton seedlings. M.S. Thesis, Agron. Dept., Univ. of Arizona (Univ. Library), 33 pp.

22. Ford, D. H., and G. D. Massey. 1971. Characteristics of the substituted dinitroaniline herbicides, treflan, balan, paarlan, and El-119. Proc. Calif. Weed Conf. 23:142-146.

23. Gagnon, S. A. 1973. Persistence of seven dinitroanilines under irrigated and fallow conditions. M.S. Thesis, Agron. Dept., Univ. of Arizona (Univ. Library), 57 pp.

24. Geissbuhler, H. 1969. The substituted ureas. Pages 79-111. In: Degradation of herbicides. P. C. Kearney and D. D. Kaufman (Eds.), Marcel Dekker, Inc., New York.

25. Guse, L. R., and J. F. Schwer. 1964. Trifluralin: Field studies in cotton and soybeans. Proc. S. Weed Conf. 17:67-72.

26. Hacskaylo, J., and V. A. Amato. 1968. Effect of trifluralin on roots of corn and cotton. Weeds 16:513-515.

27. Hacskaylo, J., J. K. Walker, Jr., and E. G. Pires. 1964. Response of cotton seedlings to combinations of pre-emergence herbicides and systemic insecticides. Weeds 12:288-291.

28. Hamilton, K. C., and H. F. Arle. 1964. Preplant layby combinations of herbicides in irrigated cotton. Res. Prog. Rept. West. Weed Contr. Conf. pp. 83-84.

29. Hamilton, K. C., and H. F. Arle. 1975. Preplanting applications of diuron with and without trifluralin in cotton. Weed Sci. 23:75-77.

30. Hamilton, K. C., H. F. Arle, W. P. Cahill, and J. M. Witt. 1966. Preplanting application of diuron in cotton. Weeds 14:145-148.

31. Hance, R. F. 1965. Observations of the relationship between the absorption of diuron and the nature of the absorbent. Weed Res. 5:108-114.

32. Harris, C. 1960. Weed control in cotton over a ten year period by use of the more promising materials and techniques. Weeds 8:616-624.

33. Hassawy, G. S. 1970. Effects of trifluralin and-or phorate on cotton roots. Ph.D. Dissertation, Agron. Dept., Univ. of Arizona (Univ. Library), 134 pp.

34. Hassawy, G. S., and K. C. Hamilton. 1971. Effects of trifluralin and organophosphorus compounds on cotton seedlings. Weed Sci. 19:166-169.

35. Heathman, E. S. 1967. Problems associated with combining chemicals. Proc. West. Weed Contr. Conf. 21:27-28.

36. Hicks, R. D., and O. H. Fletchall. 1961. The substituted dinitroaniline, trifluralin for weed control in cotton. (Abstr.). Abstract Weed Sci. Am. p. 10.

37. Hill, G. D. 1971. Characteristics of herbicides by chemical groups. I. Substituted ureas, II. Hyvar x bromacil. Proc. Calif. Weed Conf. 23:158-174.

38. Hollist, R. L., and C. L. Foy. 1971. Trifluralin interactions with soil constituents. Weed Sci. 19:11-16.

39. Jordan, L. S., C. W. Coggins, Jr., B. E. Day, and W. A. Clerx. 1964. Photo decomposition of substituted phenyl-ureas. Weeds 12:1-4.

40. Kerr, H. O. 1971. Herbicide systems for cotton. Proc. S. Weed Sci. Soc. 24:85-86.

41. Ketchersid, M. L., T. E. Boswell, and M. G. Merkle. 1969. Uptake and translocation of substituted aniline herbicides in peanut seedlings. Agron. J. 61:185-187.

42. Kirby, M., and P. W. Santelmann. 1973. Compatibility of tank mixtures of herbicides and insecticides. (Abstr.). Proc. S. Weed Sci. Soc. 26:176.

43. Lignowski, E. M., and W. G. Scott. 1972. Effect of trifluralin on mitosis. Weed Sci. 20:267-370.

44. Mallory, T. E. 1969. Some morphological and anatomical differences between cotton and safflower treated with trifluralin. Proc. Calif. Weed Conf. 21:127.

45. Menges, R. M., and S. Tamez. 1974. Movement and persistence of bensulide and trifluralin in irrigated soils. Weed Sci. 22:67-71.

46. Normand, W. C., Y. Tanakol, and C. H. Thomas. 1968. Some response of excised cotton roots to treatment with trifluralin or nitralin. Proc. S. Weed Conf. 21:344.

47. Oliver, L. R., and R. E. Frans. 1968. Inhibition of cotton and soybean roots from incorporated trifluralin and persistence in soil. Weed Sci. 16:199-203.

48. Overton, J. R., L. S. Jeffery, J. F. Brown, A. Y. Chambers, and H. D. Swingle. 1972. Dinitroaniline evaluations in Tennessee over a three year period. Proc. S. Weed Sci. 25:73-87.

49. Parka, S. J., and J. B. Tepe. 1969. The disappearance of trifluralin from field soils. Weed Sci. 17: 119-123.

50. Porter, W. K., Jr., C. H. Thomas, L. F. Curtis, and D. R. Melville. 1957. A critical evaluation of the use of pre-emergence herbicides for weed control in cotton. Weeds 5:237-242.

51. Probst, G. W., T. Golab, R. J. Herberg, R. J. Holzer, S. J. Parka, C. Van Der Schans, and J. B. Tepe. 1967. Fate of trifluralin in soils and plants. J. Agr. Food Chem. 12:592-599.

52. Savage, K. E., and W. L. Barrentine. 1969. Trifluralin persistence as affected by depth of soil incorporation. Weed Sci. 17:349-352.

53. Schrader, J. W. 1972. Performance of several substituted aniline herbicides on cotton, peanuts, and soybeans on several organic matter levels. (Abstr.). Proc. S. Weed Sci. Soc. 25-39.

54. Sheets, T. J., and A. S. Crafts. 1957. The phytotoxicity of four phenylurea herbicides in soil. Weeds 5:93-101.

55. Sloane, L. W., W. C. Normand, C. H. Thomas, and S. H. Crawford. 1970. Cotton herbicides in combination at the northeast Louisiana Experiment station. (Abstr.). Proc. S. Weed Sci. Soc. 23:50.

56. Standifer, L. C., Jr., L. W. Sloane, and M. E. Wright. 1965. The effects of repeated trifluralin applications on growth of cotton plants. Proc. S. Weed Conf. 18:92.

57. Talbert, R. E. 1965. Effects of trifluralin on soybean root development. Proc. S. Weed Conf. 18:652.

58. Upchurch, R. P. 1957. The influence of soil moisture content on the response of cotton to herbicides. Weeds 5:112-120.

59. Upchurch, R. P. 1958. The influence of soil factors on the phytotoxicity and plant selectivity of diuron. Weeds 6:161-171.

60. Vannoorbeeck, L. R. 1965. The effects of soil applications of trifluralin on cotton seedlings. M.S. Thesis, Agron. Dept., Univ. of Arizona (Univ. Library), 57 pp.

61. Waddle, B. A., C. Hughes, M. N. Christiansen, and R. E. Frans. 1957. The response of selected cotton varieties to pre-emergence herbicides. Weeds 5: 243-249.

62. Weldon, L. W., and F. L. Timmons. 1961. Photochemical degradation of diuron and monuron. Weeds 9:111-116.

63. Wright, W. L., and G. F. Warren. 1965. Photochemical decomposition of trifluralin. Weeds 13:329-331.