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Title SOME HERBICIDAL PROPERTIES OF 2-CHLORO 2', 6' - DIETHYL - N - (METHOXYMETHYL) ACETANILIDE

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(William R. Furtick)

Studies were conducted to determine the site of 2-chloro 2', 6'-diethyl-N-(methoxymethyl) acetanilide (CP 50144) toxicity on barnyardgrass (Echinocloa crusgalli (L.) (Beauv.). This was done by means of a technique which used separate layers of treated soil to expose differentially the roots and/or the shoots of barnyardgrass seedlings. Coleoptiles that emerged through treated soil were completely killed. When only the roots were exposed to treated soil, the plants survived but a significant reduction in yield occurred.

A study was conducted to investigate the possible differential susceptibility of corn strains to CP 50144. One double cross hybrid, the two single crosses and the four inbreds involved were tested at concentrations ranging from 0 to 16 ppm. Dry matter yields of shoots and roots were determined. No differential susceptibility

was encountered at any of the rates tested.

The persistence of CP 50144 in the soil was studied at four temperatures ranging from -12°C to +35°C. The study period was 151 days. Four rates of the product, ranging from 0 to 16 ppm., were tested. It was found that degradation was dependent on three factors which interacted significantly. Maximum detoxification occurred with maximum time of incubation, when temperature of storage was kept at +25°C and the rates of the chemical were minimal. A bioassay was used because no chemical analysis was available. The product was still so active after 151 days of storage that no growth could be detected at a concentration of 16 ppm. at any of the temperatures tested.

The performance of the herbicide in the field was evaluated in an experiment involving corn growing in a field heavily seeded with barnyardgrass. No special benefit was derived from incorporation when compared with surface, pre-emergence application. No differences were detected either when CP 50144 was applied to a dry or pre-irrigated soil. Paramount control of the weed was obtained with two pounds of active ingredient per acre. No difference could be detected when this rate was compared with the four pound per acre rate.

SOME HERBICIDAL PROPERTIES OF 2-CHLORO 2', 6' - DIETHYL - N - (METHOXYMETHYL) ACETANILIDE

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INTRODUCTION

Pre-emergence herbicides have certain advantages over post-emergence herbicides, particularly in the reduction or elimination of early weed competition with the crop. However, failures to obtain adequate weed control often occur due to certain environmental factors which can render a treatment completely ineffective. This is especially common with new products that are still in the experimental stage.

The product 2-chloro 2',6'-diethyl-N-(methoxymethyl) acetanilide (CP 50144) has shown promise as an effective selective grass killer in corn. Research at Oregon State University has shown that CP 50144, in combination with herbicides such as atrazine, is effective in controlling a wide spectrum of common weeds. Some of the factors that influence the herbicidal properties of the compound were studied in order to help in the formulation of practical recommendations.

Areas of study included (1) determination of the most effective site of uptake of the chemical by means of a bioassay test, (2) susceptibility of various corn strains to CP 50144, (3) persistence of CP 50144 in the soil under various temperatures, and (4) the performance of three rates of CP 50144 applied on a pre- or post-irrigated field. In addition, surface applications were compared with soil incorporated treatments.

LITERATURE REVIEW

Chemical and Physical Properties of Herbicides as Related to Phytotoxicity

In order to be useful as an herbicide, a chemical compound must be phytotoxic. The vegetation killing effect must be evident at dosages that are practical and economical. An example of such a chemical is 2, 4- dichlorophenoxyacetic acid (2, 4-D). Cruciferous weeds in a field of grain can be killed with 0. 5 lb. /A. of 2, 4-D or less. Herbicidal action of this magnitude, when converted to concentrations in plant tissues, represent minute quantities often ranging to a fraction of a part per million on a fresh weight basis and constituting only a few micrograms per plant (19).

To be effective, an herbicide must enter the plant. The two major sites of herbicide entry into the plant are through the leaves or through the roots. The route of entry depends on such factors as morphological and structural characteristics of the plant, physical properties of the herbicide, environmental conditions, etc.

The first substances used as herbicides probably entered the plants through the foliage and stem. The physical structure of the foliage itself can impede, permit or encourage the penetration of the chemical. Surfaces on which the spray does not readily adhere permit less effective absorption than surfaces which wet more easily.

For example, the leaves of garden peas have a waxy surface which makes them rather difficult to wet. As a result, foliar sprays of a given herbicide may have less effect on this species than they do on tomato, the leaves of which wet very easily. The waxiness of the surface may also influence absorption. For example, an onion leaf presents a small surface per unit of volume and its position is such as to encourage run-off of the spray droplets (39).

Several environmental factors influence the rate of absorption into leaves. Among them are temperature, wetting agents, light, nature of the carrier and pH.

Temperature conditions greatly influence absorption. Absorption of 2,4-D is considerably greater at $90^{\circ}F$ than at $50^{\circ}F$. This difference increases when comparisons are made between aqueous and non-aqueous carriers. Although the total absorption is greater at higher temperatures, the duration of absorption is apparently reduced by higher temperatures in the absence of a carrier; in other words, the rate of absorption is increased by higher temperatures, but the time over which the absorption takes place is somewhat decreased. This can be a consequence of a more rapid drying of the spray droplets (39).

The addition of wetting agents increases foliar absorption by reducing interfacial tension and by solubilizing the non-polar substances of the cuticle. This effect will reduce selectivity when selectivity is based on differential absorption (37).

The surface characteristics of the leaf can be altered by light and this can have an influence on the absorption of 2,4-D (44). Low light intensities may result in a longer period of wetting due to the lower temperature.

The nature of the carrier profoundly influences the effectiveness of the spray applied to foliage. Highly viscous materials such as lanoline paste greatly lengthens the duration of the absorption (39).

The pH of the spray solution may influence the rate of absorption. This characteristic is strongly associated with the age of the tissue sprayed; young tissue is generally more responsive to polar solutions, whereas the surface of the older foliage which has a thick cuticle responds better to non-polar solutions. Similarly, the surfaces of roots are generally polar in nature. Hence, acids and salts are more effective than esters when applied to the soil (18). The nature of the carrier or the use of detergents, however, can permit the entrance of polar acids and salts by normally non-polar pathways (39).

An herbicide that exerts its effect at a distant point from the one of entry must be translocated. Herbicide movement can take place in the plant through three pathways: (1) through the phloem, (2) through the xylem, and (3) by intercellular translocation.

Translocation through the phloem is governed by factors such as active transport of food materials from the leaves to the roots, degree of contact toxicity of the chemical, molecular structure suitable for penetration through the cuticle and mesophyll, and the capacity of being accumulated in actively growing tissues. When this accumulation reaches a certain level, the toxic effects are made visible (19). The age of the plant, closeness of the point of application to vascular tissue, amount of light, high phosphorous and potassium content are very important considerations in determining the extent of translocation (37).

Rice (44), studying the role of environmental conditions upon translocation of 2, 4-D in beans, concluded that translocation was unaffected by temperature differences ranging from 50 to 90^{o}F. He reported light has a profound effect on translocation and that its effect is proportional to the intensity. This fact is of great practical importance, since it has been demonstrated by several workers that 2, 4-D moves only with the carbohydrates (39).

Translocation through the xylem is somewhat different because of its non-living nature. Highly toxic materials can be translocated either upwards or downwards depending on the external conditions and the nature of the product. Hitchcock and Zimmerman (34) showed that auxins applied to the soil can move acropetally in plants, apparently in the transpiration stream. Weaver and DeRose (56) demonstrated that 2, 4-D passed upwards but not downwards through dead segments of the stem and its rate of translocation was proportional to the transpiration rate.

Neither phloem transportation nor xylem translocation can explain entirely the movement of auxins in the plant. A third type of movement appears to occur through the cell walls and intercellular spaces, mainly due to capillarity. The work of Rice and Rohrbaugh cited by Leopold (39) proved that 2,4-D formulated in kerosene and, applied to bean plants, circulated in the plant. This movement was independent of light and sugars.

Leopold (39) analyzed a number of factors which influenced the effectiveness of translocation. He pointed out that the degree of differentiation of the cells has an important bearing on the final effect. The less differentiated a cell the more the susceptibility to the auxin. For this reason plants in the seedling stage are more susceptible than at later stages.

Some other stages of growth may show renewed sensitivity to auxins, a good example being the boot stage of the cereals.

The excess of weakly differentiated cells in the plant is not entirely responsible for the degree of susceptibility. In some instances, a slow growing stage, such as the vegetative rosette stage of dandelion, is a particularly susceptible stage to 2,4-D application.

Ungerminated seeds of cereals are very resistant to auxins. Upon germination and commencement of growth, sensitivity increases at once and is maintained through the early stages of seedling growth. As a general pattern, it drops off at certain well defined stages characteristic for each species. This low reaction stage is maintained for a period ending with flower initiation in which it becomes high again, dropping off after heading.

The pattern in dicotyledoneous plants shows a remarkable degree of variation with stage of growth and with the kind of auxin used. In general, plants show a stage of susceptibility in the early seedling stages of growth and a period of high resistance after fruiting.

Derscheid (24) indicates that differences in susceptibility, in some instances, are better correlated with growth rate than with stage of development.

Erikson and Gault (26) demonstrated in a study under controlled irrigation that plants under moisture stress are more resistant to 2, 4-D than plants with an ample supply of water and engaged in normal growth.

The nutrient status of the plant also influences the response to an auxin treatment. Wolf et al. (59), working with soybeans grown in nutrient solutions, demonstrated that 2, 4-D injury to the roots increased with increasing nitrogen content of the solution.

For use in crops, in addition to being phytotoxic, an herbicide must be selective; in other words, it must be able to kill weeds with little or no injury to the crop. Selectivity is relative and depends on factors such as differential wetting, differential breakdown of the toxicant in the crop plants or a selective effect on the protoplasm of cells (19).

Soil applied herbicides are dependent on a number of factors that are analyzed briefly in the following section.

Factors Influencing the Effectiveness of Soil Applied Herbicides

The trend in herbicide usage has been towards preplant or pre-emergence soil applied herbicides. There are several reasons for this: Annual plants are more susceptible to herbicides at the time of germination and generally increase their resistance thereafter. Preplant or pre-emergence herbicides kill the germinating weeds sooner than herbicides that rely on post-emergence foliar entry. Their primary use is to kill weeds prior to emergence, thus giving the tremendous benefit of a very early removal of weed competition. The importance of this early damage to crops has been demonstrated time and again.

Soil applied herbicides are used for the control of germinating weeds under a wide variety of conditions:

In annual crops, soil applied herbicides are used: (a) in crops grown from seed which germinate at about the same time as the weeds; (b) in vegetatively propagated and planted crops under conditions favorable for weed germination, e. g. , potatoes; (c) after establishment of the crop, e. g. , the control of spring germinating weeds in a fall seeded crop; and (d) after transplanting of established crop seedlings, when soil conditions favor the germination of weeds.

In perennial crops, soil applied herbicides are used: (a) in herbaceous crops; (b) in woody crops, such as most temperate fruits and ornamentals; and (c) in plantation crops.

In total weed control, soil applied herbicides are used to maintain an area free of germinating weeds.

Soil active herbicides are also used for the control of weeds at the latter stages of plant growth. Examples are the application of fenuron and other substituted ureas with products such as trichloroacetic acid (TCA), ethyl N, N-di-n-propylthiolcarbamate (EPTC) and others for the control of the sprouting of rhizomes quackgrass and nutsedge (9, 31, 35).

When herbicides are applied to a dry soil surface, some are subjected to severe losses by photodecomposition and volatilization if rainfall or irrigation is not sufficient to diffuse or leach them into the soil. Other herbicides are more affected by some other factors. Degradation by ultraviolet light is particularly well substantiated with the herbicides 3-(p-chlorophenyl)-1, 1-dimethylurea (monuron) and 3-(3, 4-dichlorophenyl) 1, 1-dimethylurea (diuron) (57). Weldon and Timmons (57) found that artificial illumination of these herbicides with ultraviolet light for 28 hours resulted in a 75 percent decrease in bioactivity. Sheets (47) reported that exposure of a solution of 3-amino-2, 5-dichlorobenzoic acid (amiben) to sunlight for six hours led to breakdown of 50 percent of the product.

Volatilization can be an important factor in the loss of herbicides. Even monuron, which is not very volatile, can be lost from the soil surface if a period of hot dry weather occurs before incorporation is accomplished (33). Granular formulations can avoid this loss to a certain degree if the chemical is incorporated in the substance of the granule, rather than being surface coated. The carrier is also important in influencing herbicide loss by volatilization. Even the formulation of the spray liquid can influence vapor loss as shown by Freed *et al*. (27). A light rainfall or irrigation is frequently beneficial in carrying an herbicide into the soil to reduce losses from volatilization or photodecomposition. Heavy rain or irrigation may cause leaching, which will injure the crop or prevent effective weed control since the herbicide is moved below the germinating weed seeds. When rainfall or irrigation cannot be depended upon to move the herbicide into the soil, mechanical incorporation is sometimes beneficial. The ultimate depth of incorporation will depend on the site of uptake of the chemical and on the depth from which the weed seeds germinate. A very important consideration is the depth of crop planting because in many cases selectivity depends on an isolating barrier of untreated soil over the seed, thus preventing its contact with the chemical (35).

The problem of placing the herbicide in the proper layer is very difficult to accomplish in practice. Working with fluorescent tracers, Staniland (51) showed that one rotovation to a depth of 6 inches left 79 percent of the tracer in the top 3 inch layer of soil and only 21 percent in the 3-6 inch layer.

In summary, Antognini (2) states that for those herbicides that are benefited by mechanical incorporation, the incorporation has the following advantages: (a) increases herbicidal activity, thus rates can be lowered; (b) reduces the variability of the commercial applications; (c) allows the application of the herbicide together with insecticides and fertilizers.

Among the disadvantages, he cites: (a) the extra labor of incorporation; (b) the lack of adequate equipment for satisfactory and precise incorporation; (c) the lack of information on comparative efficiency of the chemical when surface applied or incorporated; and (d) the lack of information on compatibility with other pesticides or fertilizers.

Other factors, namely adsorption, leaching and microbiological decomposition, alone or combined are the major source of disappearance of soil applied herbicides. Due to the importance and volume of literature, these factors are treated separately.

Adsorption

Adsorption is the phenomenon of the binding in thin layers of molecules or ions on surface of solids. The adsorption forces vary from very strong ionic bonds to very weak van der Waal forces.

Adsorption is very important to chemical weed control, because very strongly adsorbed herbicides may not be available to weedy plants, therefore, their effect is lost or impaired (10).

Adsorption has been invoked by many investigators to explain the differences in the bioactivity of a particular pesticide between different soils or other pesticides. Since the effect of adsorption affects the bioactivity of pesticides in soils to different degrees, the nature of the interaction between various combinations of pesticides and soils will vary.

There are two general types of adsorption: physical and chemical. The former involves van der Waal forces, and the latter, due to coulombic forces, result in bond formation between the adsorbent and the adsorbate. The two types occur together but only the innermost monolayer of molecules is chemically adsorbed. In soil systems, the most important consideration is the adsorption from the soil solution, although other types are also present (10).

Many factors influence this phenomenon, and can be divided into micro and macrofactors. The former group, such as soil type and organic matter content, are of great importance in adsorption of herbicides. The bioactivity of a particular pesticide has been assessed by determining the percent control at a given dosage or by comparing the difference in dosage required to effect a given percent kill. Results show that the bioactivity of pesticides is lowest in soils with high organic matter content and with heavy textures.

Several workers have demonstrated that pesticides are leached less in heavy textured, organic soils than in the light ones. The organic colloids appear to be responsible for the differences. This can be seen in the works by Holstun and Loomis (36) with 2,2-dichloropropionic acid (dalapon); Upchurch and Pierce (54) with monuron; and Ashton (5) with the series of substituted ureas. There are some important deviations from this pattern; Pieczarca and Starck, cited by Bailey and White (10), working with four dinitro-anilines and chloropicrin respectively, found that adsorption was less in a muck soil than in a mineral one.

Organic matter content and cation exchange capacity are positively and highly correlated with adsorption or reduced bioactivity. Several authors (48, 52) also found that these two variables are significantly correlated. Call (16) found that organic matter content, moisture content and clay content are also highly correlated among themselves. Nevertheless, Sheets _et al_. (48) found that organic matter content is a better indicator than total clay, cation exchange capacity or pH for the prediction of the ED_{50} of atrazine.

It appears that the type of clay mineral is also important in the adsorption of pesticides. Hill (32) found that monuron was adsorbed more by bentonite than by kaolinite. Montmorillonite adsorb pesticides with greater strength than either illite or kaolinite (10).

The degree of adsorption reversibility (desorption) appears to differ between mineral and organic soils. Siegel et al. (46) found that 1,3-dichloropropene and 1,2-dibromoethane could be readily removed from bentonite by flushing with air but were irreversibly held by a muck soil. Wade (55) found that by heating soils (sandy, clay and organic) to 105°C in the presence of water vapor essentially all the adsorbed ethylene dibromide could be recovered. Aeration of dry soils showed that this compound was more readily recovered from the sandy and clay soils than from the organic soils. This indicates that the compound is bound with a higher energy by the organic matter than by the mineral constituents.

The nature of the adsorbate is also a factor since it can be seen that within a family of pesticides, the adsorption rate varies for the same adsorbent. Bailey and White (10) found that the degree of adsorption of four substituted ureas was inversely related to their order of solubility. Ashton (6) reported that the lateral movement of soil incorporated and surface treatments was greatest for 2-methoxy-4 ethylamino-6 isopropylamino-s-triazine (atratone), intermediate for 2-chloro-4 ethylamino-6 isopropylamino-s-triazine (atrazine), and least for 2-chloro-4,6-bio(ethylamino)-s-triazine (simazine) in a Yolo sandy loam; the order of solubility being 1,800 ppm.; 70 ppm.; and 5 ppm., respectively, at 20-22 ^{o}C (19). This relationships appear to be valid only in certain families of herbicides, and is very risky to generalize. Harris and Warren (30) had reported no general relationship between solubility and adsorption.

Soil reaction appears to be correlated with the extent of adsorption of herbicides. It was (10) found that the adsorption of herbicides, with many different molecular structures, increased as the pH decreased, the limits depending on the nature of the particular compound and the adsorbent. The effect of the pH is that it governs the degree of dissociation or association of the compound. That is, whether the compound is still a molecule or has dissociated into either cation or an anion; this is valid for soil particles also. This in turn may affect the amount that is adsorbed and the strength with which it is held, since the energy of adsorption may be vastly different between the dissociated and the associated form.

The nature of the saturating cation is another important factor governing the total amount of a pesticide to be adsorbed.

Some cations are more competitive than others for sites of adsorption.

Adsorption is also regulated by soil moisture. Ashton and Sheets (8) compared the adsorption capacity of various soil types for EPTC, both at field capacity and in the air dry state. Regardless of soil texture or organic matter content, more EPTC was adsorbed by the soil in the air dry state than at the field capacity.

Wade (55) found that adsorption of ethylene dibromide decreased when moisture increased beyond a certain limit, but this was not a linear relationship. In general, herbicides that are volatile have been found to be more effective in dry soil than in moist soil. One possible explanation is that for a given concentration applied under low moisture conditions the herbicide is weakly adsorbed so enough material is biologically available to produce its effect. In the case of high moisture conditions, little of the material is adsorbed, most of it being in the soil solution and susceptible to vapor loss. With vapor loss, the amount of the compound remaining is insufficient to produce toxic effects. Since adsorption is an exothermic process and desorption is endothermic, an increase in temperature will reduce adsorption and will favor desorption. This phenomenon appears to be reversible. This is highly favorable since soil temperature undergoes a diurnal and seasonal variation. It can be expected that maximum desorption occurs simultaneously with the peak of daily metabolic activity of the plants in both cases (10).

There are other factors that appear to be important in governing the amount and strength with which a compound is adsorbed, such as the formulation of the carrier. Very little is reported in the literature about the relative importance of this and other possible factors.

Complete inactivation of dipyridilium compounds, like diquat and paraquat, is thought to be due to fixation of these cationic herbicides by the base-exchange complex of the soil (35).

Upchurch and Mason (53) concluded, after studying 11 herbicides on a wide range of soil conditions, that 5 times more herbicide was needed to produce the same effect in a soil with 20 percent of organic matter than in one with 4 percent regardless of which chemical was used.

Obien et al. (42) observed that adsorption of neburon in the soil, though very variable, was correlated with organic matter and total soil nitrogen. These factors determine the degree of adsorption which in turn governs the initial and residual phytotoxicity.

Brown and Mitchel (14) studied the inactivation of 2, 4-D in the soil. They showed that the compound was readily inactivated if incorporated and maintained under conditions of high moisture and high temperature (not exceeding 70^{o}F). Low additions of manure to low organic soils hastened inactivation.

Day, Jordan and Hendrixson (23), studying the fate of 3-amino-1,2,4-triazole (amitrole) in the soil, observed that adsorption usually accounted for less than 20 percent of the amitrole added, but could be higher than 50 percent in exceptional occasions. Desorption was easily accomplished by water percolation.

The macrofactors that govern or influence adsorption are closely related to microfactors previously mentioned. Of special importance are frequency and amount of water that reaches the soil surface as well as the entrance of water into and through the soil profile.

The pore size and pore size distribution are determined mainly by soil structure. These factors will determine the rate at which water enters and moves through the soil. This should have some effect on the equilibrium between the pesticide in the soil solution and that adsorbed on the soil colloids.

Moisture content in the upper inch of soil is very important because at low rates the pesticide will be highly adsorbed. In certain areas of high and periodical rainfall, the moisture level of the soil can be kept at such level that adsorption would be lessened and bioactivity would be enhanced due to desorption (10).

Microbiological Decomposition

The dominant part played by microorganisms in disposing of herbicide residues in the soil has been demonstrated many times with a wide variety of chemicals (6, 13, 15). Their efficiency is extremely variable depending on soil conditions and on the herbicide concerned so that in some instances the period of persistence is only a week and in others it is more than a year.

Microorganisms can be very specific in the compounds they attack; this is true for example within the alkylphenoxy compounds where 4-chlorophenoxyacetic acid (4-CPA), 4-chloro-2-methylphenoxyacetic acid (MCPA), 2,4-D, and 2,4-dichlorophenoxybutyric acid (2,4-DB) are readily broken down; whereas 2,4,5,-trichlorophenoxyacetic acid (2,4,5-T), 2,4,5-trichlorophenoxybutyric acid (2,4,5-TB), 2-(2,4,5-trichlorophenoxy) propionic acid (silvex), and (2,4-dichlorophenoxy) propionic acid (2-(2,4-DP)) are much more resistant to break down (9, 58).

Nevertheless, under suitable environmental conditions almost any herbicide applied to the soil will be attacked by some microorganism. Bollen (13) states that many morphological and physiological types of organisms occur in all soils, so that there should be very few instances in which the necessary organism is not present at all. One exception has been reported by Furtick (28).

Microbiological activity depends on many factors of the environment such as temperature, moisture, soil reaction, aeration, amount of normal substrate such as organic matter, etc. It is not surprising, therefore, that many workers report large variations in the persistence of an herbicide in the soil. Day et al. (23) found more than a thirty-fold difference among several soils in the rate of breakdown under standard conditions.

Studying the kinetics of herbicide disappearance from soil, Burschel and Freed (15) found that some herbicides were inactivated following the rate of a first order reaction. They interpreted it as a result of the extreme abundance of microorganisms which in favorable media acted in a way similar to a purely chemical reaction in which the rate-limiting factor was the amount of herbicide present. These results are reviewed by Audus (9).

The most usual pattern of herbicide breakdown in the soil is an initial lag period followed by an increasingly rapid phase of detoxification. This pattern has been reported by Riepma (45), Audus (9), and others and is of general validity for many herbicides.

It has been reported by Bollen (13), as well as by many others, that the microorganisms capable of detoxifying 2,4-D and other herbicides are more abundant in the soil after a treatment with the chemical. Thus, repeated applications are less persistent than the first one. Although this is not the case with the phenylureas and s-triazines (15), it appears to be a general pattern for the breakdown of the majority of herbicides.

The phenomenon of soil enrichment is explained by Audus (9) as the result of induction of adaptive enzymes by the herbicide in all or in a large fraction of the population of certain responsive microorganisms. These adaptive processes by which the herbicide-specific enzyme system are activated may proceed in non-dividing cells so that the first phase of the lag in detoxication corresponds to this induction period. After acquiring the full enzyme potential, the sensitive bacteria would proliferate rapidly, promoted by the same favorable substrate supply and lack of competition from unadapted species; the herbicide would then disappear rapidly.

This has not been proven and there is evidence which supports the theory of mutation in the soil population of microorganisms. These mutants would appear spontaneously from time to time and would become evident when supplied with the particular chemical. Then, mutants would have an advantage over the rest of the population and would begin to reproduce rapidly. Audus (9) reports that despite all the work done, more research is needed to clarify the causes of this phenomenon.

Soil Placement Studies and Site of Uptake

The importance of the site of uptake of herbicides is illustrated by the fact that toxicity can be seriously impaired, or totally suppressed, if the herbicide is not taken up by a tissue which will allow the herbicide to reach the site of toxic action.

Many authors have reported substantial differences in uptake and toxicity by treating roots or coleoptiles of grasses (3, 4, 7). Dawson (20, 21) reported that barnyardgrass seedlings were much more susceptible to EPTC when the chemical entered through the coleoptile than when it entered through the roots. The same pattern of uptake and toxicity was determined for dimethyl 2,3,5,6-tetrachloroterephtalate (DCPA)(40), 2,3-dichloroallyl diisopropylthiolcarbamate (diallate), 2-chloroallyl diethyldithio-carbamate (CDEC) and 2-chloro-N,N-diallylacetamide (CDAA) (7) and a number of other products (38). Some herbicides can also be absorbed by the roots, but shoot entry is much more toxic, e.g., isopropyl N-phenylcarbamate (IPC) (4); N,N-di-n-propyl-2,6-dinitro-4-trifluoro-methylaniline (trifluralin); ethyl-N,N-di-n-propylthiolcarbamate (EPTC); 2-chloro-N-isopropylacetanilide (CP 31393); amiben; N-(3,4-dichlorophenyl)-N'-methoxy-N'methylurea (linuron); and atrazine (38). It appears logical to apply these herbicides as near to the soil surface as possible. This has a double benefit, that of entering through the most efficient route and avoiding the effect of dilution in a larger volume of soil.

For these reasons, determination of the site of uptake of an herbicide is of primary importance.

Differential Response of Crop Strains to Herbicide

In general, it can be expected that if one strain of a plant species is resistant to a particular chemical, other strains will also be resistant to the same chemical. Nevertheless, Eastin *et al.* (25) found that an inbred line of corn showed damage after treatment with atrazine in a breeding nursery. The line was the Mississippi selection of the inbred GT 112. Genetic studies demonstrated that a single recessive gene was responsible for this unusual behavior.

A number of studies were undertaken to bring light on this subject. Negi *et al.* (41), studying the response of resistant, tolerant and susceptible plant species, found that atrazine residues were present in all the species 11 days after a pre-emergence treatment with 1 lb. /A of atrazine. Undegraded atrazine was found to be roughly correlated with resistance, but the amount absorbed was not directly correlated with susceptibility. Detoxification of atrazine yielded hydroxyatrazine, which is innocuous to plants and was somewhat correlated with resistance. The resistant species converted at least twice as much atrazine to hydroxyatrazine as did the susceptible plants.

It was found (17) that the sap pressed out of corn seedlings could detoxify atrazine, while the sap of wheat seedlings could not.

This fact has been reproduced *in vivo* by corn seedlings and *in vitro* by corn extracts. The factor that produced this detoxication was found to be either a cyclic hydroxamate (2,4-dihydroxy-3-keto-7-methoxy-1,4-benzoxazine) or its glucoside (29).

The resistance of corn plants to atrazine was found to be linked with resistance to both the European corn borer (*Pyrausta nubilalis* (Hbn)) and stalk rot. This resistance, in turn, was associated with the Resistance Factor A (RFA) that was isolated and turned out to be the compound 6-methoxybenzoxazolinone (12).

Andersen (1) studied the behavior of the inbreds A 619 and W 22R. The two inbreds were resistant to both pests and showed little susceptibility to atrazine. In a similar fashion, the inbreds A 334 and WF 9 showed susceptibility to both pests and atrazine.

There is a strong evidence that the resistance was based upon the same biochemical structure in both cases, the pest resistance compound or factor and the herbicide.

METHODS, MATERIALS AND RESULTS

The work reported includes three greenhouse studies and one field experiment. The main objective of the study was to determine the herbicidal properties of the product CP 50144 and its ability to control barnyardgrass in corn. The greenhouse studies were designed to determine the relative sensitivity of barnyardgrass seedlings to shoot and root uptake of the chemical, to study the effect of temperature on the persistence of the product in the soil, and the differential toxicity to several strains of corn. The field experiment was designed to study the influence of rates of application, incorporation and irrigation on the control of barnyardgrass in corn.

Much of the research involved certain techniques and methods identical for all greenhouse experiments. Rather than discuss these methods in each experiment, a general description of materials and methods will be given. Equipment and techniques unique to a specific experiment will be described under the heading of each individual experiment.

General Materials and Methods

All greenhouse experiments entailed the use of soil incorporated CP 50144. The herbicide was mixed thoroughly with the soil by means of a small double cone tumbling machine equipped with an internal spraying device. A measured amount of air dry soil was screened through a 9-mesh per inch sieve, placed in the machine and as the soil tumbled and mixed, the correct amount of the chemical was applied as a water solution.

Since the formulation of the chemical was too concentrated for the purpose of the experiments, a dilute stock solution was prepared by adding 1 ml. of the 4 lbs. of active ingredient per gallon formulation to 999 ml. of tap water. A new solution was prepared each time as needed. Aliquots of the stock solution were taken so as to give enough material to provide a concentration of 0.25, 0.50, 1.00, 2.00, 4.00, 8.00, or 16.00 ppm. per gram of dry soil. Using an 8001-E Spraying Systems nozzle tip at 20 psi. of pressure, an output of 0.07 ga./min. as a fine spray, was obtained. Soil moisture was brought to approximately 75 percent of field capacity at the time of spraying the herbicide by regulating the amount of water added to the solution to be sprayed.

The bioassay plant used in all the experiments, other than the corn strains study, was barnyardgrass (*Echinocloa crusgalli* (L.) Beauv.) harvested in 1964 and having a germination of 69 percent. This plant was selected because of its sensitivity to the herbicide, as determined in a preliminary trial.

I. Greenhouse Study on the Site of Uptake of CP 50144

It was noticed in a preliminary trial that barnyardgrass was controlled completely at rates as low as 0.5 ppm. of CP 50144 mixed with the soil. Therefore, rates of 0.25, 0.50, 1.00, and 2.00 ppm. were selected.

Materials and Methods. The technique used was similar to that reported by Appleby (3) and McKinley (40) and later modified by Knake (38) who used treated and non-treated soil layers in which roots and shoots were differentially exposed. The modification used by Knake consisted only in the elimination of the plastic barriers used by the former authors for separating the treated and non-treated soil layers. The barnyardgrass seeds were planted in a thin layer of untreated soil.

For root uptake, a two-inch layer of untreated soil was placed in the bottom of quart cans. Soil treated with the herbicide was placed on top of the two-inch untreated soil layer. Eight seeds were placed in the middle of a one-inch, untreated layer that served as a buffer zone. One inch of untreated soil was placed on top.

For shoot uptake, three and one-half inches of untreated soil were placed in the bottom of each quart can. Eight seeds were planted in the center of the one-inch buffer layer that was covered with one inch of treated soil.

For root and shoot uptake, a two-inch layer of untreated soil was placed in the bottom of the cans. One-inch layer of treated soil was placed above and below the buffer layer which contained the seeds.

Chehalis silt loam soil was used. Enough tap water was added to each individual layer of soil in order to bring the moisture content to 20 percent of moisture. This value was arbitrarily selected because the value for 1/3 atm. (22.44%) proved to be excessive for practical handling of the soil and tended to produce lumpiness.

Once the filling of the cans was completed, three wooden stakes were placed adjacent to the rim, thus providing support for a polyethylene bag which was placed over the containers. The bag was secured with a rubber band. As no drainage holes were provided, each can functioned as an air tight system and the necessity of adding more water was eliminated.

Four replications were made and the cans placed on a greenhouse bench in a randomized block design. Temperature was maintained at 23^{o}C. Entire plants were harvested 28 days after planting by washing the soil with tap water. Dry weight was determined.

Results. The results of this experiment are shown in Table 1. Barnyardgrass seedlings were killed when the coleoptile was forced to emerge through a layer of treated soil. This was true even at the lowest rate (0.25 ppm.); when only the roots were

Table 1. Dry weights of barnyardgrass plants per pot. Average of four replications (mg.).

Treatments	Concentrations (ppm.) 0.25	0.50	1.00	2.00
Shoot uptake	0	0	0	0
Root uptake	99	159	60	15
Shoot and root uptake	0	0	0	0
Check	175	156	140	189

exposed, a significant reduction in growth could be noticed when compared with the corresponding checks.

When the roots and shoots of the plant were exposed to the herbicide, a complete kill resulted due to coleoptile damage.

An odd phenomenon occurred with the root treated plants at all the concentrations studied. At the time of harvest, these plants had emerged panicles with some spikelets in anthesis. This same inflorescence development was not present in the checks. No effort was made to explore this phenomenon.

II. Susceptibility of Corn Strains to CP 50144

The object of the experiment was to determine the relative susceptibility of various corn strains to CP 50144. Four inbred, including two single crosses and a double cross hybrid were tested with six rates of the chemical.

Materials and Methods. Woodburn silt loam soil was screened through a 9-mesh sieve and treated in the tumbling machine with 0, 1, 2, 4, 8, 12, and 16 parts per million. Four-inch plastic pots were filled within one and a half inch from the top with treated soil. Nine seeds were planted per pot and covered with treated soil; no isolating layers of untreated soil were used. At the two leaf stage, plants were thinned to six plants per pot. The plants were watered as needed. At the time of thinning, some showed tip necrosis. A nutrient deficiency was suspected and all the pots received 10 ml. of Hoagland solution.

The temperature was kept at 24^{o}C and artificial illumination was supplied 24 hours a day by means of a battery of fluorescent and incandescent lights.

Five weeks after planting, the pots were removed from the greenhouse. By means of a fine jet of water, the roots were washed free from the soil and the plants were blotted in paper bags for eight hours. Plants were dried in paper bags in an oven and dry weights of shoots and roots were determined.

Results. Individual analysis of variance were performed on the data of roots and shoots dry weight. Means were compared using the least significant difference test at the 0.01 level. The results are given in Tables 2, 3, 4, and 5.

Strain means of shoots and roots showed significant differences. This was expected since the strains included were genetically different.

Rates of CP 50144 exceeding 4 ppm. significantly reduce the dry matter production of shoots and roots of all the strains tested.

The interactions between strains and rates were not significant. This fact indicates that, in general, the strains were similarly affected by the rates of the herbicide.

III. Study on the Persistence of CP 50144 in the Soil under Various Temperatures

The rate of disappearance of a particular herbicide from the soil is governed in part by temperature. This study was aimed towards determining the effect of constant temperatures in the detoxification of CP 50144.

Materials and Methods. Woodburn silt loam soil was collected in the summer and carefully screened through a 9-mesh per inch sieve. Treatments consisted of the following rates: 0, 2, 8, and 16 parts per million of CP 50144. The treated samples were placed in air tight dark glass containers and stored at -12, +4, +25,

Table 2. Dry weight of corn shoots on a per plant basis. Average of four replications (mg.).

Strains	Concentration (ppm.) 0	1	2	4	8	12	16	Means
9	467.5	509.7	524.0	553.0	480.0	407.5	355.0	470.9
13	479.0	315.0	350.0	478.0	313.0	331.7	405.5	381.7
25	499.7	391.7	348.5	394.0	332.5	187.5	283.0	348.1
153	516.5	567.5	410.2	451.5	348.0	425.0	309.5	432.6
Female SC	643.2	569.7	673.7	604.0	495.2	571.5	594.5	593.1
Male SC	468.2	602.0	505.7	521.7	367.5	465.2	398.0	475.5
Ore. 355	654.2	853.0	720.2	821.5	571.2	543.5	480.7	663.5
Means	532.6	544.1	504.6	546.2	415.3	418.8	403.7	

L.S.D. 1% for strains = 111.93 (mg.)

L.S.D. 1% for rates = 114.84 (mg.)

Table 3. Dry weight of corn roots on a per plant basis. Average of four replications (mg.).

Strains	Concentration (ppm.)							Means
	0	1	2	4	8	12	16	
9	296.0	170.0	249.0	308.2	282.0	181.2	160.7	235.3
13	200.5	102.5	75.5	171.2	101.2	135.2	145.5	133.1
25	183.7	127.2	124.5	180.0	133.5	110.7	146.7	143.7
153	289.7	216.7	156.2	200.7	165.0	224.0	12.6	192.4
Female SC	296.7	304.2	272.5	348.2	292.7	394.7	373.5	326.0
Male SC	184.7	226.5	229.5	249.7	106.7	245.5	130.0	196.1
Ore. 355	455.7	523.2	451.7	643.2	367.2	436.5	355.5	461.8
Means	272.4	238.6	227.7	300.2	207.0	246.7	200.9	

L.S.D. 1% for strains = 83.23 (mg.)

L.S.D. 1% for rates = 75.69 (mg.)

Table 4. Analysis of variance. Dry weights of corn shoots.

Source of Variation	d. f.	Mean Squares
Replications	3	80,299*
Strains	6	353,996**
Error a	18	21,656
Rates	6	119,485**
Rates x Strains	36	18,245
Error b	122	27,753
Total	191	

* = significant at the 0.05 level.

** = significant at the 0.01 level.

Table 5. Analysis of variance. Dry weights of corn roots.

Source of Variation	d. f.	Mean Squares
Replications	3	91,953**
Strains	6	380,322**
Error a	18	12,180
Rates	6	35,596*
Rates x Strains	36	11,093
Error b	122	12,223
Total	191	

* = significant at the 0.05 level.

** = significant at the 0.01 level.

and +35°C. The temperature of -12°C was achieved in a commercial freezer. The +4°C temperature was located in a cold storage room, and the other two treatments, in water tanks in the greenhouse. These water tanks were equipped with a thermostatically regulated electric heater. A thermostatically activated valve permitted the injection of cold water from a refrigerated tank. The balance of these two thermal sources provided satisfactory regulation of the water temperature.

Six sampling dates were selected from June 16 to December 17. On December 17, the jars were taken out of the tanks and refrigerators. Each jar was divided into four parts, each one placed in a 2-3/4 by 2-3/4 inch plastic pots. Barnyardgrass seed was placed on the top and covered with a layer of 3/8 of an inch of the same treated soil. No attempt was made to plant the same number of seeds because germination was only 69 percent. A small spoon was made out of a gelatin capsule that held approximately 50 seeds. One spoonful was planted per pot.

Pots were placed in trays and arranged in a randomized block design. Water was applied to each one in an attempt to minimize the movement of the herbicide.

Artificial illumination was provided by a battery of fluorescent tubes suspended over the pots, and was kept constant 24 hours a day.

Temperature was kept at 25°C.

Results. The results of this experiment are given in Tables 6, 7, 8, and 9. The results are given in terms of visual ratings (average of two independent evaluations). The least significant difference test was used in all the comparisons. Length of incubation was compared with the last sampling date; temperatures were compared with the +25°C because the mean at this temperature showed the maximum breakdown of the herbicide; rates were compared always with the 0 ppm. rate.

As can be seen in Tables 6 and 7, the chemical gradually lost its phytotoxicity with time at the lower rate of application. The minimum time for the initiation of breakdown of CP 50144 was 59 days. This is shown for the lack of significance between the fifth and the sixth dates of sampling; all the others being significant.

The rate of decomposition of the chemical was affected by the temperatures of storage: all showed significant differences at the 0.05 level. The maximum rate of inactivation was observed at +25°C.

The 2, 8, and 16 ppm. rates showed significant differences when compared against the check (0 ppm.).

Later on, the tops were harvested at soil level and dried in an oven at 75°C. The dry weights were analyzed and confirmed

Table 6. Visual rating of barnyardgrass control.[1/] Average of four replications.

Date	Time of Incubation (Days)	Temperature of Incubation (°C)	Concentration (ppm.)			
			0	2	8	16
1	151	-12	0	9.1	10	10
		+ 4	0	9.8	10	10
		+25	0	6.6	7.9	10
		+35	0	5.9	10	10
2	120	-12	0	10	10	10
		+ 4	0	10	10	10
		+25	0	4.5	9.9	10
		+35	0	5.5	10	10
3	109	-12	0	10	10	10
		+ 4	0	8.9	10	10
		+25	0	3.5	10	10
		+35	0	6.5	10	10
4	88	-12	0	10	10	10
		+ 4	0	9	10	10
		+25	0	3	9.7	10
		+35	0	6.3	10	10
5	59	-12	0	10	10	10
		+ 4	0	10	10	10
		+25	0	7.4	10	10
		+35	0	7.9	10	10
6	0	-12	0	8.1	10	10
		+ 4	0	9.6	10	10
		+25	0	8.2	10	10
		+35	0	10	10	10

1/ Visual rating of two independent observers.

0 = no injury

10 = complete control

Table 7. Dry weight of tops of barnyardgrass. Average of four replications (mg.).

Date	Time of Incubation (Days)	Temperature of Incubation (°C)	Concentration (ppm.)			
			0	2	8	16
1	151	-12	565	100	0	0
		+ 4	487	50	0	0
		+25	580	125	267	0
		+35	612	182	0	0
2	120	-12	742	0	0	0
		+ 4	432	30	0	0
		+25	475	300	20	0
		+35	507	290	0	0
3	109	-12	645	2	0	0
		+ 4	535	20	0	0
		+25	540	377	10	0
		+35	692	262	0	0
4	88	-12	672	62	0	0
		+ 4	700	25	0	0
		+25	617	507	7	0
		+35	375	237	0	0
5	59	-12	534	0	0	0
		+ 4	387	5	0	0
		+25	402	105	5	0
		+35	662	117	0	0
6	0	-12	700	80	0	0
		+ 4	355	60	0	0
		+25	680	20	2	0
		+35	802	0	0	0

Table 8. Analysis of variance. Dry weight of barnyardgrass.

Source of Variation	d. f.	Mean Squares
Replications	3	122,951
Time	5	30,917*
Error a	15	7,652
Temperatures	3	124,345**
Temperatures x Time	15	17,152*
Error b	54	8,854
Rates	3	6,921,117**
Rates x Time	15	29,219**
Rates x Temperature	9	88,841**
Rates x Time x Temperature	45	32,039**
Error c	216	12,182
Total	383	

* = significant at the 0.05 level.

** = significant at the 0.01 level.

Table 9. Analysis of variance. Visual rating of barnyardgrass control.

Source of Variation	d. f.	Mean Squares
Replications	3	0.826
Time	5	3.170*
Error a	15	0.804
Temperatures	3	27.953**
Temperatures x Time	15	1.757**
Error b	54	0.878
Rates	3	2,150.930**
Rates x Time	15	2.720**
Rates x Temperature	9	22.294**
Rates x Time x Temperature	45	2.180**
Error c	216	0.770
Total	383	

* = significant at the 0.05 level.

** = significant at the 0.01 level.

the results of the visual observations.

IV. Effect of Irrigation, Incorporation and Rates of CP 50144 on Barnyardgrass Control in Corn

The object of this experiment was to determine the effect of pre- or post-irrigation, incorporation or surface application, and rates of the herbicide in the control of barnyardgrass in corn under field conditions.

Materials and Methods. An experiment was conducted at Smith Farm near Corvallis on a Woodburn silt loam soil. The experiment was established as split-split plot. Two irrigation treatments, two forms of application, and three rates of the chemical were studied. Each treatment was replicated six times.

The land was planted with oats the previous fall, and was plowed in early spring. The field was seeded with barnyardgrass at a very heavy rate by means of a cyclone type seeder and incorporated with a light harrow.

Treatments (factor a) consisted of an application of the herbicide to a pre-irrigated field and application of the herbicide to a dry field. Sub-treatments (factor b) were represented by surface application or incorporation of the herbicide into the soil. Sub-sub-treatments consisted of the rates of 0, 2, or 4 lbs. a.i. per acre of CP 50144. The chemical was applied post-planting but pre-emergence to the crop. Incorporation was accomplished by means of a tractor driven rototiller working at a very shallow depth (one inch).

The experiment consisted of six blocks. Each block was divided in two, pre-irrigated and post-irrigated treatments. Each irrigation treatment was split in two, incorporated treatments and surface applied treatments. Each of the incorporated and the surface treatments had one replication of each of the herbicide rates: 0, 2, and 4 lbs. a. i. per acre.

Sprinkler irrigation was set up in such a way as to permit the application of two inches of water to either the pre- or post-irrigated plots. After the irrigated blocks reached a workable stage, the whole field was planted with Oregon 355 double cross hybrid corn by means of a cereal seeder. After planting, one half of each block was sprayed with 0, 2, and 4 lbs. of CP 50144 active ingredient per acre by means of a bicycle type sprayer. Immediately after the application, a tractor driven rototiller was passed over at one inch depth in order to avoid disturbing the planted corn seeds. The other half of the block was sprayed with the same rates, but were not incorporated.

Uniform sprinkler irrigation was applied as needed during the entire growing season. Twenty days after planting, the whole field received a uniform application of 2, 4-D (dacamine) at 0.75 lb./A. to control the broadleaved weeds.

Because of a late planting, a grain crop was not obtained. Data were, therefore, collected by harvesting the entire corn plants. Fresh weights were determined and a sample of ten plants per plot was dried for dry matter determination. Weeds were harvested with a motor mower from a strip 3 feet wide by 20 feet. Dry weights were determined from the harvested weeds.

Results. The results of the field experiment are shown in Tables 10 and 11. Excellent control of grassy weeds was obtained with the 2 and 4 pound rates. The control was effective until harvest time, although some seedlings were emerging in the treated plots at the end of the season.

Several methods were tested for evaluating the effect of the chemical before harvest. The quadrat (1 square foot) did not give accurate results because of the prostrate habit of growth of barnyard-grass and the late emergence of seedlings. Each seedling had to be recorded, thus giving a strong bias. Some plants were more than one foot in diameter but with the method were recorded as only one plant. In summary, the number of plants per square foot was not a true estimate of the weed damage.

The prostrate habit of the weed impaired the use of the frame

Table 10. Dry matter yield of corn (Kg. /plot). Average of six replications.

Rate Lb./A.	Pre-irrigated Incorp.	Pre-irrigated Surface	Post-irrigated Incorp.	Post-irrigated Surface
0	14.99	13.72	20.52	19.35
2	25.43	19.38	31.29	29.55
4	25.88	20.78	31.04	35.81

L. S. D. 1% for rates = 5.02 (kg. /plot).

Table 11. Analysis of variance. Dry weight of corn shoots.

Source of Variation	d. f.	Mean Squares
Replications	5	335.52
Irrigations	1	1,124.10
Error a	5	296.49
Incorporation	1	56.27
Incorporation x Irrigation	1	102.26
Error b	10	85.50
Rates	2	862.89**
Rates x Irrigation	2	30.83
Rates x Incorporation	2	22.00
Rates x Incorp. x Irrig.	2	36.32
Error c	40	41.73
Total	71	

** = significant at 0.01 level.
L. S. D. for rates at 1% level = 5.02 (Kg. /plot).
Means for rates: 0 = 17.14
2 = 26.41**
4 = 28.37**

method for the same reason.

The visual rating method showed clear advantages over the quadrat and frame methods, because several factors, such as percent of the area covered, number of plants, plant size and vigor, could be combined into a single estimate of control.

The check plots showed the tremendous impact of weed competition: corn plants were very reduced in size and vigor and showed clear effects of nitrogen deficiency.

Both the 2 and 4 lbs. a. i. per acre were equally effective in controlling the weed.

The statistical analysis of the dry matter yields of corn confirms the results of the visual observations.

The differences among rate means were tested with the New Multiple Range Test and showed significant differences between the 2 and 4 lbs. of active ingredient per acre and the check plots. No difference was encountered between 2 and 4 lbs./A. rates.

DISCUSSION AND CONCLUSIONS

Studies were conducted to determine the site of maximum toxicity of CP 50144 in barnyardgrass seedlings, the variable susceptibility of corn strains, and factors influencing the persistence and activity of this herbicide under both greenhouse and field conditions.

Although CP 50144 was absorbed through both the roots and the coleoptile of barnyardgrass seedlings, it was more toxic when absorbed by the coleoptile. Contrary to the effect of EPTC reported by Dawson and other authors, no abnormal coleoptile developed. The tip of the shoot became dry and ceased to grow when exposed to very low rates of the herbicide.

The roots also absorbed the chemical, but the damage was not as evident as with coleoptile absorption. A significant reduction in yield of dry matter was observed. Rates up to two parts per million were not sufficient to kill the seedlings during the study period, but its appearance was such as to suppose that they will never recover enough to mature seedlings. When absorbed through the roots, CP 50144 promoted an early development of the inflorescence. In 28 days, treated plants presented emerged panicles shedding pollen. This contrasted with the check plants, where no symptom of panicle emergence was noted.

The absorption of CP 50144 by the coleoptile of barnyardgrass seedlings indicates that a surface application of the chemical would be more effective than deep incorporation. At the rates studied, it is not possible to state conclusively whether coleoptile absorption alone is as effective as root and coleoptile uptake combined. It is possible that at lower rates both root and coleoptile uptake may be much more effective than coleoptile uptake by itself. This could be due to the simultaneous toxic effect of shoot and root uptake. If this were true, incorporation could be better than surface application.

One shortcoming of this study is that only one species, barnyardgrass, was studied. No indication is provided on what would be the effect of CP 50144 on other grass weeds. Recent research at Oregon State University indicates that some herbicides are active through root uptake. This could be true for CP 50144 on other species.

It has been found by several authors that corn usually has wide tolerance to atrazine. However, some strains have shown marked susceptibility to this compound. With this in mind, several strains of corn were tested for susceptibility to the compound CP 50144. A sample consisting of a commercial hybrid, the two single crosses, and the inbreds were tested. All strains were equally tolerant to the compound. Although the sample was not chosen at random, which prevents generalizations, the chances of finding a susceptible strain is rather remote, because strains widely different in vigor, such as inbreds and hybrids, were included and the rates of the product were greatly exaggerated. No interaction was found among rates and strains. A more detailed study with a random sample should bring more light on this subject.

In order to study the persistence of CP 50144 in the soil, treated soil was incubated at different temperatures and allowed to remain at these temperatures for a period of time ranging from 0 to 151 days. As no chemical analysis is available yet, a bioassay using barnyardgrass was conducted. The trend observed was that the product was gradually detoxified in the soil. This process was definitely associated with the temperature and the amount of product present. The fact that at 25^{o}C detoxification was at a maximum, suggests that microbiological decomposition is one of the key factors in breakdown. No attempt was made to duplicate the experiment in sterilized soil in order to evaluate the relative importance of microbiological decomposition. For this reason, the possibility of chemical breakdown cannot be discarded.

Maximum rate of detoxification at 25^{o}C occurred at 2 ppm. and slightly at 8 ppm. No detoxification was observed at 16 ppm. It is probably that the bioassay method of evaluation was not suitable to measure breakdown at this concentration. Nevertheless, it seems that for the period studied, the 8 ppm. rate was in the threshold of decomposition. It is very likely that if the experiment would have been kept for a longer period of time (more than 151 days), or if a more sensitive method of analysis were available, the decomposition of the 8 and 16 ppm. would have become evident.

Two criteria were used for evaluating this experiment. One was visual rating of the bioassay plants and the other was the dry weights of tops. Both methods gave comparable results. This indicates that visual evaluation can be used safely in experiments of this nature.

The fact that the coleoptile absorption was much more effective than the root absorption in producing barnyardgrass control was fully appreciated in the field study. Incorporation of the chemical failed to improve performance of this herbicide as compared to surface application. Nevertheless, this can be misleading because the depth of incorporation used was very shallow. It would be interesting to further explore the influence of depth of incorporation upon herbicidal activity.

No differences were encountered in the performance of CP 50144 when applied to dry or irrigated soil. This can be a consequence of the degree of adsorption of the product in the soil. If the product is held in the soil with enough force to prevent leaching, no special benefit can be expected. The degree of adsorption was not measured though, and it is very doubtful that any more conclusions can be drawn from the information gathered.

The degree of control obtained with the 2 and 4 pounds of active ingredient per acre was comparable and no special benefit from the higher rate was observed in this soil. Probably the product is so active that rates even lower than 2 pounds per acre can be satisfactory for controlling barnyardgrass.

SUMMARY

Studies were conducted to determine the site of toxicity of 2-chloro-2', 6'-diethyl-N-(methoxymethyl) acetanilide (CP 50144) to barnyardgrass. Additional studies were carried out to evaluate the differential susceptibility of several corn strains to various rates of CP 50144, the persistence of the chemical in the soil under a range of temperatures and at several rates, and the performance of the herbicide as a grass killer in a corn field. The results showed that:

1. CP 50144 was more toxic to barnyardgrass seedlings when the coleoptiles emerged through treated soil than when the roots grew into treated soil.

2. The chances of finding a strain of corn susceptible to CP 50144 are very small.

3. The product loses its bioactivity with time. The rate of detoxification was strongly dependent on the temperature of incubation and on the amount of the chemical present. Temperatures of 25^{o}C and 35^{o}C were more effective in producing detoxification of CP 50144 than either 4^{o}C or -12^{o}C. Maximum detoxification occurred at 25^{o}C. At this temperature, the two parts per million rate was broken down after 59 days of incubation. The 8 ppm. rate was in the threshold of toxicity after 151 days of storage. No symptom

of decomposition was encountered at the rate of 16 ppm. at any temperature. Detoxification was evaluated by the amount of control of barnyardgrass seedlings. The cause of decomposition of the chemical was not investigated.

4. Rates of 2 and 4 pounds of active ingredient per acre promoted excellent control of barnyardgrass in corn planted in the field. No deleterious effects to the crop were observed. The 4 pound rate did not show better barnyardgrass control than the 2 pound rate. No special benefit was derived from incorporation of the product when compared with surface application. No difference was encountered either when the product was applied in a dry or in an irrigated soil.

BIBLIOGRAPHY

1. Andersen, R. N. Differential response of corn inbreds to simazine and atrazine. Weeds 12:60-61. 1964.

2. Antognini, J. Soil incorporation of herbicides. In: Proceedings of the California Weed Conference, Sacramento, 1960. p. 112-114.

3. Appleby, A. P. The influence of soil temperature and soil placement on the phytotoxic properties of EPTC and other carbamate herbicides. Ph. D. thesis. Corvallis, Oregon State University, 1962. 84 numb. leaves.

4. Appleby, A. P., W. R. Furtick and S. C. Fang. Soil placement studies with EPTC and other carbamate herbicides on Avena sativa. Weed Research 5:115-122. 1965.

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

6. ______________. Fate of amitrole in soil. Weeds 11:167-170. 1963.

7. Ashton, F. M. and K. Dunster. The herbicidal effect of EPTC, CDEC, and CDAA on Echinocloa crusgalli with various depths of soil incorporation. Weeds 9:312-317. 1961.

8. Ashton, F. M. and T. J. Sheets. The relationship of soil adsorption of EPTC to oats injury in various soil types. Weeds 7:88-90. 1959.

9. Audus, L. J. Herbicide behaviour in the soil. Part II. Interactions with soil microorganisms. In: The physiology and biochemistry of herbicides, ed. by L. J. Audus. London, Academic Press, 1964. p. 162-206.

10. Bailey, G. W. and J. L. White. Soil pesticide relationship. Review of adsorption and desorption of organic pesticides by soil colloids with implications concerning pesticide bioactivity. Journal of Agricultural and Food Chemistry 12(4):324-332. 1964.

11. Baker, J. B. An explanation for the selective control of barnyardgrass in rice with CIPC. Weeds 8:39-47. 1960.

12. Beck, S. D. and E. E. Smissman. The European corn borer, _Pyrausta nubilalis_, and its principal host plant. Part IX. Biological activity of chemical analogs of corn resistance Factor A (6 methoxybenzoxalinone). Annals of the Entomological Society of America 54 (1):53-61. 1961.

13. Bollen, W. B. Herbicides and soil microorganisms. In: Proceedings of the Nineteenth Western Weed Control Conference, Las Vegas, Nevada, 1962. p. 48-50.

14. Brown, J. W. and J. W. Mitchell. Interaction of 2,4-dichlorophenoxyacetic acid in soil as affected by soil moisture, temperature, the addition of manure, and autoclaving. Botanical Gazette 109:314-323. 1948.

15. Burschel, P. and V. H. Freed. The decomposition of herbicides in soils. Weeds 7:157-161. 1959.

16. Call, F. Soil fumigation. Part IV. Sorption of ethylene dibromide on soils at field capacity. Journal of the Science of Food and Agriculture 8:137-150. 1957.

17. Castelfranco, P., C. L. Foy and D. B. Deutsch. Non-enzymatic detoxification of 2-chloro-4-,6-bis (ethylamino)-s-triazine (simazine) by extracts of _Zea mays_. Weeds 9:580-591. 1961.

18. Crafts, A. S. A theory of herbicidal action. Science 108:85-86. 1948.

19. Crafts, A. S. and W. W. Robbins. Weed control: a textbook and manual. 3d ed. New York, McGraw-Hill, 1962. 660 p.

20. Dawson, J. H. The effect of EPTC on barnyardgrass. Ph. D. thesis. Corvallis, Oregon State University, 1961. 107 numb. leaves.

21. ______________. Development of barnyardgrass seedlings and their response to EPTC. Weeds 11:60-67. 1963.

22. ______________. Effects of EPTC on barnyardgrass seeds. Weeds 11:184-186. 1963.

23. Day, B. E., L. S. Jordan and R. T. Hendrixson. The decomposition of amitrole in California soils. Weeds 9:443-456. 1961.

24. Derscheid, L. A. Physiological and morphological responses of barley to 2,4-dichlorophenoxyacetic acid. Plant Physiology 27(1):121-134. 1952.

25. Eastin, E. F., R. D. Palmer and C. O. Grogan. Mode of action of atrazine and simazine in susceptible and resistant lines of corn. Weeds 12:49-53. 1964.

26. Erikson, L. C. and H. S. Gault. The duration and effect of 2,4-D toxicity to crops grown on calcareous soil under controlled irrigation conditions. Agronomy Journal 42(5):226-229.

27. Freed, V. H., J. Vernetti and M. Montgomery. The soil behaviour of herbicides as influenced by their physical properties. In: Proceedings of the Nineteenth Western Weed Control Conference, Las Vegas, Nevada, 1962. p. 21-36.

28. Furtick, W. R. FC 518: Herbicide Science and Technology. Farm crops. Class notes. Corvallis, Oregon State University, Dept. of Farm Crops, 1966.

29. Hamilton, R. H. and D. E. Moreland. Simazine degradation by corn seedlings. Science 135:373-374. 1962.

30. Harris, C. I. and G. F. Warren. Adsorption and desorption of herbicides by soil. Weeds 12:120-126. 1964.

31. Hartley, G. S. Herbicide behaviour in the soil. Part I. Physical factors and action through the soil. In: The Physiology and Biochemistry of Herbicides, ed. by L. J. Audus. London, Academic Press, 1964. p. 110-161.

32. Hill, G. D. Soil factors and herbicide action. In: Abstracts of the 1956 meeting of the Weed Society of America, New York City, 1956. p. 42-43.

33. Hill, G. D., et al. The fate of substituted urea herbicides in agricultural soils. Agronomy Journal 47:93-104. 1955.

34. Hitchcock, A. E. and P. W. Zimmermann. Absorption and movement of synthetic growth substances from soils as indicated by the response of aerial parts. Contributions of the Boyce Thompson Institute 7:447-476. 1935.

35. Holly, K. Herbicides acting through the soil; a review. In: Proceedings of the Sixth British Weed Control Conference, Brighton, 1962. Vol. 2. London, n.d. p. 467-477.

36. Holstum, J. T., Jr. and W. E. Loomis. Leaching and decomposition of 2,2-dichloropropionic acid in several Iowa soils. Weeds 4:205-217. 1956.

37. Klingman, G. C. Weed control: as a science. 4th print. New York, Wiley, 1966. 421 p.

38. Knake, E. L., A. P. Appleby and W. R. Furtick. Soil incorporation on site of uptake for preemergence herbicides. Corvallis, Oregon State University, Dept. of Farm Crops. Personal communication, 1967.

39. Leopold, A. C. Auxins and plant growth. 3rd print. Berkeley, University of California Press, 1963. 354 p.

40. McKinley, J. R. Factors influencing the herbicidal activity of dimethyl 2,3,5,6-tetrachloroterephtalate. Master's thesis. Corvallis, Oregon State University, 1965. 66 numb. leaves.

41. Negi, N. S., H. H. Funderburk, Jr. and D. E. Davis. Metabolism of atrazine by susceptible and resistant plants. Weeds 12:53-57. 1964.

42. Obien, S. R., R. H. Suehisa and D. R. Younge. The effect of soil factors on the phytotoxicity of neburon to oats. Weeds 14:105-109. 1966.

43. Parker, C. The importance of shoot entry in the action of herbicides applied to the soil. Weeds 14:117-121. 1966.

44. Rice, E. L. Absorption and translocation of ammonium 2,4-dichlorophenoxyacetate by bean plants. Botanical Gazette 109: 301-314. 1948.

45. Riepma, P. Preliminary observations on the breakdown of 3-amino 1,2,4-triazole in soil. Weed Research 2:41-50. 1962.

46. Sheets, T. J. Effect of soil type and time on the herbicidal activity of CDAA, CDEC, and EPTC. Weeds 7:442-448. 1959.

47. ________________. Persistence of herbicides in soil. In: Proceedings of the Nineteenth Western Weed Conference, Las Vegas, Nevada, 1962. p. 37-42.

48. Sheets, T. J., A. S. Crafts and H. R. Drewer. Soil effects on herbicides: Influence of soil properties on the phytotoxicities of the s-triazines herbicides. Journal of Agricultural and Food Chemistry 10(6):458-462. 1962.

49. Sheets, T. J. and L. L. Danielson. Herbicides in soils. In: Nature and fate of chemicals applied to soils, plants, and animals, a symposium. Washington, D. C., 1960. p. 170-181. (U.S. Dept. of Agriculture. Agricultural Research Service. ARS 20-9)

50. Siegel, J. J., A. E. Erickson and L. M. Turk. Diffusion characteristics of 1,3 dichloropropene and 1,2-dibromo-ethane in soils. Soil Science 72:333-340. 1951.

51. Staniland, L. N. Trials of fluorescent tracers for insecticides in soil. Plant Pathology 10:78-84. 1961.

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

53. Upchurch, R. P. and D. D. Mason. The influence of soil organic matter on the phytotoxicity of herbicides. Weeds 10:9-14. 1962.

54. Upchurch, R. P. and W. C. Pierce. The leaching of monuron from Lakeland sand soil. Part II. The effect of soil temperature, organic matter, soil moisture, and amount of herbicide. Weeds 6:24-33. 1958.

55. Wade, P. Soil fumigation. Part I. The sorption of ethylene dibromide by soils. Journal of the Science of Food and Agriculture 5:184-192. 1954.

56. Weaver, R. J. and H. R. DeRose. Absorption and translocation of 2,4-dichlorophenoxyacetic acid. Botanical Gazette 107:509-521. 1946.

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

58. Whiteside, J. S. and M. Alexander. Measurement of microbiological effects of herbicides. Weeds 8:204-213. 1960.

59. Wolf, D. E. et al. Effect of 2,4-D on carbohydrates and nutrient element content and on capacity of kill of soybean plants growing at different nitrogen levels. Botanical Gazette 112:188-197. 1950.