FACTORS INFLUENCING THE EFFECT OF SYSTEMIC INSECTICIDES APPLIED AS SEED TREATMENTS TO GRAIN SORGHUM

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APPLIED AS SEED TREATMENTS TO GRAIN SORGHUM

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PREFACE

The practicability of applying systemic insecticides as seed treatments for control of early season crop pests has created much interest among research workers. The need for investigating the possibility of controlling early season sorghum pests with systemic insecticidal seed treatments was brought to the attention of the author, while working under the supervision of Mr. C. F. Henderson, Leader, Small Grains Insects Investigation, Entomology Research Division, USDA. It was also suggested that this study would be an excellent, worth-while thesis problem.

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INTRODUCTION

The 1950's brought us hope that one day we may solve some of our most serious crop-insect problems with a class of insecticides called systemics (U.S.D.A., 1960). The term "systemic insecticide" is given to any compound that is readily absorbed by a growing plant and translocated in the sap stream of the plant in sufficient amount to render the plant toxic to insects that feed upon it.

Man has known of systemic chemical behavior from the Fifteenth Century, when Leonardo da Vinci injected arsenic into a peach tree trunk, killing the pests on the tree. However, the use of systemic insecticides in economic entomology did not become of practical importance in insect control until 1947 when Germany's Gerhard Schrader synthesized a series of new organic phosphorus and fluorine compounds.

The advantages of systemic insecticides are self-evident, and much research has been done in the development of their use. Once absorbed and translocated, systemics provide "built-in" protection against several plant-sucking pests and a few chewing insects without seriously affecting insectivorous parasites and predators. Therefore, systemics can supplement natural and biological control.

Since systemics can be absorbed through the foliage or the roots of plants, they have an advantage over nonsystemics in the methods by which they may be applied. Research has shown that systemics are absorbed and translocated in the plant when applied as a foliage spray, soil drench, seed treatment, or as granules applied on the ground.

A systemic that can be applied to the seed has certain advantages over other methods of application. The savings in material and labor make seed treatment a highly desirable method wherever it is effective in insect control. Seed treatments also have an advantage in that the insecticide is translocated early in the growth of the plant, thereby giving plant protection before a foliage treatment can ordinarily be made. It also gives a longer period of protection than most foliage treatments. However, seed treatments have a disadvantage in that the insecticide usually possesses high mammalian toxicity and phytotoxicity. The use of systemic seed treatments also involves many effects which the insecticide might exert upon germination, plant emergence, and plant growth and development. Therefore, possibilities of systemic seed treatments for insect control are still quite limited.

The work reported here is an attempt to evaluate some factors that are believed to influence the effect of systemic insecticides applied as seed treatments to grain sorghum. The factors studied were as follows: (1) insecticide and concentration, (2) age of treated seed, (3) soil moisture, (4) depth of planting, (5) soil texture, (6) rate of plant growth, and (7) insect species.

These factors were studied for their effect on plant emergence, plant survival, plant growth and development, and insect control. Since these factors were studied under greenhouse conditions, the results reported in this paper are not necessarily indicative of those which would occur in the field. However, the results should be of value in pointing out the factors that could influence the effect of systemic seed treatments when used under various climatic and environmental conditions.

REVIEW OF LITERATURE

Metcalf (1918) obtained results similar to the classic work of da Vinci when he injected potassium cyanide into pear and apple tree trunks, freeing the trees of scale insects. One of the first practical demonstrations of systemic insecticidal action was conducted by Hurd-Karrer and Poos (1936). They demonstrated that red spider mites and aphids were killed by small amounts of selenium taken up by wheat plants. Neiswander and Morris (1940) utilized sodium selenate in a nutrient solution to control mites and aphids attacking roses and chrysanthemums.

Immediately after Schrader's epoch-making contribution, workers in France, England, and the United States confirmed the fact that these compounds were readily absorbed by a growing plant and translocated into the sap stream of the plant in sufficient amount to render the plant toxic to insects that feed upon it.

Bennett (1949) in preliminary tests with systemic insecticides, showed that the organic compounds, bis-fluoroethoxymethane, bis-dimethyl=aminofluorophosphine oxide and tetradimethylamidopyrophosphate were translocated and gave control of the bean aphid, *Aphis fabae* Scopoli, on bean plants.

Of the various systemic insecticides that Schrader discovered, schradan (octamethylpyrophosphoramide, OMPA) and demeton (O,O-diethyl O(and S)-2-(ethylthio)ethyl phosphorothioates, Systox) were the most promising and most extensively studied. Ripper et al. (1949) demonstrated that schradan exhibited a weak contact insecticidal effect and that the residual film on the plant was almost non-insecticidal. No fumigation effect could be demonstrated either of the substance itself or of the treated foliage. He concluded from his results that the application of schradan could supplement biological control of insects since the chemical would have little effect on parasites and predators.

Ripper et al. (1950) conducted extensive tests with schradan and found that the compound controlled 21 species of insects and arthropods. They also demonstrated the systemic action by watering the roots of plants with a solution of the compound which controlled aphids feeding on the upper parts of the plants. Application of the compound to the upper surface of leaves controlled aphids on the lower surface. Painting one-half of the leaf also killed aphids feeding on the other side of the mid-rib. Field tests with schradan gave three to five weeks' control of cabbage aphid, Brevicoryne brassicae (Linnaeus), while parathion gave control for only a few days. Schradan did not affect Syrphid larvae, coccinellids, cecidomyiids, or parasitic Hymenoptera, while parathion killed them.

The advantages of systemic insecticides over nonsystemic insecticides were also pointed out by Ripper and his coworkers (1950). They stated that the greatest advantages of systemic insecticides are: (1) that the systemics are translocated to the growing point of the plant which was not in existence at the time of application, (2) that systemics lend themselves to several methods in which they can be applied since they are absorbed and translocated when applied to roots, stems or foliage of plants, and (3) that once they are absorbed and translocated they will not affect parasites and predators.

Reynolds et al. (1957), in discussing the advantages of applying systemics as either soil or seed treatments, pointed out that (1) seedling plants are particularly susceptible to pest attack, (2) there is little plant surface to receive and retain insecticidal deposits, and (3) the rapid rate of growth of small plants makes it difficult to obtain much more than initial mortalities with foliar application. Ivy (1952) also pointed out that soil applications required more insecticide but will be absorbed by the plant for a longer period of time, that spray applications take less material and kill quicker but do not last as long, and that seed treatments are most promising from the standpoint of economy of material and ease of application.

Application of systemic insecticides at planting time are, in general, preventive or so-called "insurance" applications. According to Reynolds (1958) the economics must be considered since the insecticides should pay their way by showing a profit to the farmer; on a majority of crops it is not normally necessary to make insecticidal applications in the seedling stage of growth. Also it is not considered a wise practice to apply insecticide just for the sake of the plants' appearance or on the chance that the crop would necessitate insecticidal applications at a later date anyway. Some crops, however, such as cotton, cruciferous crops, and alfalfa, almost invariably require insecticidal applications in early stages of growth.

Parencia et al. (1947) pointed out that an effective seed treatment for cotton would have several advantages over conventional methods. These advantages would be that: (1) after obtaining a stand, the grower would not have to be concerned about insects until midseason, (2) there is no need for timing applications, which are important in the conventional early season control program, and (3) tractors and manpower would be released for use in other farm activities.

A considerable amount of interest has been shown among research workers concerning the practicability of applying systemic insecticides at the time of planting. The methods of application which have been used are: seed soaks, seed coating with impregnated powders, and application of liquid or granular formulations at the time of planting. However, regardless of the method used, any treatment which places the insecticide in intimate contact with germinating seed may cause phytotoxicity or plant injury.

Chao (1950) showed that germination of bean seeds was reduced when seeds were soaked in a solution of schradan. David and Gardiner (1955) recommended impregnating an insecticide into a carrier which can be adhered to the seed coat rather than soaking the seed. They pointed out that by coating the seed, a much greater quantity of the toxicant can be tolerated without injury to the embryo. They mentioned another disadvantage of seed soaks--that seeds are left wet and must be planted immediately after soaking. Ivy (1952) stated that cotton seed treated with schradan reduced germination 10 per cent in greenhouse tests and 40 per cent under field conditions. However, he showed that activated charcoal as a carrier reduced phytotoxicity considerably. Ashdown and Cordner (1952) used demeton impregnated in activated charcoal successfully without a reduction in germination of pea seeds.

The use of activated charcoal formulations has resulted in some problems and difficulties. It has been reported that there were delays of 24 to 36 hours in germination of treated seed (Anonymous 1956) and that it was possible the delayed germination may be partially due to heavy charcoal applications. According to Adkisson (1958) the planting rate of seed treated with charcoal formulations is less than that of untreated seed. He suggested that the seed planter should be carefully calibrated to compensate for the reduction in flowability of treated seed.

It is also difficult to obtain a uniform distribution and a firm seed coating of the activated charcoal which will not come off when the seed is handled. Various stickers have been used with some success in adhering the charcoal formulations to the seed. Reynolds et al. (1957) suggested the use of two or three per cent solutions of methyl cellulose to adhere the carrier to the seed coat.

Gifford et al. (1959) reported that germination of wheat was seriously reduced when oils of peanut, corn, and soybean were used as stickers. The phytotoxicity was counteracted when the fungicide Chloranil was used with the oils alone; however, Chloranil did not reduce phytotoxicity when a combination of oils and insecticides was used.

The phytotoxicity of seed treatments varies among crops and with the insecticide and concentration used. Parencia et al. (1957) found that American Cyanamid compounds 12008 (O,O-diethyl S-isopropylthiomethyl phosphorodithioate) and 12009 (O,O-diethyl S-_n_-propylthiomethyl phosphorodithioate) reduced emergence of cotton 13 and 39 per cent, respectively. Emergence was severely reduced with phorate (O,O-diethyl S-ethylthiomethyl phosphorodithioate, 3911) applied at 1.0 pound actual toxicant per 100 pounds of seed following a heavy rain on the day after planting. Cotyledons showed phytotoxic effects from all three compounds, but the effect was considered greatest from phorate. There was no evidence of phytotoxicity of true leaves. They also pointed out that the plants from treated seed made better growth due to insect control than those from untreated seed.

According to Hacskaylo and Clark (1957) phorate applied as charcoal formulation at 4.0 pounds actual toxicant per 100 pounds of cotton seed showed only a slight reduction in emergence as compared with check. However, seedling vigor was affected and it was said, "the possibility exists that plant loss under adverse environmental conditions would be increased."

Parencia et al. (1957) showed that phorate and Di-Syston (0,0-diethyl S-2-(ethylthio)ethyl phosphorodithioate) applied at 1.0 and 2.0 pounds per acre had no effect on emergence of cotton seedlings. However, there was a reduction of approximately 27 per cent when phorate granules were applied in the drill row with phorate-treated seed. Both treatments produced phytotoxic effects on young cotyledons, but none was considered serious. Phorate seemed to have a greater effect than Di-Syston.

Robertson (1957) reported that seed treatments of phorate and Di-Syston applied at 1.0 pound per acre caused severe reductions in the stand of cotton. However, Stanley and Breeland (1957) found that phorate reduced the stand of cotton while Di-Syston showed no reduction in stand and increased yields when compared with yields from untreated seed. Dobson (1958) stated that phorate and Di-Syston applied as seed treatments reduced emergence of the varieties Pima S-1 and Acala 1517. Both materials retarded growth in early stages of development, but there was no difference in the height of plants from treated and untreated seed at three months after planting.

Hanna (1958) noted that American Cyanamid compounds 12008 and 12009 seriously reduced cotton stands when compared with stands from untreated seed. He suspected that the low emergence was partially due to the high moisture content of the soil during germination. He also reported that at 11 days after planting, plants from treated seed weighed considerably less than plants from untreated seed. However, at 25 days after planting there was little difference in the average weight of the plants from either treated or untreated seed. Hopkins et al. (1958) showed that phorate and Di-Syston significantly reduced the stand of cotton but did not affect plant height at any time during the growing period.

Parencia et al. (1958) reported that the cotton stands obtained from untreated seed were better than the stands obtained from seed treated with phorate and Di-Syston at the rate of 2.0 pounds per acre. They also reported that when phorate-treated seed was planted in the drill rows in which a previous such planting had been made, severe phytotoxicity occurred. According to Adkisson (1958) phorate and Di-Syston seed treatments caused apparent reductions in emergence of cotton seedlings. However, these reductions were attributed to cool temperatures and wet soils. He indicated that if conditions were favorable for germination, the seed treatments would not reduce stands. He also found that the addition of the fungicide nabam increased plant stands of treated seed when the soil was wet and damp.

Bishop and Burkhardt (1959) reported that phorate and Di-Syston as alfalfa seed treatments caused no significant reduction in germination or emergence, but demeton caused some reduction when treated seed was stored for six months. None of the materials produced any visible phytotoxic effect on young seedlings. However, Reynolds et al. (1957) found that alfalfa plants grown from seed treated with phorate and Di-Syston showed marginal leaf burn; but the insecticides did not cause serious plant injury.

According to Dobson (1957) phorate applied as granules and seed treatments reduced the stand of alfalfa seedlings, the granules having the greater effect. Roth (1959) reported that phorate and Di-Syston did not affect germination in the field but caused some phytotoxicity in laboratory tests.

Systemic seed treatments have also been found to be phytotoxic to several vegetable crops. Goymerac (1956), in his tests, showed that phorate seed treatments severely reduced germination and stunted growth of sugar beets and that granular treatment was more phytotoxic than seed treatment. Harries and Valcarce (1957) reported that phorate and American Cyanamid 12008 applied as seed treatments caused only slight reduction in sugar beet emergence, but there was considerable stunting and curling of the leaves of young plants. Gates (1959) reported reductions in emergence from 15 to 49 per cent when phorate was applied to sugar beet seeds while Di-Syston had very little effect on emergence. Allen et al. (1961) found that the addition of the fungicide Captan reduced the phytotoxicity produced by phorate-treated seed. Andres et al. (1959) showed that seed treatments of phorate and Di-Syston reduced stands of cabbage. They also stated that plants in phorate-treated plots were smaller than plants in untreated plots at 37 days after planting but that plants in both plots were of equal size at 46 days after planting.

Bowling (1957) found that phorate retarded emergence and produced stunting in rice plants. Phorate and Di-Syston as seed treatments reduced wheat stands, but stands were not affected by granular formulations (Skoog 1959). In his tests, phorate and Di-Syston reduced emergence 50 and 35 per cent, respectively; however, in laboratory tests the two materials reduced germination only 8 and 7 per cent, respectively. He concluded that a standard laboratory germination test was a poor index of the stand to be expected from treated seed. Kirk and Wilson (1960) found that phorate applied as a seed treatment to wheat reduced germination, while Di-Syston had very little effect. In addition, the phytotoxic effect may be greatly reduced by using the fungicides Captan or Arasan. He also stated that much of the reduction in seed viability following storage of treated seed is largely due to the sticker used.

In testing the effect of soil type and moisture on germination of phorate-treated seed, Kirk and Wilson (1960) found that emergence of wheat seed treated with phorate was very poor when soil moisture was in excess, regardless of soil type. With low soil moisture, germination in muck soil was relatively high while germination was low in clay-silt loam soil, the difference being due to the water-holding capacity of the soils. Germination of phorate-treated seed was found to be the highest in highly organic soils which fact may be attributed to the apparent property of an organic soil to tie up an organic insecticide so that it is unavailable to the seed. They also suggested that phytotoxicity will be reduced in soils that favor rapid germination and growth and that phytotoxicity will be increased under conditions which tend to delay germination.

According to Reynolds et al. (1957) phorate and Di-Syston severely reduced the stand of sorghum both as granular applications and as seed treatments. Applied at 4.0 pounds per 100 pounds of seed, phorate and Di-Syston reduced emergence 72 and 61 per cent, respectively. Granular treatments were somewhat less phytotoxic with 38 and 20 per cent reductions, respectively.

Everly and Pickett (1960) reported that phorate applied to sorghum seed at 2.0 and 4.0 pounds per 100 pounds of seed seriously reduced emergence and delayed plant development as measured by pollen shed. The sticker used caused some effect on germination, which was reduced when combined with the fungicide Arasan.

Systemic insecticidal seed treatments are effective on a surprisingly wide range of insect and mite pests. However, most of the research on the practical use of systemic insecticides has been directed toward crops of cotton, alfalfa, sugar beets and to a lesser extent toward small grain crops and sorghum.

In tests with schradan, Ivy et al. (1950) found that the material was highly specific for aphids and mites on cotton plants and the compound was absorbed from the soil through the roots or from sprays applied to the foliage. Effective seed treatment required lower concentration of toxicant than did effective soil treatment. No control was obtained with either of the methods against the boll weevil, *Anthonomus grandis* Boheman; bollworm, *Heliothis zea* (Boddie); cotton leafworm, *Alabama argillacea* (Hubner); differential grasshopper, *Melanoplus differentialis* (Thomas); leafhopper or whitefly.

Chao (1950) reported good control of the bean aphid for 50 days when bean seeds were soaked in an aqueous solution of schradan and planted immediately after treatment. When seeds were allowed to dry before planting, the material did not lose any of its insecticidal properties but resulted in a significant decrease in germination and stunting of the plants which developed. In other experiments good results were obtained with cotton and peas which were successfully protected from aphids and red spider mites. Chao also observed slight stimulation of growth of the plants receiving the insecticide, suggesting utilization of phosphorus by the plant.

Schradan was also found to be very effective against the pea aphid, Macrosiphum pisi (Harris), applied as a spray, poured on the soil, or poured on the seed before planting (Bronson 1951). Seed treatments afforded control for six weeks under field conditions. Similar results were also obtained with demeton applied as a soil, seed, or spray treatment by Ashdown and Cordner (1952). They reported control of the pea aphid on pea plants for 80 days with soil or seed treatment compared to 40 days with spray treatment. They also indicated that emergence was not influenced, nor was growth permanently affected by any of the treatments and yields increased directly with the insect control obtained.

Reynolds et al. (1953) compared schradan and demeton as spray treatments on vegetable and field crops. Both materials gave excellent control of the cabbage aphid on cabbage plants for 50 days after treatment and good control of the pea aphid and strawberry spider mite, Tetranychus atlanticus McGregor, on alfalfa for three weeks. In general, demeton was more effective than schradan although both materials failed to control onion thrips, Thrips tabaci Linderman, on seed onions or cyclamen mites, Steneotarsonemus pallidus (Banks), on strawberry plants.

Ivy et al. (1954), in search for systemic insecticides that were effective against chewing insects, tested American Cyanamid compounds 12008, 12009, and 12013 (O,O-diisopropyl S-isopropylthiomethyl phos= phorodithioate). Each compound applied as seed treatments was highly effective on cotton seedlings infested one week after treatment with boll weevils and cotton leafworms. Only compound 12008 gave satisfactory control at three weeks after treatment.

Clark et al. (1955) evaluated 27 compounds for their systemic action.

They showed a direct correlation between mammalian toxicity and systemic activity. Of the compounds tested they found two, American Cyanamid 12008 and phorate, that showed promise as systemic insecticides. In field tests compound 12008 applied to cotton seed as 50 per cent powder on activated carbon at the rate of 4.0 pounds per 100 pounds of seed gave protection against thrips and aphids for four to six weeks. In greenhouse tests, phorate showed considerably longer residual effectiveness than compound 12008. As foliage sprays and soil treatments both compounds were effective against aphids, mites, scale insects, leafhoppers, and flea beetles. Phorate was also promising against the boll weevil.

Compounds 12008 and 12009 killed larvae of newly hatched cotton leaf perforators, Bucculatrix thurberiella Busck, and larvae of salt-marsh caterpillars, Estigmene acrea (Drury); but compound 12013 was only slightly effective on these two insects. None of the compounds were effective against the bollworm. All three compounds were effective against sucking insects: cotton aphid, Aphis gossypii Glover; desert spider mite, Tetranychus desertorum Banks; and cotton fleahopper, Psallus seriatus (Reuter).

Harries and Vacarce (1957) reported excellent control of beet leafhoppers, Circulifer tenellus (Baker), for 60 days and lygus bugs for 35 days with demeton, schradan, phorate, and American Cyanamid 12008 applied as seed treatments.

Dobson and Watts (1957) reported that phorate as a seed or granular treatment did not reduce populations of spotted alfalfa aphid, Therioaphis maculata (Buckton), at 56 days after treatment. Di-Syston gave good control of this insect for 28 days after treatment. Rodgers (1960) found that phorate and Di-Syston when applied to alfalfa seed as activated charcoal alone did not give adequate control of the spotted alfalfa aphid. However, when the materials were pelleted on the seed with hydroxyethyl cellulose or methyl cellulose, good control was obtained for 32 to 36 days.

Ivy et al. (1957) in their work on cotton insects found that phorate persisted longer than American Cyanamid compounds 12008, 12009, and 12013. Phorate also gave longer control of boll weevil, cotton aphid, spider mite, salt-marsh caterpillar, bollworm, onion thrips, cotton leaf perforator, and flower thrips, *Frankliniella tritici* (Fitch). They stated that for a systemic insecticide to be effective against chewing insects most compounds must be applied to the soil or seed, as they do not translocate efficiently when applied as sprays.

According to Hackaylo and Clark (1957) and Parencia et al. (1957), control of early season cotton insects was very successful with systemic insecticides employed as seed treatments. American Cyanamid compounds 12008, 12009, and phorate gave good control of cotton aphids, cotton fleahoppers and thrips for three and a half to eight weeks after planting, depending on the insect. Phorate gave good control of overwintering boll weevils for 15 and 21 days after plant emergence, although control was very poor at 28 days and no kill was observed at 32 days after planting.

In further tests with systemic insecticidal seed treatments, Parencia et al. (1957) reported that phorate and Di-Syston gave good control of thrips for three to four weeks after emergence. Placing granules in the drill row did not increase the efficiency of either material. Both materials controlled cotton fleahoppers for two weeks after emergence; however, no control was obtained after four weeks.

Reynolds et al. (1957) compared the effectiveness of systemic insecticides and the methods in which they were applied. In field tests Di-Syston and phorate applied as seed treatments gave 90 to 100 per cent control of the spotted alfalfa aphid for two weeks after planting but lost their effectiveness about one month after planting. In greenhouse tests Di-Syston, phorate, and demeton gave three to four weeks' protection against this insect. Concentrations used in the greenhouse were not effective under field conditions. Reynolds et al. suggested that 4.0 to 8.0 pounds actual toxicant per 100 pounds of seed would be needed to give adequate control in the field.

For cotton insect control phorate and Di-Syston were effective as seed treatments against thrips and aphids and reduced populations of the southern garden leafhopper, Empoasca solana DeLong, and flea beetle considerably. Di-Syston was slightly superior to phorate both as seed and granular treatments. In general, granular treatments were more effective than seed treatments.

Andres et al. (1959) reported good control with phorate and Di-Syston against the cabbage aphid for 51 days after treatment. Seed treatments were not as good as sprays or granular treatments. Di-Syston resulted in longer control than phorate.

Phorate and Di-Syston were also shown to be effective against the beet leafhopper on sugar beets by Reynolds et al. (1957). Phorate gave plant protection for two to three weeks and was superior to Di-Syston. However, both materials failed to give satisfactory control of the beet armyworm, Spodoptera exigua (Hubner). Gates (1959) reported reductions of aphid populations for two months after planting with phorate and Di-Syston. Allen et al. (1961) found that phorate as a seed treatment was not as effective as other nonsystemics in control of sugar-beet root maggot, *Tetanops myopaeformis* (Roder).

Several investigators have also reported favorable results with systemic insecticides against small grain and sorghum pests. Kantack and Knutson (1958) found that seed treatments with demeton and American Cyanamid 12008 and 12009 gave good control of the wheat curl mite, *Aceria tulipae* (Keifer), for one week after planting; but all materials were unsatisfactory thereafter. Seed treatments were better than soil drenches, but neither was as good as granular treatments, which gave control for five weeks after planting. Skoog (1959) reported excellent control of grasshoppers with phorate and Di-Syston applied as seed treatments to wheat seed. Both materials gave 100 per cent mortality when grasshoppers were caged for three days on wheat that was four weeks old. However, at five weeks after planting it took ten days to give 100 per cent control.

Wilson et al. (1960) reported that phorate applied as seed treatment to winter wheat seed controlled the fall brood of hessian fly, *Phytophaga destructor* (Say); the apple grain aphid, *Rhopalosiphum fitchii* (Sanderson); and the English grain aphid, *Macrosiphum granarium* (Kirby). Increasing the dosage above 0.5 pound of toxicant per 100 pounds of seed did not increase control significantly.

Everly and Pickett (1960) reported that good control of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), was obtained with phorate applied as seed treatments to grain sorghum during early periods of growth. However, this treatment gave no control of aphid populations on bagged heads of sorghum in the field.

Knowledge concerning the absorption and translocation of systemic insecticides is not only of scientific interest but also of considerable practical importance. The performance of most plant systemics as insecticides is dependent on the fate of the compounds within the plant and on the conditions that may alter the plants' physiological processes.

According to Metcalf (1957) the properties for systemic action in plants appear to be (1) ability to penetrate into the plant through roots, stem, leaves, or fruits; (2) sufficient water solubility to enable the compound to move with the transpiration stream; and (3) sufficient stability in the plant environment to enable the compound or its metabolic products to exert the desired degree of residual insecticidal action.

According to Reynolds (1957) most of the toxicant is absorbed by the roots when the material is applied as a seed treatment. After absorption the insecticide is transported to other parts of the plant in the sap stream of the xylem tissue and follows the route of plant nutrients (Mitchell 1960).

Reynolds et al. (1957) demonstrated by using P^{32}-Di-Syston applied by a charcoal seed coating to alfalfa seeds that the concentration of P^{32} was the highest in the cotyledons and that the concentration in the trifoliate leaves and the growing tip was about one-third to one-fifth of the concentration in the cotyledons. The stems contained the least concentration of the material from two to seven weeks after planting.

According to Reynolds (1958), Ripper proposed the following classification of systemic insecticides based upon the fate of the compounds within the plant: (1) stable systemic insecticides, which include those that are not metabolized by the plant, (2) endolytic systemic insecticides in which the toxic compound is present to 98 per cent in its original form when ingested by the insect until it is decomposed by the plant,

(3) endometatoxic systemic insecticides, which are transformed in the plant partially or wholly into other toxic substances and which also act as insecticides when ingested by the pest until they are rendered non-toxic to the plant.

Reynolds (1958) classified phorate and Di-Syston as being endometatoxic systemic insecticides. According to Vero Beach Laboratory, Inc., there is evidence that the major activity of Bayer compound 30911 (methyl-O-methyl 2, 4, dichlorophenyl phosphonothioate) is associated with its metabolites. This indicates it is an endometatoxic systemic chemical.

Metcalf et al.(1959) demonstrated that Di-Syston undergoes oxidative metabolism in cotton and alfalfa plants and is rapidly converted to its toxic derivatives. The rate at which these oxidative derivatives are formed has a definite bearing upon the toxic residues in plant tissue. Phorate was also shown to undergo oxidative metabolism similar to Di-Syston but the rate of metabolism is somewhat different (Metcalf et al.).

Metcalf et al. (1959) showed that the toxic residues of phorate or Di-Syston applied as seed treatments to alfalfa varied depending on the rate of plant growth--the slower the plant growth, the longer the persistence. They also pointed out that plant species is a factor affecting the rate of metabolism. Di-Syston was metabolized very rapidly in the tomato plant, while metabolism was very slow in the cotton plant and toxicity was shown to persist for several weeks.

Temperature was also shown to be an important factor influencing the length of effectiveness of systemic insecticide. Di-Syston metabolism was accelerated in cotton leaves by increased temperatures between 37 and 100 degrees F. In their tests, the rate of oxidation of the sulfoxide metabolite increased about 1.9 times for each 10 degree C. rise in temperature. Roth (1959) reported that alfalfa seed treatments with phorate and Di-Syston gave good control of the spotted alfalfa aphid depending on the temperature and growing conditions. When the mean temperature was 62 degrees F. and conditions were favorable for rapid growth, control was obtained for 30 days. However, when the mean temperature was 57 degrees F. and conditions favored poor growth, control was obtained for 52 days.

GENERAL PROCEDURES

All experiments were conducted in a greenhouse with all factors other than temperature and humidity being controlled as uniformly as possible. Greenhouse temperatures ranged from 65 to 95 degrees F. throughout the testing period.

RS-610 hybrid sorghum seed was the test variety used in all experiments. The seed was selected from one certified lot which had a germination of 86 per cent and 99.6 per cent purity. The seed had been treated with a fungicide, Arasan, at 3 ounces per 100 pounds of seed.

Di-Syston (O,O-diethyl S-2-(ethylthio)ethyl phosphorodithioate), phorate (O,O-diethyl S-ethylthiomethyl phosphorodithioate), and Bayer 30911 (methyl-O-methyl 2, 4, dichlorophenyl phosphonothioate) were the systemic insecticides tested. The three insecticides were compared for their effect on plant emergence, plant growth and development, plant survival, and control of the corn leaf aphid, Rhopalosiphum maidis (Fitch). In other experiments Di-Syston was used alone as the test material.

The insecticides were applied as activated charcoal formulations containing 50 per cent Di-Syston or Bayer 30911 and 44 per cent phorate. The materials were applied at the concentrations of 0.25, 0.5, and 1.0 pound actual toxicant per 100 pounds of seed.

Hydroxyethyl cellulose (Cellosize by Union Carbide Chemicals Company) was used as a sticker to adhere the toxicant to the seed coat.

A stock solution of 5 per cent (by weight) of this material was maintained by dissolving 10 grams in 200 milliliters of warm water (approximately 130 degrees F.).

The process of treating the seed was accomplished by the following steps: (1) one-fourth pound of seed was placed in a quart jar; (2) Hydroxyethyl cellulose solution was added at the rate of one milliliter to 20 grams of seed; (3) the jar was then sealed and thoroughly agitated to insure an even distribution of the sticker; (4) the desired amount of insecticide was then introduced into the jar and again the jar was shaken vigorously by hand until all the insecticide had adhered to the seed coat; (5) the treated seeds were spread out on paper to dry before being sacked for later use.

Since the effect of storage on treated seed was not known, numerous seed treatments were made as described above. Seeds that had been treated for more than 30 days were not used in any of the experiments except in the one where the age of treated seed was the factor under study.

All plantings were made in either 6- or 16-ounce ice cream cartons containing sand or soil as the growing medium.

When soil moisture was not the factor being studied, water was added to the medium by punching holes in the bottom of the cartons and placing them in metal trays filled with sufficient amounts of water to facilitate capillary movement. When the medium in all the cartons showed signs of containing sufficient amounts of water for germination, the excess water was drained out of the trays. To insure better germination, one-half inch mesh wire screen was placed in the bottom of the trays to allow air to circulate beneath the cartons.

Since the seed treatments consisting of sticker, charcoal and insecticide were compared with untreated seed in all experiments, a test was conducted to determine the effect of the charcoal and the sticker on plant emergence and growth.

Untreated seed; seed treated with sticker and charcoal at 0.5 pound per 100 pounds of seed; and seed treated with sticker, charcoal and Di-Syston at 1.0 pound actual toxicant per 100 pounds of seed were planted in 6-ounce cartons containing soil. Each treatment was represented by ten cartons in each of which ten seeds were planted at a depth of approximately one-half inch. Emergence counts were taken at various days after planting and were considered final after ten days. At ten days after seeding, the plants in each treatment were measured. The results were as follows:

Treatment	Number Plants Emerged	Average Height(cm)
Untreated	75	3.7
Sticker and Charcoal	73	4.0
Sticker, Charcoal and Di-Syston	62	2.8

From these results it was assumed that the sticker and the charcoal had little effect on plant emergence or growth at the concentrations used.

Since several factors were studied for their influence on the effect of systemic insecticides, the procedures used in evaluating these factors varied with experiments; therefore, more detailed procedures are presented in the discussion of each experiment.

PLANT EMERGENCE TESTS

Several investigators have reported that systemic insecticidal seed treatments tend to be phytotoxic and reduce plant stands of certain crops. However, the phytotoxic effects reported have not been consistent. It is believed that the phytotoxicity produced by systemic insecticides when employed as seed treatments may depend upon several interacting factors including insecticide and concentration, soil moisture, depth of planting, etc.

When applied as seed treatments, systemic insecticides tend to be phytotoxic since they are in contact with the seed at the time of germination. Although the insecticides may not interfere with germination, they may weaken the young seedlings to the extent that they may not be able to survive in the presence of adverse environmental conditions.

The objective of the following experiments was to evaluate some factors that may affect plant emergence of treated seed.

<u>Procedures</u>:

Five experiments (Tests I, II, III, IV, and V) were conducted to study some factors that were believed to affect plant emergence. Each test consisted of a combination of two or more factors. The tests and the factors studied were as follows: Test I - insecticide and concentration; Test II - insecticide, concentration, and age of treated seed; Test III - concentration of insecticide and soil moisture; Test IV - concentration of insecticide and depth of planting; Test V - concentration of insecticide and soil texture.

Test I

Insecticide and Concentration

Untreated seed and seed treated with Di-Syston, phorate, and Bayer 30911 at three concentrations were planted in 6-ounce cartons containing sand. The experiment consisted of ten treatments including a check. Each treatment was represented by ten cartons in each of which twenty seeds were planted at a depth of approximately one-half inch. The ten treatments were arranged on a table in randomized blocks. Emergence counts were taken at various days after planting and were considered final after ten days. Results are expressed as the average number of plants that emerged in each carton and the per cent reduction in plant emergence. Reduction percentages were based on the number of plants that emerged in the untreated check.

Test II

Insecticide, Concentration, and Age of Treated Seed

Untreated seed and seed treated with Di-Syston, phorate, and Bayer 30911 at three concentrations were stored at approximately 70 degrees F. for four months.

Plantings were made at five days and at one, two, and four months after treatment. Each planting consisted of ten treatments including a check. The seeding procedure, number of treatments, and arrangement of cartons were the same as given in Test I; but only five replications were made. Emergence counts were taken ten days after planting. The results of the test are expressed as per cent emergence of the number of seed planted. This direct comparison with the number of seed planted was used because the germination of the untreated seed was essentially the same at all planting dates.

Test III

Concentration of Insecticide and Soil Moisture

Untreated seed and seed treated with Di-Syston at two concentrations were planted in 6-ounce cartons containing 190 grams of soil having three moisture levels. The soil moisture levels were 30-40, 60-70, and 90-100 per cent of moisture-holding capacity which were considered to be minimum, optimum, and excessive for seed germination. The experiment consisted of ten treatments including a check for each soil moisture level. Each treatment was represented by five cartons in each of which twenty seeds were planted at a depth of approximately one-half inch. The ten treatments were arranged on a table in randomized blocks. Emergence counts were made at several intervals after planting since the soil moisture levels affected the time required for the seedlings to emerge. Counts were considered final after 15 days. The results are expressed as the average number of plants emerged in each carton and the per cent reduction in plant emergence.

The soil moisture levels were based on the dry weight of the soil and the weight of the soil at maximum moisture-holding capacity. A 190-gram sample of the soil was oven dried at temperatures of 105-110 degrees C. for 24 hours. When the soil had cooled, the sample was weighed. The weight of the sample represented the dry weight of the soil. Another 190-gram sample was placed in a 6-ounce carton containing holes in the bottom. The carton was set in a pan of water, and the soil was allowed to become saturated. The carton was then removed from the pan and the top was sealed. The carton was allowed to stand until drainage ceased. At the end of 24 hours the sample was weighed, the weight of the sample representing the maximum moisture-holding capacity of the 190-gram sample.

The weight of the water that the soil would hold at maximum moisture capacity is the difference between the weight of the dry soil and the weight of the soil at maximum moisture capacity. The weight of the soil for each moisture level was calculated by multiplying the percentages of moisture-holding capacity desired by the weight of the water the soil would hold and adding the dry weight of the soil.

The calculations for the three percentages of moisture-holding capacity for the 190-gram soil sample were as follows:

Weight of soil at maximum moisture-holding capacity	248 grams
Weight of dry soil	167 grams
Weight of water in the soil	81 grams

Weight of soil to contain:

(a) Moisture content of 30-40 per cent moisture-holding capacity

81 grams	81 grams
x.30	x.40
24.30 grams	32.40 grams
167.00 grams	167.00 grams
191.30 grams	199.40 grams

(b) Moisture content of 60-70 per cent moisture-holding capacity

81 grams	81 grams
x.60	x.70
48.60 grams	56.70 grams
167.00 grams	167.00 grams
215.60 grams	223.70 grams

(c) Moisture content of 90-100 per cent moisture-holding capacity

81 grams	81 grams
x.90	x1.00
72.90 grams	81.00 grams
167.00 grams	167.00 grams
239.90 grams	248.00 grams

Since a certain amount of evaporation occurred, the weight of the soil in the moisture levels was allowed to vary 10 per cent. The moisture levels were maintained between these desired weights by making daily weighings of the cartons. Water was added to each carton until the desired weight was obtained. The weight of the soil was not allowed to go below the lowest desired weight.

Test IV

Concentration of Insecticide and Depth of Planting

Untreated seed and seed treated with Di-Syston at three concentrations were planted at three depths in 16-ounce cartons containing sand. The depths of planting were 0.5, 1.5, and 3.0 inches. The experiment consisted of twelve treatments including a check for each planting depth. Each treatment was represented by ten cartons in each of which twenty seeds were planted. The ten treatments were arranged in randomized blocks.

Plantings were made at each depth by measuring and marking the inside of the carton from the top to the desired depth. The cartons were filled with sand to this level and the seeds planted. The seeds were then covered with sand to the top of the carton.

Emergence counts were made at various intervals after planting depending on the depth, and counts were considered final after 25 days. After the emergence counts had been made, the sand was poured out of the cartons and the seeds that had germinated but had failed to emerge were counted. The results are expressed as the average number of plants emerged and the average number of seeds germinated in each carton and per cent reduction in plant emergence.

Test V

Concentration of Insecticide and Soil Texture

Untreated seed and seed treated with Di-Syston at three concentrations were planted in 6-ounce cartons containing soils of three textural classes. These were sandy loam, silt loam and clay loam, which are considered coarse, medium, and fine textured soils. The experiment consisted of 12 treatments, including a check, in each soil texture. Each treatment was represented by ten cartons in each of which twenty seeds were planted at a depth of approximately one inch. Emergence counts were taken at several intervals after planting and were considered final after 15 days. Results are expressed as the average number of plants emerged in each carton and per cent reduction in plant emergence.

The soils were collected from three locations near Stillwater, Oklahoma, and had previously been classified according to texture by the Soil Survey Staff, Department of Agronomy, Oklahoma State University. The soils were brought into the greenhouse and screened to remove large clods and rocks. They were then fumigated with methyl bromide.

Since it was desired that the conditions for seed germination be the same in each soil, the pH and the moisture-holding capacity were determined. A pH meter was used to determine the pH of each soil.

In determining the moisture-holding capacity of each soil, the cartons were filled approximately three-fourths full with 277 grams of sandy loam soil, 223 grams of silt loam soil, and 245 grams of clay loam soil.

Two samples of the above weights were taken of each soil, and the moisture-holding capacity was determined as described in Test III. The plantings were made by pouring one inch of the soil out of each carton and planting the seed at this depth. The seeds were then covered, and water was added to the soil in each carton until they contained a soil moisture level of 50-60 per cent of maximum moisture capacity. This moisture level was maintained for each textural class during the entire testing period as described in Test III.

The pH and the calculations for 50-60 per cent of the moisture-holding capacity for each soil textural class were as follows:

(a) Sandy loam pH 5.9

Weight of soil in each carton	277 grams
Weight of soil at moisture-holding capacity	340 grams
Weight of dry soil	271 grams
Weight of water in soil	69 grams

Weight of soil to have 50-60 per cent moisture-holding capacity

69 grams	69 grams
x.50	x.60
34.50 grams	41.40 grams
271.00 grams	271.00 grams
305.50 grams	312.40 grams

(b) Silt loam pH 6.4

Weight of soil in each carton	223 grams
Weight of soil at moisture-holding capacity	290 grams
Weight of dry soil	208 grams
Weight of water in soil	82 grams

Weight of soil to have 50-60 per cent moisture-holding capacity

82 grams	82 grams
x.50	x.60
41.00 grams	49.20 grams
208.00 grams	208.00 grams
249.00 grams	257.20 grams

(c) Clay loam pH 6.6

Weight of soil in each carton	245 grams
Weight of soil at moisture-holding capacity	333 grams
Weight of dry soil	235 grams
Weight of water in soil	98 grams

Weight of soil to have 50-60 per cent moisture-holding capacity

98 grams	98 grams
x.50	x.60
49.00 grams	58.80 grams
235.00 grams	235.00 grams
284.00 grams	293.80 grams

Results:

In Test I the insecticides produced some phytotoxicity and reduced plant emergence (table 1). However, only phorate and Di-Syston at the 1.0-pound concentration were considered as seriously affecting plant emergence. The 0.25- and 0.5-pound concentrations for all of the insecticides caused only moderate to slight reductions in emergence. However, in general, plant emergence decreased as the concentration was increased for each insecticide, except for Bayer 30911 in which the 1.0-pound concentration did not seem to affect plant emergence any more than the 0.5-pound concentration. Phorate had the greatest over-all effect on plant emergence with an average of 14 per cent reduction for the three treatment levels. Di-Syston and Bayer 30911 had the least effect with 9 and 6 per cent reductions, respectively.

The effect of systemic insecticides on plant emergence as influenced by age of treated seed is shown in table 2. Only phorate at the 1.0-pound concentration showed signs of reducing plant emergence as the seed became older. The phytotoxicity produced by the other treatments did not seem to increase when compared with the emergence of plants from

Table 1. The effect of three systemic insecticides on plant emergence as influenced by concentration of insecticide. Stillwater, Oklahoma. 1960.

Insecticide	Pounds Actual Toxicant Per 100 Lbs. Seed	Number of Plants Emerged Per Carton		Per Cent Reduction in Emergence[a]
		Range	Average	
Phorate	1.0	8-14	12.5	26.0
	0.5	11-16	14.9	11.8
	0.25	13-18	16.2	4.1
Di-Syston	1.0	11-15	14.3	15.4
	0.5	13-17	15.4	8.9
	0.25	13-18	16.4	3.0
Bayer 30911	1.0	13-18	15.6	7.7
	0.5	14-18	15.4	8.9
	0.25	14-19	16.5	2.4
Untreated	--	14-20	16.9	--

[a]Compared with untreated check.

Table 2. The effect of three systemic insecticides on plant emergence as influenced by concentration of insecticide and the age of treated seed. Stillwater, Oklahoma. 1960.

Insecticide	Pounds Actual Toxicant Per 100 Lbs. Seed	Per Cent Emergence — Age of Treated Seed: 5 Days	1 Mo.	2 Mos.	4 Mos.
Phorate	1.0	62	69	53	57
	0.5	65	72	67	69
	0.25	74	83	77	79
Di-Syston	1.0	65	71	68	68
	0.5	68	78	70	74
	0.25	74	83	71	80
Bayer 30911	1.0	67	72	66	72
	0.5	69	75	70	76
	0.25	71	81	74	79
Untreated	--	78	82	78	80

the untreated seed.

In Test III the soil moisture levels and the concentrations of Di-Syston produced different effects on plant emergence (table 3). The 0.5-pound concentration was more phytotoxic, with an average of 21 per cent reduction, than the 0.25-pound concentration, with an average of 4.9 per cent reduction for the three moisture levels.

Although more plants emerged in the 60-70 per cent moisture level, the per cent reduction in emergence increased as the soil moisture increased. Therefore, it is evident that the combination of 0.5-pound concentration and 90-100 per cent moisture level would result in the greatest effect on plant emergence. The 0.25-pound concentration and the 30-40 per cent moisture level had no effect on plant emergence when compared with that from untreated seed at the same moisture level.

The effect of depth of planting and concentration of Di-Syston on plant emergence of treated seed is shown in table 4. As in the preceding results, the phytotoxicity produced by the insecticide increased as the concentration was increased from the 0.25-pound to the 1.0-pound rate.

The number of plants that emerged varied greatly with the depth of planting. The 0.5-inch depth had very little effect on plant emergence, and the phytotoxicity that occurred was attributed to the insecticide. The 0.5- and the 1.0-pound concentrations at the 1.5-inch depth gave 15 and 36 per cent reductions, respectively, while the 0.25-pound concentration had very little effect at this depth. The combination of the 3.0-inch depth of planting and the insecticide at all three concentrations seriously affected emergence.

Since plant emergence was greatly affected by the 1.5- and the 3.0-inch depths of planting, actual germination counts were taken. These

Table 3. The effect of Di-Syston on plant emergence as influenced by concentration and soil moisture. Stillwater, Oklahoma. 1960.

Per Cent Soil Moisture	Pounds Actual Toxicant Per 100 Lbs. Seed	Number of Plants Emerged Per Carton		Per Cent Reduction in Emergence[a]
		Range	Average	
30-40	0.5	11-13	11.8	6.3
	0.25	11-17	13.0	0.0
	Untreated	11-15	12.6	--
60-70	0.5	11-16	14.4	6.5
	0.25	13-16	15.0	2.6
	Untreated	13-18	15.4	--
90-100	0.5	0-8	5.8	29.3
	0.25	6-12	7.2	12.2
	Untreated	5-10	8.2	--

[a]Compared with untreated checks.

Table 4. The effect of Di-Syston on plant emergence as influenced by concentration and depth of planting. Stillwater, Oklahoma. 1960.

Depth of Planting	Pounds Actual Toxicant Per 100 Lbs. Seed	Number of Plants Emerged Per Carton		Per Cent Reduction in Emergence[a]
		Range	Average	
0.5 in.	1.0	12-17	15.4	14.4
	0.5	12-18	16.0	11.1
	0.25	15-18	17.2	4.4
	Untreated	17-19	18.0	--
1.5 in.	1.0	7-12	10.3	36.0
	0.5	11-16	13.7	14.9
	0.25	13-20	15.8	1.9
	Untreated	14-19	16.1	--
3.0 in.	1.0	0-2	0.7	93.6
	0.5	0-6	4.0	63.6
	0.25	2-10	7.1	35.4
	Untreated	5-15	11.0	--

[a]Compared to untreated checks.

counts showed that the low emergence was not due to the failure of the seed to germinate but to the failure of the seedlings to emerge (table 5). It can be seen that the number of seeds germinating in each treatment approaches the number that emerged at the 0.5-inch depth. This indicates that the seed treatments, regardless of concentration, weakened the young seedlings to the extent that they were unable to emerge from deep plantings.

The effect of Di-Syston on plant emergence as influenced by concentration and soil texture is shown in table 6. As in previous results, plant emergence decreased as the insecticide was increased from the 0.25-pound to the 1.0-pound concentration.

The sandy loam soil had the greatest over-all effect on emergence, with an average of 12.9 per cent reduction for the three treatment levels, followed by the clay loam and the silt loam soils, with 7.3 and 4.3 per cent reductions, respectively. The 0.25-pound concentration had very little effect on emergence in any of the soils. Under the conditions of this test, the 1.0-pound concentration in the sandy loam soil was the only treatment that was considered as seriously affecting plant emergence.

Table 5. Comparison of plant emergence and germination of Di-Syston-treated seed planted at three depths. Stillwater, Oklahoma. 1960.

Depth of Planting	Pounds Actual Toxicant Per 100 Lbs. Seed	Number of Plants Emerged Per Carton		Number of Seeds Germinated Per Carton	
		Range	Average	Range	Average
0.5 in.	1.0	12-17	15.4	12-17	15.4
	0.5	12-18	16.0	12-18	16.0
	0.25	15-18	17.2	15-18	17.2
	Untreated	17-19	18.0	17-19	18.0
1.5 in.	1.0	7-12	10.3	12-17	15.1
	0.5	11-16	13.7	13-18	16.1
	0.25	13-20	15.8	13-20	16.2
	Untreated	14-19	16.1	15-19	17.0
3.0 in.	1.0	0-2	0.7	12-17	14.4
	0.5	0-6	4.0	14-16	15.1
	0.25	2-10	7.1	13-18	15.7
	Untreated	5-15	11.0	15-19	16.8

Table 6. The effect of Di-Syston on plant emergence as influenced by concentration and soil texture. Stillwater, Oklahoma. 1961.

Soil Texture	Pounds Actual Toxicant Per 100 Lbs. Seed	Number of Plants Emerged Per Carton		Per Cent Reduction in Emergence[a]
		Range	Average	
Sandy Loam	1.0	11-15	12.6	28.4
	0.5	13-18	16.0	9.1
	0.25	15-19	17.4	1.1
	Untreated	16-19	17.6	--
Silt Loam	1.0	13-18	16.0	9.6
	0.5	15-20	17.2	2.8
	0.25	15-19	17.6	0.6
	Untreated	16-20	17.7	--
Clay Loam	1.0	13-17	15.4	11.5
	0.5	15-19	16.2	6.9
	0.25	15-19	16.8	3.4
	Untreated	16-20	17.4	--

[a]Compared to untreated checks.

PLANT SURVIVAL TEST

Since several factors may be responsible for the phytotoxicity produced by systemic insecticides in the pre-emergence state of development, it was believed that phytotoxicity in young plants could also depend on certain factors. Therefore, an experiment was designed to determine whether or not phytotoxicity might vary with the conditions to which the plants were exposed.

Procedures:

Untreated seed and seed treated with Di-Syston, phorate, and Bayer 30911 at two concentrations were planted in 6-ounce cartons containing soil having 50-60 per cent of moisture-holding capacity. The experiment consisted of seven treatments including a check. Each treatment was represented by ten cartons in each of which twenty seeds were planted at a depth of approximately one-half inch. The seven treatments were arranged in randomized blocks.

The seeds were germinated and seedlings allowed to emerge in a soil moisture content of 50-60 per cent of moisture-holding capacity. Emergence counts were taken at seven days after planting.

After emergence five replications of each treatment were maintained at a soil moisture level of 50-60 per cent, while the other five replications were maintained at a soil moisture level of 20-30 per cent. At 16 days after planting the number of plants that survived in each soil moisture level was compared with the number of plants that emerged at seven days after planting. Results were recorded as the number of plants surviving and per cent reduction in plant stands.

The cartons were filled with 200 grams of soil, and the moisture-holding capacity and the weight of each carton to have 50-60 per cent of moisture-holding capacity was determined by the method as described in the previous tests. In the replications that were to be maintained at the 20-30 per cent soil moisture level, the soil was allowed to dry until the weight of each carton of soil was reduced to the weight that would be equal to 20-30 per cent of moisture-holding capacity.

The moisture levels were maintained between the desired weights by making daily weighings of the cartons. The weights of the cartons were not allowed to go below the lowest desired weight.

The calculations for the moisture-holding capacity and the weight of the soil in each carton to have 50-60 and 20-30 per cent of moisture-holding capacity were as follows:

Weight of soil in each carton	200 grams
Weight of soil at maximum moisture-holding capacity	262 grams
Weight of dry soil	174 grams
Weight of water in the soil	88 grams

Weight of soil to have:

(a) Moisture content of 50-60 per cent of moisture-holding capacity

88 grams	88 grams
x.50	x.60
44.00 grams	52.80 grams
174.00 grams	174.00 grams
218.00 grams	226.80 grams

(b) Moisture content of 20-30 per cent of moisture-holding capacity

88 grams	88 grams
x.20	x.30
17.60 grams	26.40 grams
174.00 grams	174.00 grams
191.60 grams	200.40 grams

Results:

Plant stand counts taken at 16 days after planting showed considerable differences in the number of plants surviving in each soil moisture level (table 7). The 50-60 per cent level had very little effect on plant survival for any given treatment when the number of plants surviving were compared at 7 and 16 days after planting. However, when the soil moisture level was decreased to 20-30 per cent of moisture-holding capacity, plant stand was severely reduced when compared with the reduction in the untreated check.

Since the untreated check in the 20-30 per cent moisture level had only 4 per cent reduction of the original plant stand, it was believed that this moisture level was adequate for the young plants from untreated seed to survive.

Little difference in reduction between concentrations could be shown, although pronounced differences among insecticides were obvious. Bayer 30911 was the only material that produced an increase in reduction as the concentration was increased. Phorate had the greatest effect on plant stand at both concentrations, while Di-Syston was only moderately phytotoxic at both concentrations.

Observations during the test showed that the 50-60 per cent moisture level and the insecticides used had very little effect on plant growth. Growth appeared to be rapid and normal, except for the plants from seed treated with 1.0-pound concentrations, which showed mild leaf burn and malformity in the young leaves. However, insecticides at the 20-30 per cent moisture level seriously affected plant growth. Plant growth was very poor, and the leaf burn that was produced by the insecticide increased in area, which resulted in the death of the plants.

Table 7. The effect of three systemic insecticides on plant survival as influenced by concentration and soil moisture. Stillwater, Oklahoma. 1960.

Per Cent Soil Moisture	Insecticide	Pounds Actual Toxicant Per 100 Lbs. Seed	Number of Plants Surviving at Indicated Days after Planting 7	16	Per Cent Reduction in Plant Stands at 16 Days[a]
50-60	Di-Syston	0.5	63	62	1.6
		1.0	66	67	0.0
	Phorate	0.5	71	71	0.0
		1.0	68	67	1.5
	Bayer 30911	0.5	56	56	0.0
		1.0	60	61	0.0
	Untreated	--	67	65	2.9
20-30	Di-Syston	0.5	71	62	12.7
		1.0	63	56	11.1
	Phorate	0.5	64	45	29.7
		1.0	59	43	27.1
	Bayer 30911	0.5	64	56	12.5
		1.0	66	52	21.2
	Untreated	--	72	69	4.0

[a]Compared to stands at 7 days after planting.

PLANT GROWTH AND DEVELOPMENT TESTS

It was noted in preliminary tests that the insecticides caused some extensive leaf burn and retarded growth of young plants. Therefore, tests were designed to measure the effect of insecticides on plant growth and to determine if these effects were permanent.

<u>Procedures</u>:

Test I

The objective of this test was to compare three insecticides at various concentrations for their effect on plant growth. Untreated seed and seed treated with Di-Syston, phorate and Bayer 30911 at three concentrations were planted in 16-ounce cartons containing soil. The experiment consisted of ten treatments including a check. Each treatment was represented by ten cartons in each of which ten seeds were planted at a depth of approximately one-half inch. The ten treatments were arranged on a table in randomized blocks.

After seedlings had emerged, stands were thinned to five plants per carton. Observations of phytotoxicity and plant height measurements were taken at ten-day intervals after planting. The plants were measured from the soil level to the tip of the longest leaf. Results of the test are expressed as the average plant height (cm) of 50 plants at ten-day intervals after planting.

Test II

The objective of this test was to compare the growth rate of plants grown from treated seed and untreated seed when plants were under heavy infestation of corn leaf aphids. Untreated seed and seed treated with Di-Syston at 1.0 pound actual toxicant per 100 pounds of seed were planted in 16-ounce cartons containing soil. The seeding procedure, number of treatments, number of plants per carton, and arrangement of cartons were the same as given in Test I.

At ten days after planting, plants in each treatment were measured and infested with ten aphids per plant. Since 100 per cent of the aphids on the plants from the treated seed were killed by the insecticide, these plants were reinfested at ten-day intervals. Aphids were allowed to build up on the plants from untreated seed during the test. Plant height measurements were taken every ten days, and the growth rates (cm) were calculated on the increase in height during each ten-day interval.

<u>Results</u>:

At ten days after planting, young plants grown from seed treated with phorate and Di-Syston at the 0.5- and the 1.0-pound concentrations showed mild to severe marginal leaf burn and severe curling and malformation of young leaves. However, all phytotoxic symptoms had disappeared at 30 days after planting. Bayer 30911 had no phytotoxic effect at either of these concentrations, nor did any of the insecticides at the 0.25-pound concentration.

Plant height measurements taken ten days after planting showed that different amounts of growth, as indicated by plant height, were associated with the concentration of insecticide (table 8). The plants grown from

Table 8. The effect of three systemic insecticides on plant growth and development as influenced by concentration of insecticide. Stillwater, Oklahoma. 1960.

Insecticide	Pounds Actual Toxicant Per 100 Lbs. Seed	Plant Height(cm) at 10-Day Intervals after Planting: 10 Days Range	10 Days Average	20 Days Range	20 Days Average	30 Days Range	30 Days Average
Di-Syston	0.25	5.8-10.8	7.4	10.2-18.5	14.8	14.5-27.3	21.6
	0.5	2.6-8.8	6.5	10.0-17.0	14.0	15.3-25.5	21.0
	1.0	2.0-8.7	5.6	9.0-18.4	13.5	17.3-28.0	21.7
Phorate	0.25	4.6-9.1	7.0	11.0-16.5	13.7	14.5-24.0	19.5
	0.5	3.5-9.1	6.8	9.0-17.0	14.0	14.5-28.6	21.7
	1.0	1.5-8.6	6.0	6.1-20.0	13.3	11.5-28.5	20.8
Bayer 30911	0.25	5.1-10.1	7.8	10.5-17.0	14.0	16.0-23.3	19.5
	0.5	5.0-10.3	7.1	6.5-18.5	14.4	15.8-29.2	21.3
	1.0	3.3-9.8	6.6	11.0-19.0	13.6	14.2-28.6	21.2
Untreated	--	7.0-10.6	9.4	13.0-20.8	16.9	18.0-28.5	22.8

the 0.5- and the 1.0-pound concentrations showed the least amount of growth, while the plants grown from the 0.25-pound concentration and the untreated seed made the most growth. Very little difference occurred between insecticides although Bayer 30911 did appear to have the least effect on growth. However, the average plant height in any of the seed treatments was not as high as in the untreated check.

Measurements at 20 days after planting showed some difference in the average height of the plants in each treatment, although there was little difference in the amount of growth that the plants in each treatment made during the 10-to-20-day interval.

Measurements at 30 days after planting showed that different amounts of growth, as indicated by plant height, were associated with the concentration of insecticide. However, the relation of growth to insecticidal concentration was the reverse of that shown in the first ten days of growth. Plants grown from seed treated with the 0.5- and 1.0-pound concentrations made the most growth, while the plants from seed treated with the 0.25-pound concentration and the untreated seed had the least amount of growth. At the end of 30 days, plants failed to show any appreciable difference in the average height of plants grown from treated and untreated seed. Therefore, it is possible that the insecticides had a retarding effect on growth which was not permanent.

The results of Test II are shown in table 9. At ten days after planting, plant measurements showed that Di-Syston at the 1.0-pound concentration retarded growth when compared to the plants from untreated seed. However, when the plants were infested with corn leaf aphids, the plant measurements at 20 and 30 days after planting showed that the plants from treated seed made more growth than the plants from untreated seed.

Table 9. Growth rate of plants from seed treated with Di-Syston[a] when infested with corn leaf aphids, *Rhopalosiphum maidis* (Fitch). Stillwater, Oklahoma. 1961.

	Days after Planting					
	10 Days		20 Days		30 Days	
	Treat.	Untreat.	Treat.	Untreat.	Treat.	Untreat.
Average Growth Rate (cm)	4.0	5.8	10.2	8.7	9.4	4.4
Range in Plt. Ht. (cm)	1.5-5.8	3.8-8.0	9.5-18.0	9.5-19.5	19.1-24.7	13.2-23.0
Average Plt. Ht. (cm)	4.0	5.8	14.2	14.5	23.6	18.9
No. Aphids Placed on Plt.	10	10	10	--	10	--
Avg. No. Aphids Surviving Per Plt.	--	--	0	45	0	35

[a]One pound actual toxicant per 100 pounds seed.

This difference in growth was due to the rapid build-up of aphids on plants grown from untreated seed, while those from the treated seed gave plant protection during the infesting periods.

INSECT CONTROL TESTS

Treatment of sorghum seed with systemic insecticides, if effective and not injurious, would offer certain advantages over other methods of controlling early season pests. However, the effectiveness of systemic insecticides may depend upon several factors such as insect species, insecticide and concentration, rate of plant growth, etc.

Procedures:

Three experiments (Tests I, II, and III) were conducted to determine the effectiveness of systemic insecticidal seed treatments for insect control and to determine some factors which may be responsible for the residual effectiveness of the insecticide.

In Test I the objective was to determine the insecticide and the concentration which was the most effective for controlling the corn leaf aphid, *Rhopalosiphum maidis* (Fitch); the corn flea beetle, *Chaetocnema pulicaria* (Melsheimer); and the chinch bug, *Blissus leucopterus* (Say).

In Tests II and III the objective was to determine if the age of treated seed and the rate of plant growth had any effect on the residual effectiveness of the insecticide.

Test I

Di-Syston, phorate, and Bayer 30911 at three concentrations were compared for control of the corn leaf aphid. Untreated and treated seed were planted in 16-ounce cartons containing soil. The experiment consisted of ten treatments including a check. Each treatment was represented by ten cartons in each of which ten seeds were planted at a depth of approximately one-half inch. The ten treatments were arranged on a table in randomized blocks.

After the seedlings had emerged, the plants in each carton were thinned to five. The plants in each treatment were initially infested at ten days after planting with two aphids per plant. Mortality counts were taken every ten days by counting the number of live aphids in each treatment. After each mortality count, the aphids were brushed off the plants in each treatment. An inspection was made to see that no aphids remained on the plants before reinfesting each with two aphids. When a treatment failed to show 80 per cent control, it was terminated and considered ineffective.

Aphid colonies were reared in the greenhouse by collecting aphids from the field and caging them on young sorghum plants. When infestations were made, the aphids from these plants were transferred by a small camel's hair brush to the test plants.

Three concentrations of Di-Syston were also tested for control of the corn flea beetle and the chinch bug.

The corn flea beetle control test was designed so that the flea beetles would be caged on the plants; therefore, a preliminary test was conducted to observe the activity of the beetles under caged conditions. Since some systemic insecticides may kill by fumigation as well as by stomach poisoning, it was also desirable to determine if some mortality of the flea beetles would be due to fumigation rather than to the systemic action of the insecticide.

In testing the possibility of mortality by fuming action, ten untreated seeds were planted in 6-ounce cartons containing soil. In addition to the ten untreated seeds, ten seeds treated with Di-Syston at 1.0 pound actual toxicant per 100 pounds of seed were planted in two small vials. The vials were placed vertically in the carton and filled with soil. Five treated seeds were planted in each vial at a depth that would be approximately equal to the untreated seeds outside the vial. Since it was desired that the treated seeds in the vials not germinate, the seeds were heated to kill the embryo before they were treated.

To serve as checks, seed treated with Di-Syston at the 1.0-pound concentration and untreated seed were planted in 6-ounce cartons. Each treatment was represented by five cartons in each of which ten seeds were planted. The three treatments were arranged in randomized blocks. After the plants emerged, they were thinned to five plants per carton. At 20 days after planting, a cellulose nitrate cage was placed over the plants in each carton and ten flea beetles introduced through a hole in the top of the cage (50 beetles per treatment). The beetles began to feed immediately, and some mating was observed during the test. At ten days after infesting, the number of beetles surviving in each treatment was as follows:

Treatment	Number of Beetles
Plants from untreated seed	44
Plants from untreated plus Di-Syston-treated seed	47
Plants from Di-Syston-treated seed	4

From this preliminary test it was assumed that mortality of flea beetles due to fumigation under caged conditions would be unlikely. Therefore, the control test against this insect was conducted as planned.

Untreated seed and seed treated with Di-Syston at three concentrations were planted in 6-ounce cartons containing soil. The experiment consisted of four treatments including a check. The seeding procedure and arrangement of cartons were the same as in the preliminary test, except that ten replications were made.

After emergence the plants were thinned to five per carton (25 plants per treatment). At 20 days after planting, the plants were covered with cages and 15 flea beetles introduced into each cage (75 beetles per treatment). Mortality counts were taken at six and nine days after infesting.

The flea beetles used in this test were collected in the field by sweeping young sorghum plants with an insect net from which they were removed with an aspirator and placed in a holding jar containing sorghum leaves. The aspirator was later used to introduce the beetles into the test cages.

The experiment on chinch bug control was performed in the same manner as the previous one, except that only ten insects were introduced to a carton (50 bugs per treatment) and mortality counts were taken only nine days after infestation.

The chinch bugs were collected from mature sorghum plants with an aspirator and then transferred to a holding jar. They were brought into the greenhouse, and the desired number was introduced into the cages.

The results of these insect control tests are expressed as per cent control, computed by Abbott's Formula (Abbott, 1925).

Test II

Two lots of seed that had been treated for four months and for ten days, respectively, prior to the test were compared in effectiveness against the corn leaf aphid at 20 to 50 days after planting. The experiment consisted of three treatments including a check. Each treatment was represented by ten cartons containing five plants each. The cartons were arranged in randomized blocks.

At ten days after seeding, plants were infested with two aphids per plant. Mortality counts were taken and plants cleaned of aphids and reinfested every ten days.

Test III

Untreated seed and seed treated with Di-Syston at the 0.25-pound concentration were planted in 16-ounce cartons containing soil. The experiment consisted of two seed treatments and two checks. The seeding procedure, number of seeds planted, and arrangement of cartons were the same as in Test II.

After the plants emerged, stands were thinned to five plants per carton. The test was then divided into two groups, with a seed treatment and a check in each group.

To produce different rates of plant growth in the two groups, one was watered with a complete nutrient solution (a solution containing all the major and trace elements essential for plant growth), while the other was watered with tap water.

At ten days after seeding, plants were measured and infested with two corn leaf aphids per plant. Mortality counts, reinfestation of aphids, and plant measurements were made at ten-day intervals after planting.

The residual effectiveness of the treatments was based on the per cent aphid control and the number of days after planting during which control was maintained. The per cent control for each treatment was based on the check.

The average rate of growth during each ten-day period was calculated for each treatment to determine if the residual effectiveness of the insecticide would depend on the rate of plant growth.

Results:

The results of the corn leaf aphid control test are shown in table 10. The effectiveness of the seed treatments varied greatly with the insecticide and concentration. Di-Syston was more effective than either phorate or Bayer 30911. Di-Syston at the 1.0-pound concentration gave excellent control for 50 days after planting. Di-Syston at the 0.5-pound concentration gave as good control as phorate and much better control than Bayer 30911 at the 1.0-pound concentration. Bayer 30911 gave very poor control, and therefore it appears that this material would not be effective for aphid control at any of the concentrations tested. Since the 0.25-pound concentrations of Di-Syston and phorate gave satisfactory control for only 30 days after planting, this concentration would be inadequate for aphid control.

It is apparent that the control of this insect depends on the insecticide used, and the residual effectiveness of the insecticide depends on the concentration.

Treatments with Di-Syston resulted in very good control of the corn flea beetle infested on 20-day-old sorghum plants (table 11). The 1.0-pound concentration gave good and excellent control at six and nine days after infestation. The 0.25- and the 0.5-pound concentrations gave good control at nine days after infestation, although considerable plant damage occurred before control was obtained.

Ineffective control of the chinch bug was very disappointing because

Table 10. The effectiveness of three systemic insecticides for control of the corn leaf aphid, Rhopalosiphum maidis (Fitch), as influenced by concentration of insecticide. Stillwater, Oklahoma. 1960.

Insecticide	Pounds Actual Toxicant Per 100 Lbs. Seed	Per Cent Control at Indicated Days after Planting 20	30	40	50	60
Di-Syston	0.25	100.0	100.0	78.2	--	--
	0.5	100.0	100.0	90.3	73.8	--
	1.0	100.0	100.0	100.0	91.6	75.0
Phorate	0.25	100.0	94.5	27.4	--	--
	0.5	100.0	100.0	83.0	40.1	--
	1.0	100.0	100.0	91.1	61.6	--
Bayer 30911	0.25	67.6	--	--	--	--
	0.5	73.6	--	--	--	--
	1.0	85.3	33.3	--	--	--

-- indicates less than 80 per cent control.

Table 11. The effectiveness of Di-Syston for control of the corn flea beetle, *Chaetocnema pulicaria* (Melsheimer), as influenced by concentration of insecticide. Stillwater, Oklahoma. 1960.

Pounds Actual Toxicant Per 100 Lbs. Seed	Average Number of Beetles Per Plant at		Per Cent Control at	
	6 Days	9 Days	6 Days	9 Days
0.25	0.9	0.2	63	86
0.5	0.4	0.12	83	91
1.0	0.2	0.0	92	100
Untreated	2.4	1.4	--	--

this insect is considered a serious pest of young sorghum. Di-Syston at all concentrations failed to give satisfactory control, although the per cent control was associated with the concentration (table 12). The reason for the poor control was believed to be due to the feeding site. It was noted that the chinch bugs congregated and fed at the bases of plants where perhaps the insecticide was at one of its weakest concentrations. According to Reynolds et al. (1957) the stems of alfalfa plants contained the least concentration of Di-Syston at two and seven weeks after planting, while the cotyledons, trifoliate leaves, and the growing tips had the highest concentration.

The storing of treated seed for four months had very little influence on the residual effectiveness of Di-Syston when compared with seed treated for ten days (table 13). Both treatments gave excellent control of the corn leaf aphid at 30 days after planting and good control at 40 days. Although control began to decrease rapidly after 40 days, there was essentially no difference in the effectiveness of the two treatments.

The results of Test III indicate that the residual effectiveness of systemic seed treatments depends on the rate of plant growth (table 14). There was very little difference in the average growth rate of the plants in each treatment at ten days after planting, and both materials gave good control of the corn leaf aphid at 20 days after planting. The plant measurements at 20 days showed that the plants which were watered with the complete nutrient solution made more growth than the plants which received tap water. The treatment in which the plants made the most growth also gave the poorest control at 30 days. At 40 and 50 days, considerable differences in aphid control were achieved between the treatments. At 50 days the treatment in which the plants made the most growth was only

Table 12. The effectiveness of Di-Syston for control of the chinch bug, *Blissus leucopterus* (Say), as influenced by concentration of insecticide. Stillwater, Oklahoma. 1960.

Pounds Actual Toxicant Per 100 Lbs. Seed	Average Number of Bugs Per Plant at 9 Days	Per Cent Control at 9 Days
0.25	1.3	19
0.5	1.0	38
1.0	0.76	53
Untreated	1.6	--

Table 13. The effectiveness of Di-Syston against the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), as influenced by the age of treated seed. Stillwater, Oklahoma. 1961.

Pounds Actual Toxicant Per 100 Lbs. Seed	Age of Treated Seed	Per Cent Control at Indicated Days after Planting			
		20	30	40	50
0.5	10 Days	100	98	91	60
0.5	4 Months	100	100	89	65

Table 14. The effectiveness of Di-Syston[a] against the corn leaf aphid, Rhopalosiphum maidis (Fitch), as influenced by the rate of plant growth. Stillwater, Oklahoma. 1961.

Ten-Day Intervals after Planting	Plants Received Complete Nutrient Solution				Plants Received Tap Water Only			
	Per Cent Control	Average Growth Rate (cm)	Plant Ht. (cm) Range	Plant Ht. (cm) Avg.	Per Cent Control	Average Growth Rate (cm)	Plant Ht. (cm) Range	Plant Ht. (cm) Avg.
0-10	--	8.4	5.3-10.4	8.4	--	7.0	4.0-8.8	7.0
10-20	100	13.6	17.0-25.5	22.0	100	9.0	10.5-18.5	16.0
20-30	88	8.8	25.0-38.0	30.8	93	4.3	14.5-26.0	20.3
30-40	69	9.0	31.0-45.3	39.8	89	5.4	17.5-32.0	25.7
40-50	35	10.3	41.4-56.5	50.1	63	6.4	24.0-37.5	32.1

[a]One-fourth pound actual toxicant per 100 pounds seed.

about one half as effective as the treatment in which the plants made the least growth. The poorer control was believed to be due to the more rapid dilution and metabolism of the toxicant within the plants which made the most growth. Metcalf et al. (1959) showed that the toxic residues of phorate and Di-Syston persisted longer in alfalfa plants when plant growth was poor than when it was more favorable.

SUMMARY AND CONCLUSIONS

Eleven experiments were conducted to study some factors that were believed to affect plant emergence, plant survival, plant growth and development, and insect control when systemic insecticides were applied as seed treatments to grain sorghum.

Five factors were studied for their effect on plant emergence. Plant emergence from treated seed depends on the insecticide and concentration used, soil moisture, depth of planting, and soil texture.

Phorate was found to be more phytotoxic than either Di-Syston or Bayer 30911. However, of the concentrations tested only phorate and Di-Syston at the 1.0-pound level seriously reduced emergence. In general, the phytotoxicity produced by the insecticide increased as the concentration increased.

Storage of treated seed for four months at 70 degrees F. did not seriously reduce plant emergence when compared with treated seed stored for five days. However, it is felt that treated seed should be stored at various temperatures for a longer period than four months to determine if these conditions would affect plant emergence.

Plant emergence was dependent on the combination of insecticidal concentration and soil moisture. Seed treated with a high concentration of insecticide planted in soil with a high moisture content seriously reduced plant emergence. In general, plant emergence decreased as insecticidal concentration and soil moisture increased. Therefore, plant stands could be reduced, depending on the concentration used and the amount of moisture in the soil at or immediately after planting time.

It was also found that plant emergence depends on insecticidal concentration and depth of planting. Planting treated seed at the 3.0-inch depth severely reduced emergence regardless of insecticidal concentration. Only the 0.5- and the 1.0-pound concentrations seriously reduced emergence at the 1.5-inch depth. Reduction in emergence was not due to the failure of the seed to germinate but of the seedlings to emerge.

Plant emergence was also affected by soil texture. Sandy loam soil had the greatest effect on emergence when compared with clay and silt loam soils. Silt loam soil had the least effect on plant emergence.

Therefore, it is concluded that plant emergence would be expected to be low when the following factors were present: high insecticidal concentration, high soil moisture content, or deep plantings in either sandy or clay loam soils.

The phytotoxicity produced by systemic seed treatments after emergence depended on the insecticide used and soil moisture. The insecticides had very little phytotoxic effect on young plants grown in soils containing 50-60 per cent moisture, but plant stands were seriously reduced in soils with 20-30 per cent moisture. Phorate had the greatest effect on plant stands followed by Bayer 30911 and Di-Syston. There was little difference between concentrations of the same insecticide.

It is apparent that a period of drought following plant emergence could be detrimental to the stand of sorghum, depending upon the insecticide.

Systemic insecticides retarded growth of plants grown from treated seed. However, the plants were not permanently affected and at 30 days after planting there was very little difference in the average height of the plants grown from treated and untreated seed. However, when plants were under heavy infestation of corn leaf aphids, the plants grown from treated seed made much better growth and were in better condition than those grown from untreated seed.

Insect control with systemic insecticides applied as seed treatments was dependent on the insecticide and concentration used and the insect species. Di-Syston gave better control of the corn leaf aphid than either phorate or Bayer 30911. Di-Syston gave good control of the corn flea beetle but gave poor control of the chinch bug.

The residual effectiveness of Di-Syston was not affected by storing treated seed at room temperature for four months. Treated seed having been stored for four months gave control of the corn leaf aphid for as long a period as treated seed stored for ten days.

The residual effectiveness of systemic insecticidal seed treatments depended on the rate of plant growth, and therefore no definite period of control can be predicted. When conditions exist that favor rapid growth, the period of plant protection will be shorter.

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Education: Graduated from Mangum High School, Mangum, Oklahoma, May 1953. Received Associate of Science Degree at Cameron State Agricultural College, Lawton, Oklahoma, May, 1957. Received Bachelor of Science Degree from Oklahoma State University with majors in Entomology and Agricultural Education in May, 1959. Completed requirements for Master of Science Degree in May, 1961.

Experience: Served two years in the U.S. Army, 1954-56. Employed part time, 1956-57 as DHIA District Supervisor, Oklahoma Agricultural Extension Service, Lawton, Oklahoma. Research Assistant, Oklahoma State University, Summer of 1959. Employed part time 1960-61 as Field Aide, Entomology Research Division, U.S. Department of Agriculture, Stillwater, Oklahoma.

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