Mirex Incorporation in the Environment: Phytotoxicity on Germination, Emergence, and Early Growth of Crop Seedlings[1]

by BETTAIYA RAJANNA[2] and ARMANDO A. DE LA CRUZ
Department of Zoology, Mississippi State University
P.O. Drawer Z, Mississippi State, Miss. 39762

In recent years, phytotoxic effects of pesticides and herbicides on seed germination, survival, and growth of seedlings have been reported by several investigators (e.g., COX and LILLY 1952; AMEEN et al. 1960; BOWLING 1964; OLIVER and FRANS 1968; DALVI et al. 1972; GAWAAD et al. 1972b). Laboratory and greenhouse studies by CHANG and FOY (1971) revealed that picloram (4-amino-3, 5, 6-trichloropicolinic acid) inhibited germination of soybean and safflower whereas radish and barley were not affected. COX and LILLY (1952) reported that germination and early growth of several field crops were affected by aldrin and dieldrin. CULLINAN (1949) stated that small quantities of DDT, BHC, chlorodane, and toxaphene, when applied to soil, depressed the growth of some crop seedlings. Similarly, GAWAAD et al. (1972a) observed that lindane was highly toxic to clover seedlings and suppressed growth, whereas the effects of DDT and heptachlor were very slight.

Mirex (dodecachloropentacyclo-1, 3, 4-metheno-2H-cyclobuta (cd) pentalene) was put into general field use in 1962 to control the imported fire ant (Solenopsis saevissima Forel, Formicidae). Mirex residue and toxicity to non-target organisms have recently received increasing attention (NAQVI and DE LA CRUZ 1973; DE LA CRUZ and NAQVI 1973). Little work has been done on the effect of this persistent insecticide on plants, specifically on seed germination, seedling emergence, survival and growth. It was observed that no mirex residue could be detected in several crops and grass grown in soil having residues of 0.01 ppm level (MARKIN et al. 1972) although bahiagrass (Paspalum notatum Flugge) contained 0.0003 to 0.017 ppm residues when grown in soil containing 0.001 to 0.002 ppm mirex. Using higher concentrations of mirex (0.3 to 3.5 ppm) we observed that seedlings of different crops take up and accumulate varying amounts of residues in different parts of the plant.

---

[1]Supported by a USDA grant under Cooperative Agreement no. 12-14-100-10, 935-33 with the Agricultural Research Service.

[2]Present address: Department of Agronomy, Mississippi State University, P.O. Drawer 5248, Mississippi State, Ms. 39762.

Bulletin of Environmental Contamination & Toxicology, Vol. 14, No. 1 © 1975 by Springer-Verlag New York Inc.

The objective of this study is to determine the effects of mirex on germination, emergence, and growth of seedlings of several commonly grown field and pasture crops. In order to achieve the objective of this investigation we used mirex concentrations higher than what is naturally found in the environment.

MATERIALS AND METHODS

The six crops tested were crimson clover (Trifolium incarnatum L. Var: elatius Gibelli and Bali.), johnson grass (Sorghum halpense (L.) Pers.), annual rye grass (Lolium multiflorum Lam.), tall fescue (Festuca arundunacea. Var: 'Alta'), alsike clover (Trifolium hybridum L.) and alfalfa (Medicago sativa L. Var: 'Cody'). The seeds were surface-sterilized by soaking in 5% chlorox solution (sodium hypochlorite) for 5 min before planting. For laboratory germination experiments, final test concentrations of mirex were prepared from a stock solution of recrystallized technical mirex dissolved in acetone and diluted with water. Twenty ml of acetone without mirex accordingly diluted with 4 liters of water, and water without acetone served as controls.

Germination experiments were conducted under constant temperature (25C). Four replicates of 50 seeds each for each species were planted on 15 x 30 cm germination blotters presoaked in the prepared mirex test solutions. After planting, the blotters were folded and placed in "Ziploc" plastic bags to keep them moist. During the germination period, tap water was used to keep the blotters moist. The plastic bags were placed in an automatic daylight controlled growth chamber. Germination counts were begun 4 days after planting and continued daily for 21 days on which day all the tests were terminated. Percent germination based on number of seeds planted was recorded.

Emergence and seedling growth experiments were conductedin a sandy substrate. Sand was used because it contains only a trace amount (0.04%) of organic matter which can bind and retain mirex residue. The other characteristics of the sand used and the manner by which mirex was applied to the test substrate to achieve different concentrations have already been described by us elsewhere in this volume. Sand treated with 100 ml acetone in 1 liter water and sand treated only with water served as controls.

The 5 kg sand for each test concentration was held in aluminum germination trays (50x30x10 cm). A total of 400 seeds of each crop was planted in 4 replicates consisting of 4 rows of 25 seeds for each replication. The seeds were covered with a thin layer of sand during planting. Five grams of 13-13-13 fertilizer per tray was applied in the initial irrigation.

Emergence counts were started 4 days after planting and continued daily up to 21 days, when no more seedlings emerged. Per cent emergence was based on number of seeds planted. A seedling was considered emerged when the coleoptile or hypocotyl emerged through the sand.

A duplicate emergence test similar to the above was conducted for seedling dry weight determination. All the emerged seedlings for each crop were clipped at the base immediately above the sand surface two weeks after planting and dried for 12 hrs at 120C. The dry weight obtained was computed on the basis of 100 seedlings.

RESULTS AND DISCUSSION

GLC analysis of the experimental planting substrate revealed final mirex concentrations of 0.15, 0.3, 0.7, 3.5, 7.5, 12.0, and 20.0 ppm. The results of the germination and emergence experiments shown in Table 1 indicate a significant (at 5% level) reduction in germination and emergence as the concentration of mirex increased. A close visual examination of seedlings revealed that some of the seedlings were poorly developed suggesting that the uptake of mirex by the young seedlings caused damage. The results also revealed that acetone, which is used as a "carrier" to bind mirex in the sand, had no effect on the emergence or germination of seeds.

The effects of mirex on seedling growth rate on the basis of dry weight of 100 seedlings after 2 weeks growth for each crop are presented in Table 2. It can be seen that seedling dry weight also decreased at higher amounts of mirex concentrations. Crimson clover, johnson grass, and annual rye grass showed initial significant reduction in growth rate at 0.15 ppm mirex concentration; tall fescue and alfalfa at 0.30 ppm concentration; and alsike clover at 0.70 ppm.

Insecticide and herbicide suppression of germination, emergence, survival and seedling growth of crop seeds have been demonstrated earlier by works of CULLINAN (1949), KAPPELMAN and BUCHANAN (1968), CHANG and FOY (1971), RANNEY and HEARTLEY (1972), PHILLIPS et al. (1972). The selective nature of mirex phytotoxicity of crop seeds observed by us agrees with the findings of CHANG and FOY (1971), GAWAAD et al. (1972b), and COX and LILLY (1952).

The exact mechanism and mode of toxicity of mirex on germination and development of seedlings has not yet been fully resolved. We have observed in one of our studies (elsewhere in this volume) that mirex is taken up and accumulated by seedlings of different crops. The uptake and accumulation of mirex was directly related to the mirex concentration in the rooting medium.

TABLE 1

Percentage germination and emergence of crop seeds exposed to mirex

Treatments	Crimson clover	Johnson grass	Annual Rye grass	Tall fescue	Alsike clover	Alfalfa
Controls			% Germination			
Water alone	93a*	57a	96a	86a	87a	83a
Water & acetone	92a	57a	96a	84a	87a	82a
Mirex (ppm)						
0.15	84a	42ab	90a	56b	63b	73b
0.30	80b	33b	92a	49b	61b	67b
0.70	71c	30bc	79b	56b	53b	71ab
3.50	74c	33b	78b	49b	55b	69b
7.50	71c	34b	64c	33c	50c	66b
12.00	70c	28c	68c	36c	45c	62c
20.00	72c	29c	59c	35c	46c	70b
Controls			% Emergence			
Water alone	94a	54a	93a	53a	78a	89a
Water & acetone	94a	54a	92a	53a	78a	88a
Mirex (ppm)						
0.15	87a	40ab	86a	47a	58b	69b
0.30	80b	30c	88a	36b	40c	69b
0.70	73c	28c	74b	38b	38c	62b
3.50	65cd	26c	66c	32bc	36c	66b
7.50	67c	23d	66c	30c	30cd	57c
12.00	60d	22d	58cd	30c	22d	58c
20.00	51d	23d	56d	28c	22d	54c

* Means within an array followed by the same letter do not differ significantly at the 0.05 level according to Duncan's Multiple Range Test

TABLE 2

Dry weight (mg) of 100 seedlings of various crops after 2 weeks growth in sand contaminated with different concentrations of mirex.

Treatments	Crimson clover	Johnson grass	Annual Rye grass	Tall fescue	Alsike clover	Alfalfa
Controls						
Water alone	786a*	755a	684a	694a	656a	775a
Water & acetone	780a	750a	687a	690a	640a	760a
Mirex (ppm)						
0.15	721b	637b	577b	675a	630a	750a
0.30	700b	677b	550b	590b	600a	650b
0.70	710b	660b	562b	618b	430b	484c
3.50	536c	571c	387d	550b	398b	484c
7.50	535c	548c	440c	413c	380c	394c
12.00	558c	513d	428c	385c	332c	353c
20.00	575c	518d	412c	392c	304c	380c

* Means within an array followed by the same letter do not differ significantly at the 0.05 level according to Duncan's Multiple Range Test.

The reduction in seed germination, seedling emergence and growth reported in the present study could be due to a rapid diffusion of water containing mirex into germinating seeds during the germination process.

The results of this study indicate that total germination, seedling emergence, and early growth are reduced in several plant species when exposed to concentrations of mirex exceeding 0.15 ppm. Normally the amount of mirex (incorporated in the bait) applied to areas infested by fire ants is small (4.2 g per hectare). No data are available to establish the exact quantity of this insecticide in the soil. Increasing concern about the effect of mirex on non-target organisms and its fate in the environment prompted the present investigation on the effect of mirex on germinating seeds and growing seedlings.

LITERATURE CITED

ALLEY, E.G.: J. Environ. Qual. 2, 53(1973).

AMEEN, O.A., A.D. DAY, and K.C. Hamilton: Agron. J. 52, 87(1960).

BOWLING, C.C.: J. Econ. Entomol. 57, 83(1964).

CHANG, I.K., and C.L. FOY: Weed Sci. 19, 58(1971).

COX, H.C. and J.H. LILLY: J. Econ. Entomol. 45, 421(1952).

CULLINAN, E.P.: J. Econ. Entomol. 42, 387(1949).

DALVI, R.R., B. SINGH, and D.K. SALUNKHE: J. Agri. Food Chem. 20, 1000(1972).

DE LA CRUZ, A.A. and S.M. NAQVI: Arch. Environ. Contam. Toxicol. 2, 255(1973).

GAWAAD, A.A.A., F.H. EL GAYAR and A.A. KHADR: Indian J. Agri. Sci. 42, 969(1972a).

GAWAAD, A.A.A., F.H. EL GAYAR, A.S. SOLIMAN, F.E. REHAB, and N.M. ALI: Phytopath. Z. 73, 189(1972b).

KAPPELMAN, A.J. JR., and G.A. BUCHANAN: Agron. J. 60, 600(1968).

MARKIN, G.P., J.H. FORD, J.C. HAWTHORNE, J.H. SPENCE, J. DAVIS, H.L. COLLINS, and C.D. LOFTIS: USDA APHIS. 81-3, 19(1972).

NAQVI, S.M. and A.A. DE LA CRUZ: Bull. Environ. Contam. Toxicol. 10, 305(1973).

OLIVER, L.R. and R.E. FRANS: Weed Sci., 16, 199(1968).

PHILLIPS, R.E., D.B. EGLI, and L.T. THOMPSON, JR.,: Weed Sci. 20, 506(1972).

RANNEY, C.D. and W.H. HEARTLEY, JR.: Crop Sci. 12, 847(1972).