THE EFFECT OF EPTC ON BARNYARD GRASS

by

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The author with full-grown barnyard grass plant.

THE EFFECT OF EPTC ON BARNYARD GRASS

INTRODUCTION

Barnyard grass (*Echinochloa crusgalli* (L.) Beauv.) is a summer annual grass of the millet tribe (Paniceae). The vigorous growth of barnyard grass in areas where it is adapted makes it a very serious weed in many crops. Ethyl N,N-di-*n*-propylthiolcarbamate (EPTC) is an effective soil-applied herbicide for the control of barnyard grass seedlings. The basic principles involved in the action of EPTC on barnyard grass are not known. The main objective of this research was to determine the site(s) of EPTC uptake and injury in barnyard grass and to characterize this injury. A second objective was to map the progression of germination, emergence and early growth of barnyard grass with respect to time, temperature, and depth of seeding. The information obtained should aid in controlling barnyard grass more effectively with EPTC.

REVIEW OF LITERATURE

Several authors have discussed barnyard grass from the standpoint of description (20, p. 712-715; 29, p. 73-75) or weed control (3, p. 39-47; 11, p. 105-115). These publications attest to its weedy characteristics and vigor as a crop competitor. Under some conditions, it is desirable as a soil stabilizer (33, p. 186) and as a wildlife food plant (5, p. 259; 6, p. 424-432; 22, p. 11). However, in most cases where barnyard grass occurs in crop land it is considered a serious weed and demands strict control measures. Apparently little attention has been given the species from the standpoint of its life history and development as no literature pertaining directly to this problem was found.

Grass Seedling Morphology

The morphology of grass embryos and the developmental morphology of grass seedlings have been investigated by many workers. The literature has been reviewed by McCall (23, p. 283-285). Van Tiegham (cited by McCall (23, p. 283) and Avery (2, p. 1)) early observed that there were three somewhat distinct patterns of grass seedling development represented by oats (Avena), corn (Zea), and wheat (Triticum). Recent papers by McCall (23, p. 283-322), Avery (2, p. 1-39), and Boyd and Avery (7, p. 765-779) deal very thoroughly with developmental morphology and anatomy of grass seedlings, especially oats, corn and wheat. These papers are helpful in understanding the developmental morphology of barnyard grass, also.

McCall disagrees with Boyd and Avery, and Avery about the interpretation of the structure of the grass embryo. This has resulted in a confusion of terminology concerning the parts of the grass seedling, because each partisan names certain significant morphological structures according to his own interpretation. McCall (23, p. 307) interprets the epiblast as a rudimentary leaf at node number 1, and the scutellum the second leaf at node number 2. The coleoptile is interpreted as the third leaf so that the elongating structure in the Zea type (representing barnyard grass) is the second internode. Avery (2, p. 37) and Boyd and Avery (7, p. 765-778) directly oppose McCall's interpretation. They state that the epiblast is not a leaf. Thus the scutellum is the first leaf attached at the first node. They interpret the coleoptile as the second leaf so the elongating structure of the Zea type is the first internode.

Existing knowledge does not allow one to decide which interpretation is correct; both are based on a justified opinion and backed by good data. Therefore, favoring the interpretation of one or the other in order to establish consistent terminology seems expedient. Because Avery's interpretation agrees better with the external morphology of the seedling, it will be accepted. The terms used in this work are therefore as follows: The scutellum and coleoptile are not controversial terms and will be used as generally defined. The elongating region of the seedling stem will be called the first internode. The second node at which the coleoptile (second leaf) is attached will be termed the coleoptilar node. Subsequent leaves will be termed first foliar leaf, second foliar leaf, etc. The primary seminal roots will be called primary roots. Any adventitious roots will be descriptively termed such as coronal adventitious roots for those developing at the crown. This, in general, is the terminology used by Kiesselbach (21, p. 13-16) in his detailed description of corn.

Some people have applied the term "mesocotyl" to the elongating internode below the coleoptile. Avery (2, p. 37), Boyd and Avery (7, p. 778) and McCall (23, p. 316-317) agree the term is obsolete and should not be used. It is misleading, being based on an early interpretation that the scutellum plus the coleoptile constitute the cotyledon; thus the elongating internode below the coleoptile would be in the middle of the cotyledon, hence "mesocotyl". Current use (15, p. 19-21) is still made of the term, however. The present investigator agrees with Avery and McCall that the term is of little value. This variously named structure will be termed first internode in this work.

Baker (3, p. 39-47) has demonstrated that the pattern of developmental morphology of seedlings may be very important with respect to herbicide sensitivity. Isopropyl N-(3-chlorophenyl) carbamate kills barnyard grass without harming rice. This selectivity apparently results because the coleoptilar node of barnyard grass is near the soil surface, whereas in rice it remains fairly deep in the soil.

EPTC as a Herbicide

The herbicide ethyl-N,N-di-*n*-propylthiolcarbamate (EPTC) has been shown to be a potent graminicide (30, p. 446-447) and especially effective in controlling barnyard grass (11, p. 105-115). Ashton and Sheets (1, p. 89-90) report that concentrations of 0.24 - 1.55 parts per million of EPTC in different soil types are sufficient to reduce the fresh weight of 30-day-old oat plants by 50%. Reports on the use of EPTC for weed control are voluminous. The Stauffer Chemical Company, manufacturer of EPTC, has prepared a brochure (31, p. 1-69) containing 259 abstracts of reports on the use of Eptam which is their trade name for EPTC. Most of the articles abstracted are from the progress reports of American and Canadian weed control conferences. No detailed reports concerning the fundamental action of EPTC on barnyard grass or any other species were found in the literature. Pieczarka and Warren (28, p. 137) report some limited work which indicated germination of pigweed, purslane, tomato, muskmelon and watermelon seed was not harmed by exposure to EPTC vapors for 24 hours.

Fang and Theisen (16, p. 295-298) and Yamaguchi *et al* (37, p. 86-87) report work with radioactively tagged EPTC which indicates that roots of several species pick up EPTC readily. The EPTC, or at least the radioactive portion of it was translocated throughout the plants. Fang and Yu (17, p. 91-92) allowed seeds of several species to imbibe water containing radioactively labeled EPTC. The breakdown rate of EPTC in the seedlings was studied. Differences in the rate of breakdown were found and it was suggested that tolerance to EPTC may be due to the ability of plants to degrade EPTC, while susceptible species may lack this ability. Yamaguchi et al (37, p. 86-87) reported that EPTC passed readily through the leaves of 11 species, including barnyard grass. Half of the material diffused through the leaves and was absorbed by carbon pads.

Sites of Uptake and Action of Herbicides

Several investigators have studied sites and mechanisms of phytotoxicity of some other herbicides (8, p. 1-14; 10, p. 85-86; 12, p. 15-21; 14, p. 473-493; 19, p. 352-361; 24, p. 147-166; 25, p. 15-17; 26, p. 432-435; 27, p. 65-73; 36, p. 250-254). The plant part or parts where herbicides enter plants has been determined for many materials. Isopropyl N-phenylcarbamate was found to enter via roots more readily than leaves (4, p. 430; 13, p. 95-96; 14, p. 483-487). Muzik et al (27, p. 72) reported that 3-(p-chlorophenyl)-1,1-dimethylurea entered velvet bean plants via root, stem or leaves. Weaver and DeRose (35, p. 510-511) report ready absorption of 2,4-dichlorophenoxy acetic acid by leaves of emerged plants. Taylor (32, p. 598-599) found the same material entered the roots of plants in nutrient solution. Funderburk and Davis (18, p. 9) report that sodium 2,2-dichloropropionate is absorbed by both the roots and the shoots of emerged corn plants, but more readily by the roots.

These limited citations of literature indicate root, stem and leaf tissue may serve as avenues for entrance of herbicides. Although shoot tissue (leaves and stems) absorbs various herbicides, all published work cited has dealt with application to shoot tissue above ground. Apparently no one has given particular attention to the subterranean leaf and stem tissue of emerging seedlings as specific sites of entrance for soil-applied herbicides. It seems to be commonly supposed that herbicides acting through the soil affect the plant via the roots.

EQUIPMENT

Certain specialized equipment had to be developed for some phases of this investigation. Equipment used by the personnel of the Crops Research Division, U. S. Department of Agriculture at Beltsville, Maryland[1], was used to expose plant parts to EPTC vapors. This consisted of a one-quart motor oil can, a ring jelly mold, and a clear plastic bag (Figure 1). Plants grown in untreated soil in the oil can were exposed to vapors from EPTC applied to a filter paper in the jelly mold. The plastic bag confined the EPTC vapors and vapor contact to the plants was effected.

A technique was developed for exposing selected parts of emerging barnyard grass seedlings to EPTC. A polyethylene sheet separated untreated soil from soil containing EPTC. A small polyethylene cone with a perforated apex was fitted into an x-shaped cut in the sheet (Figure 2). Soil pressure caused an effective seal between the sheet and cone. Emerging barnyard grass seedlings were able to pass through the holes in the cones. Predetermined parts of emerging barnyard grass seedlings were exposed to EPTC by various arrangements of the seed, the plastic barrier, and the treated soil.

The cones were made so the hole in the apex was covered by two flaps. Pressure from the soil closed these flaps preventing EPTC movement through the hole, yet plant parts could penetrate it. Bioassays of untreated soil separated by the plastic barrier from

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[1] Suggested by Dr. W. C. Shaw, Leader, Weed Investigations-Agronomic Crops, Plant Industry Station, Beltsville, Maryland.

Fig. 1. Apparatus consisting of a ring jelly mold, a quart oil can, and a plastic bag used for exposing barnyard grass seedlings to EPTC vapors.

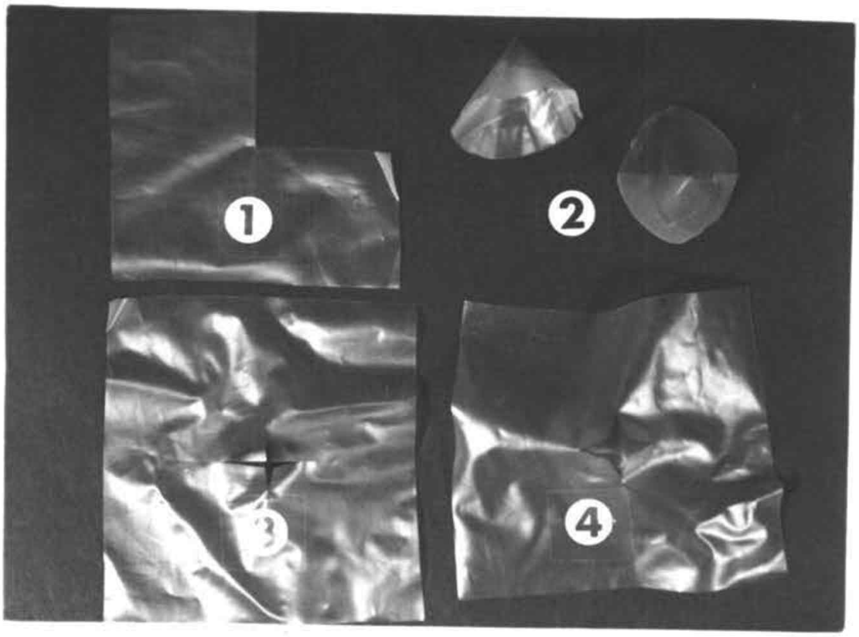


Fig. 2. Square of plastic sheet with corner removed (1) made into cones with perforated tips (2) which fit into x-shaped cut in plastic sheet (3) to form plastic barrier (4) used in selective exposure of seedling parts to EPTC.

EPTC-treated soil or an atmosphere containing EPTC vapors indicated that the barrier prevented EPTC movement into the untreated soil.

The oil can-jelly mold method and the plastic cone method were sometimes combined to effect vapor exposure of selected seedling parts.

The soil used in all the greenhouse studies was Ritzville very fine sandy loam.

SYMPTOMS OF EPTC INJURY IN BARNYARD GRASS

Materials and Methods. In order to observe the effect of EPTC on barnyard grass, and to determine at what concentrations the symptoms were produced, the following test was conducted. EPTC in petroleum ether was applied to dry soil in a flat pan. After the solvent had evaporated, the EPTC was thoroughly mixed with the soil in a mechanical soil mixer. Concentrations of 0, 1/4, 1/2, 1, 1 1/2, 2, 2 1/2, 3, 4, 5 and 6 parts per million by weight (ppm) were prepared. Four six-inch pots were filled with soil from each rate of EPTC and approximately 60 barnyard grass seeds were planted 1 inch deep in each pot. The pots were then placed in a warm greenhouse in a randomized block design with four replications. The pots were sub-irrigated from saucers.

Seventeen days after planting, emerged seedlings in each pot were counted. At this time the seedlings in one replicate were washed free of soil so the under-ground parts could be examined. As the remaining seedlings developed, they were observed periodically for symptoms of EPTC injury. They were discarded 10 weeks after planting.

Results. Barnyard grass seedlings emerged at about the same time in all treatments. Compared with soil having no EPTC, the emergence after 17 days was significantly reduced by 4, 5, and 6 ppm of EPTC (Figure 3, Table 1). Reduction in seedling emergence was due to cessation of growth of some seedlings before emergence rather than a reduction in percent germination. At the rates used, EPTC did not affect germination of barnyard grass seeds.

Fig. 3. Barnyard grass seedlings 17 days after planting in soil containing the indicated ppm of EPTC.

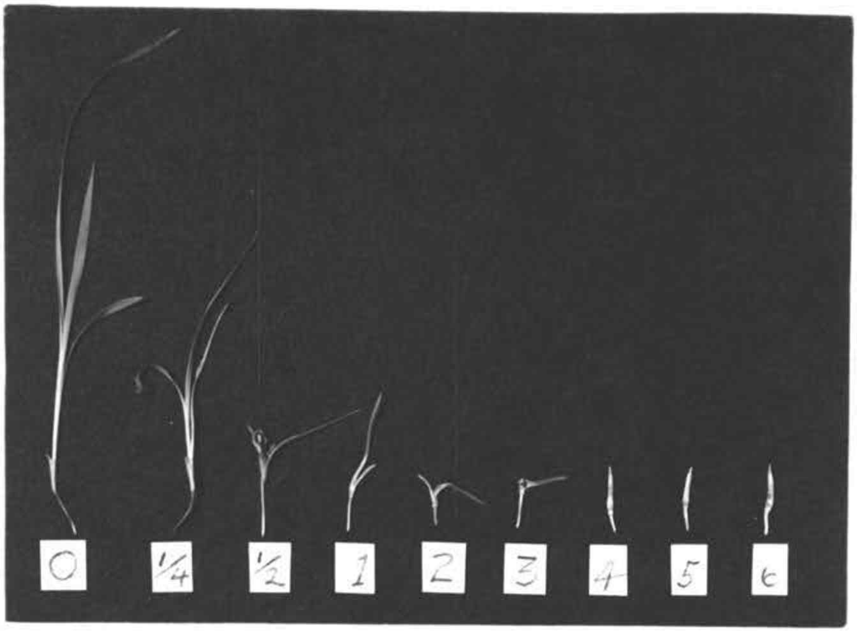


Fig. 4. Representative 4-week-old seedlings of barnyard grass grown in soil containing the indicated ppm of EPTC.

Table 1. Number of emerged barnyard grass seedlings from approximately 60 seeds planted in EPTC-treated soil. Counted 17 days after planting.

ppm of EPTC										
0	1/4	1/2	1	1 1/2	2	2 1/2	3	4	5	6
57	60	59	54	54	53	49	52	42*	43*	35**

* Significantly different from 0 ppm at 5% level of probability.
** Significantly different from 0 ppm at 1% level of probability.
LSD (5%) = 11.8 LSD (1%) = 15.6

In the untreated check, the foliar leaves contained within the coleoptile continued to develop after emergence. The coleoptile was split near the tip and the first foliar leaf grew upward, followed in order by subsequent leaves. Each grew in length and unrolled normally. After the seedlings emerged, abnormal foliar development was evident at all rates of EPTC. At 1 - 6 ppm of EPTC seedling development was arrested shortly after emergence and normal foliar leaves usually did not expand beyond the coleoptile. The coleoptiles with the enclosed foliar leaves were very dark green and appeared water-soaked. Swelling in the region of the coleoptilar node was common.

Four weeks after planting, the symptoms described below were observed. There was considerable overlapping of symptoms, but the progressive severity of injury shown in Figure 4 is representative.

At 1/4 ppm of EPTC, the first foliar leaf elongated beyond the coleoptile in most seedlings, but usually remained rolled longitudinally rather than unrolling normally. As time went on, additional foliar leaves were produced. In some cases the second leaf was normal; in others it was rolled similar to the first. In a few plants at 1/4 ppm, injury was more severe and normal leaves did not develop for quite some time. Whenever one foliar leaf developed normally, all subsequent leaves were normal.

At 1/2 ppm, some seedlings were similar to those described above. Most plants were more severely injured, however. Abnormal leaves grew beyond the coleoptile in most plants. Some eventually produced normal leaves and recovered but most produced no normal leaves and eventually died.

At 1 ppm, one foliar leaf sometimes developed beyond the coleoptile but remained tightly rolled longitudinally, and the plants eventually died.

At 2, 2 1/2 and 3 ppm, one tightly rolled foliar leaf sometimes grew a short distance beyond the coleoptile. More commonly, no leaves grew beyond the coleoptile. Instead, a distorted growth of foliar tissue ruptured the coleoptile just above the coleoptilar node and protruded a short distance.

At 4, 5 and 6 ppm, no expansion of the foliar leaves beyond the coleoptile occurred and the seedlings remained just as they were shortly after emergence until they died.

Death of the EPTC-injured plants progressed rather slowly. Many of the severely injured plants remained alive and unchanged in appearance 2 - 4 weeks after emergence. Beginning about ten days after emergence, some injured seedlings began to dry up and fall to the soil surface. The seedlings in which expansion of foliar leaves was limited to a rupturing of the side of the coleoptile (2 - 4 ppm of EPTC) were first to die, followed by those with more foliar leaf expansion and the ones in which the coleoptile was never broken.

Five weeks after emergence nearly all seedlings in the soil with 2 1/2 - 6 ppm of EPTC were dead. These seedlings were then discarded, but those treated with the lower rates of EPTC were maintained.

EPTC at 1/4 ppm did not kill any of the seedlings. Some were quite severely injured, but eventually recovered. Once a normally expanded foliar leaf was produced, the plant recovered. A leaf showing symptoms of EPTC injury never followed a normal leaf. Seedlings in soil containing 1/4 ppm of EPTC were quite variable six weeks after planting (Figure 5). Some had several normal leaves and were similar to the untreated plants. Others were very small and had just produced their first normal leaf.

Figure 6 shows a single seedling which has recovered from the effects of 1/4 ppm of EPTC. The first foliar leaf elongated but remained tightly rolled. The second and third foliar leaves were quite normal, but could not grow up through the center of the preceding leaf because it was too tightly rolled. Instead, they broke out through the leaf sheath near its base causing the seedling to appear branched. Remnants of the coleoptile can be seen about the base of both "branches".

The treatments which had 0, 1/4, 1/2, 1, 1 1/2, and 2 ppm of EPTC were discarded 10 weeks after planting. Representative 7- and

Fig. 5. Six-week-old barnyard grass seedlings grown in soil containing 1/4 ppm of EPTC.

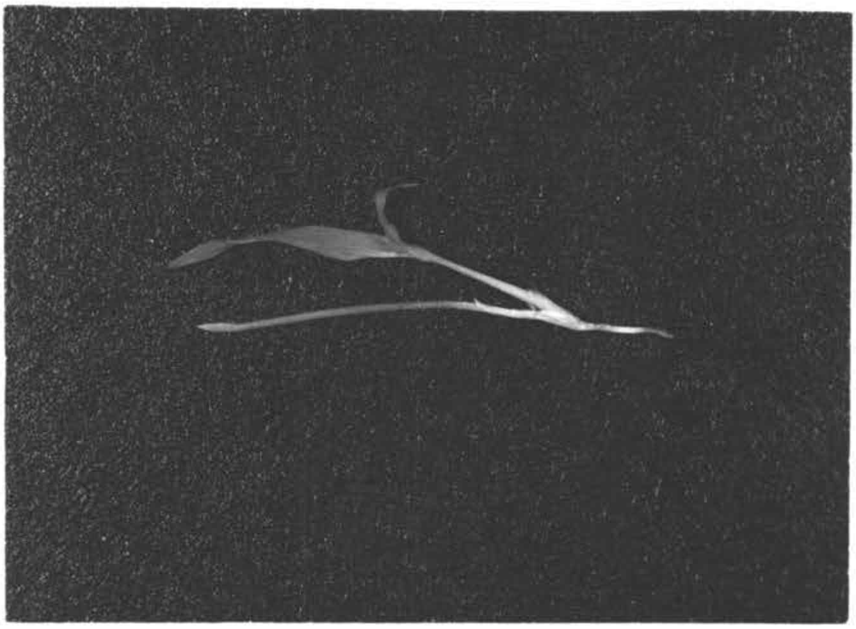


Fig. 6. Four-week-old seedlings of barnyard grass grown in soil containing 1/4 ppm of EPTC showing recovery from effects of EPTC.

10-week old plants are shown in Figures 7 and 8. The plants which recovered are normal and free of any EPTC symptoms. Even at 2 ppm, one plant recovered; although it was small, it appeared normal.

When the seedlings in one replicate were washed free of soil 17 days after planting, unusual symptoms were found. The first internodes of many treated plants were extremely kinked. This kinking was invariably restricted to the portion of the first internode below the soil surface. When barnyard grass grows out of doors in the spring, all of the first internode normally is below the soil surface. Elongation of this tissue ceases when the coleoptile is illuminated. The present experiment was conducted in a warm greenhouse in December with no supplemental light. As a result of the limited light the first internode elongated beyond the soil surface so that usually 1/2 - 1 inch of this stem tissue was above ground.

Mild kinking was evident in a few plants at 1/2 ppm. The kinking became more severe and more plants had kinked stems as the rate of EPTC increased. Typical seedlings from soil with 3 - 6 ppm of EPTC are shown in Figures 9 and 10, with a seedling of the same age from untreated soil. Notice the sharp distinction between the kinked and unaffected portions of the first internode. The soil surface was always at this line of separation.

Several seedlings from the higher rates of EPTC which failed to emerge are shown in Figure 11. In general, the first internodes of the unemerged seedlings were very severely kinked.

No adverse effects of EPTC on the roots of barnyard grass were observed.

Fig. 7. Barnyard grass seven weeks after planting in soil containing the indicated ppm of EPTC.

Fig. 8. Barnyard grass ten weeks after planting in soil containing the indicated ppm of EPTC.

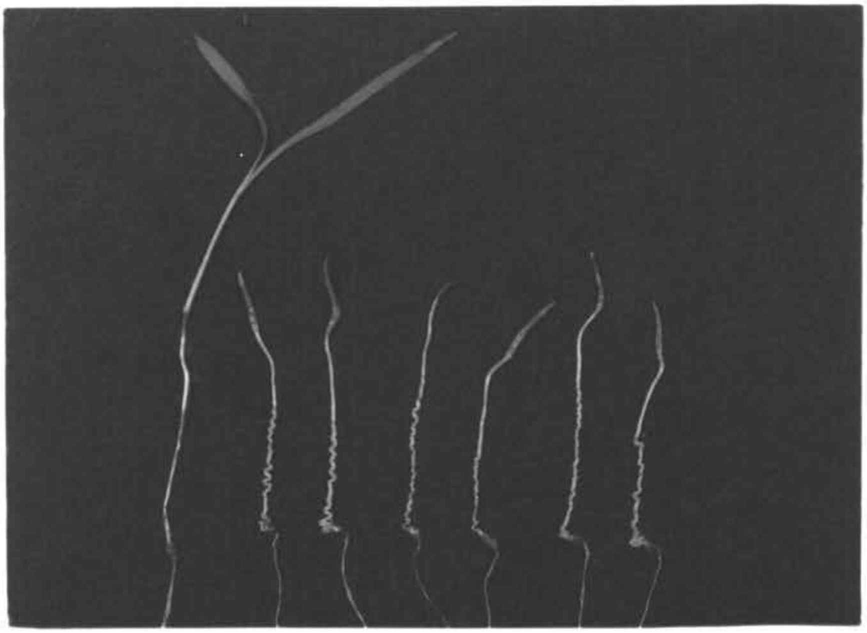


Fig. 9. Seventeen-day-old barnyard grass seedlings which emerged from soil containing 3-6 ppm of EPTC. Untreated plant of the same age on left.

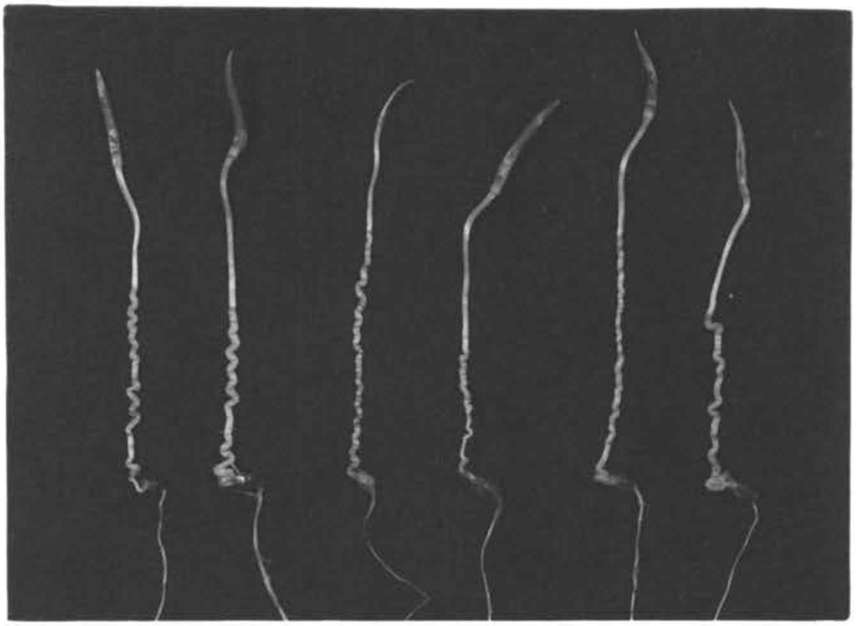


Fig. 10. Seventeen-day-old barnyard grass seedlings which emerged from soil containing 3-6 ppm of EPTC.

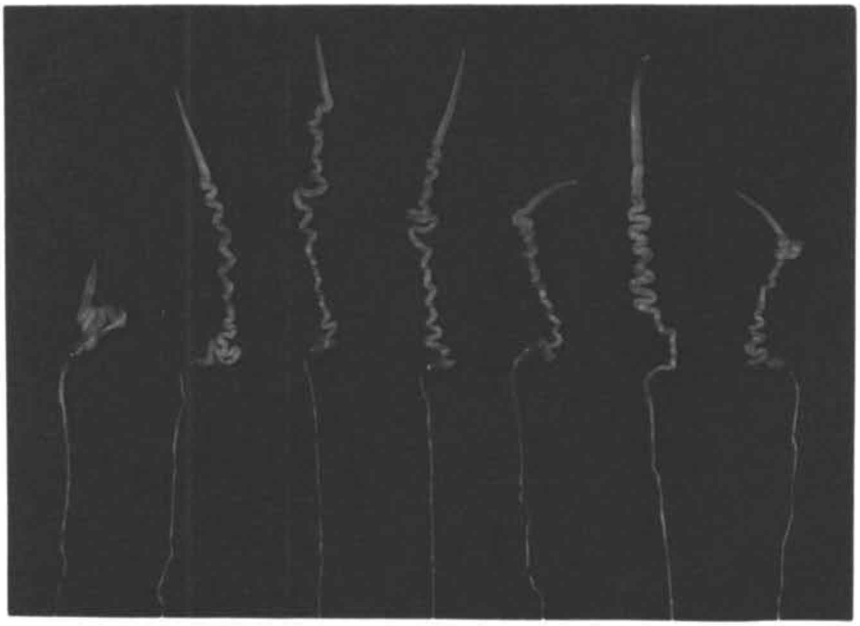


Fig. 11. Seventeen-day-old barnyard grass seedlings which failed to emerge from soil containing 3-6 ppm of EPTC.

RESPONSE OF THE FIRST INTERNODE TO EPTC

The kinking of the first internode of barnyard grass frequently associated with EPTC injury was studied to determine whether this is a primary or secondary effect of the herbicide.

Seedling Development in Paper Towels in the Presence of EPTC

Materials and Methods. Aqueous solutions were prepared containing 0, 5, 15 and 30 ppm of EPTC. Assuming complete solution, these rates correspond roughly to the concentrations in the soil solution of a fine sandy loam at field capacity containing 0, 1, 3, and 6 ppm of EPTC. Thirty-two rolls of paper towels, each containing 25 barnyard grass seeds were prepared as follows. A paper towel folded in half was marked with a pencil line 3 inches from one end. Twenty-five barnyard grass seeds were distributed on this line and a second folded towel was laid on top of them. The towels with the seeds were then rolled up loosely and secured with a rubber band. Four of these rolls were placed in each of eight 800 ml beakers and held upright by a cardboard circle with 4 holes to accommodate the rolls (Figure 12). These beakers were set up in pairs. One hundred ml of one of the EPTC solutions was added to each beaker of a pair. A small plastic bag was then fitted over the towel rolls and secured to the beaker with a rubber band to prevent water loss by evaporation. The 100 ml of solution wet the towels leaving about 25 ml in the beaker. The beakers were placed in a dark germinator at 32° C. The barnyard grass seedlings were able to elongate vertically

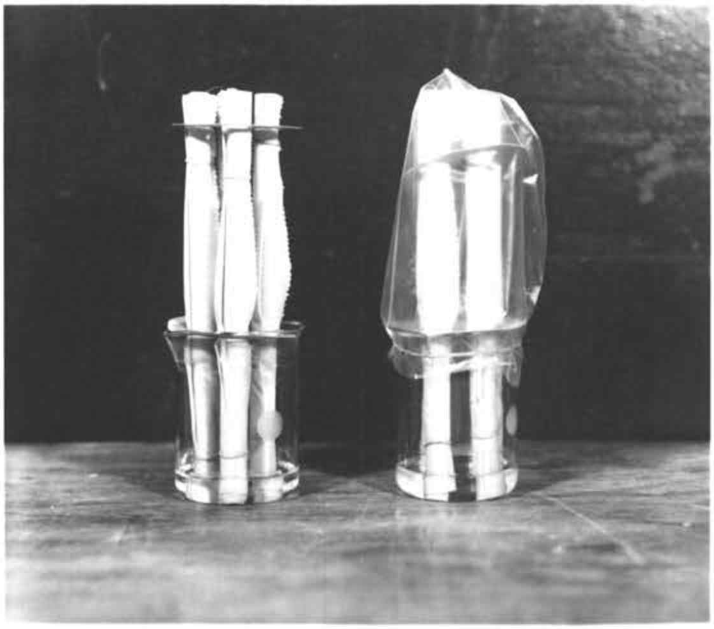


Fig. 12. Apparatus consisting of an 800 ml beaker and four rolls of paper towels in which barnyard grass germinated and elongated.

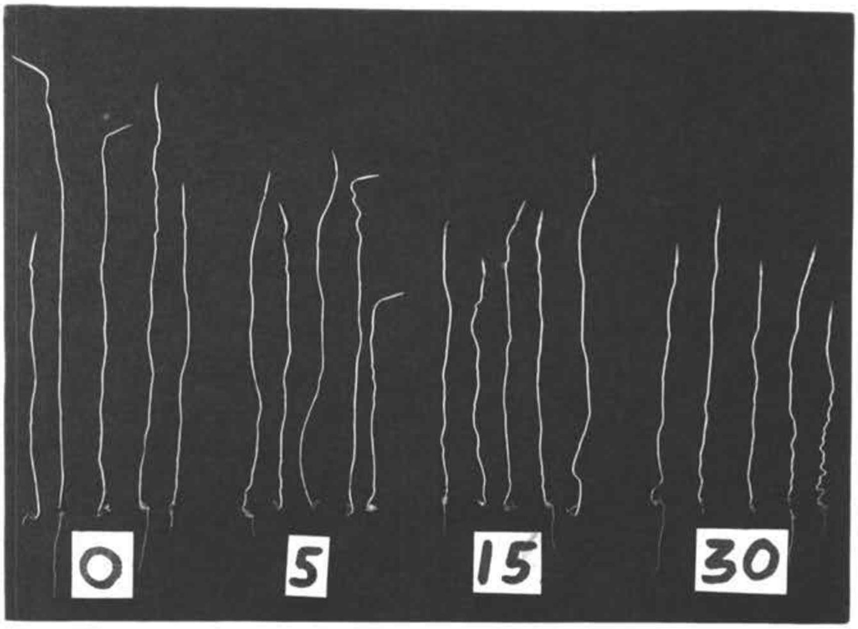


Fig. 13. Representative barnyard grass seedlings 7 days after placing seed in rolled paper towels moistened with water containing the indicated ppm of EPTC.

between the folds of paper with less resistance than would be encountered in emerging through soil.

On the fifth and seventh days, one towel roll was removed from each beaker. This provided duplicate rolls from each concentration of EPTC on each day. The lengths of primary root, first internode, coleoptile and total shoot were determined for the 20 largest seedlings in each roll. Seedlings in the remaining rolls were not measured but were observed for general appearance on the seventh day.

Results. Barnyard grass seeds germinated equally well at all concentrations of EPTC. About 90% of the seeds germinated. Table 2 contains a summary of the seedling measurements. Each figure is an average of 20 seedlings. Lengths of first internode, coleoptile and total shoot decreased with increased concentration of EPTC. The length of the primary root varied considerably; the root length of individual seedlings ranged from 0 to 45 mm. There was no relationship between concentration of EPTC and root length, nor were there any visible formative effects of EPTC on the roots.

The kinking of the first internode which is commonly observed in barnyard grass seedlings grown in soil with EPTC (Figure 10) was rarely observed in the seedlings germinated in towels. Only about 15% of the seedlings at 30 ppm showed some degree of this symptom and it was mostly absent at the lower concentrations. The coleoptiles of the plants exposed to EPTC appeared injured, and many of them became brown by the seventh day. The coleoptilar node was often swollen, as had been observed earlier. Representative

Table 2. Lengths in mm of root, first internode, coleoptile and total shoot of barnyard grass seedlings grown in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

Concentration	Primary root	First internode	Coleoptile	Total shoot
		5 Days after seeding		
0 ppm	3.1	71.4	4.1	75.5
5 ppm	4.1	66.7	3.3	70.0
15 ppm	5.3	60.5	2.8	63.3
*30 ppm	4.6	51.1	3.5	54.6
		7 Days after seeding		
0 ppm	7.9	85.7	5.6	91.3
5 ppm	4.2	77.0	4.5	81.5
15 ppm	5.7	70.8	3.9	74.7
30 ppm	8.8	57.5	3.9	61.4

* Measurements for 30 ppm taken after 6 days instead of 5.

seedlings from the 4 concentrations of EPTC are shown in Figure 13.

The formation of adventitious roots on the first internode of barnyard grass seedlings was not inhibited by EPTC. In fact, these roots were more abundant at the higher rates.

First Internode Elongation in Loose Dry Soil Containing EPTC Vapors

Materials and Methods. In this experiment, seeds of barnyard grass were germinated in untreated moist soil. The emerging shoots passed through a plastic barrier into loose, dry soil containing EPTC vapor (Figure 14). Eight barnyard grass seeds in two cans were exposed to EPTC vapors. In addition, seeds were planted in two other cans without exposure to EPTC vapors. After the seedlings emerged, they were recovered and observed for symptoms of EPTC injury.

Results. Seedling emergence was very good. All seedlings in the presence of EPTC vapors were injured. The coleoptilar node swelled, the young leaves within the coleoptile became dark green and appeared water-soaked, and leaves did not grow beyond the coleoptile. The part of the first internode which elongated in the loose dry soil containing EPTC vapors was straight and normal in appearance. A certain amount of kinking occurred in the first internode within the cone before exposure to EPTC, but the EPTC vapor did not induce kinking. Representative treated and untreated seedlings are shown in Figure 15.

A few seedlings failed to emerge because the hole in the apex of the cone was too small. A seedling from the untreated check in which the tip of the coleoptile lodged in the hole is shown in Figure 16. The first internode became very much coiled and kinked. This kinking was somewhat similar to that associated with EPTC injury shown in Figure 10.

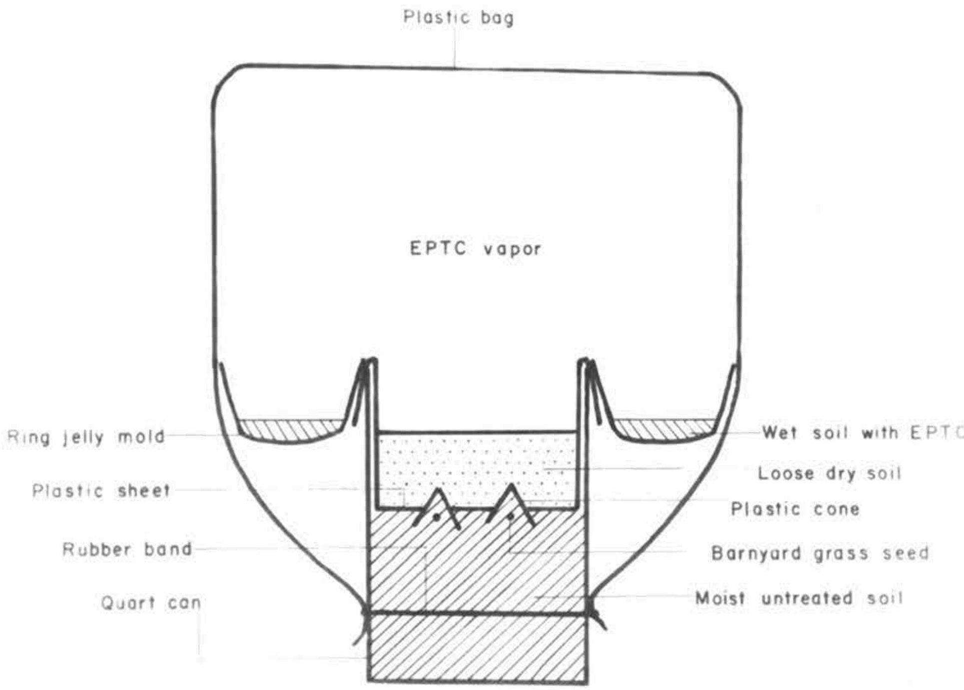


Fig. 14. Diagram of apparatus used wherein shoots of barnyard grass seedlings elongated in loose, dry soil containing EPTC vapors.

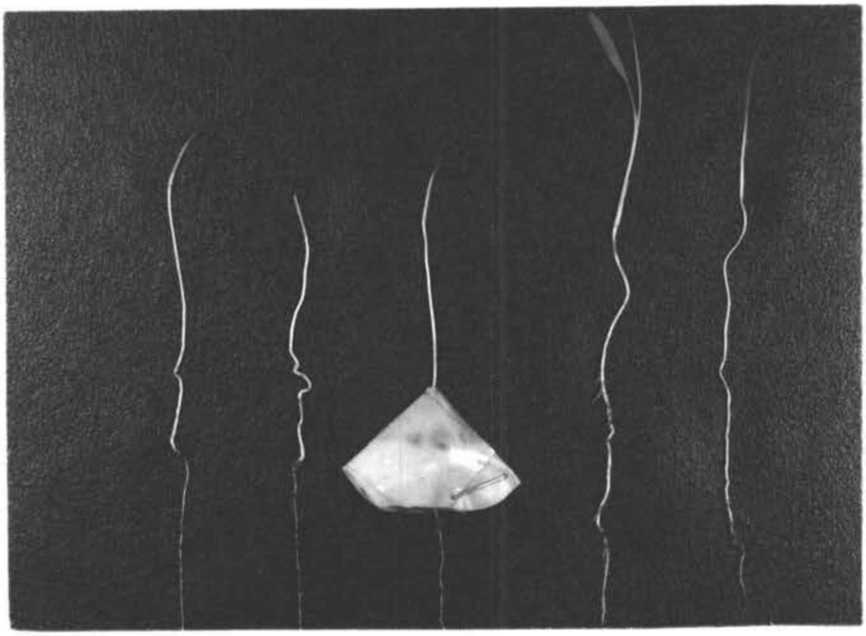


Fig. 15. Barnyard grass seedlings which germinated in untreated soil under plastic cones. Shoots of three on left elongated in loose, dry soil containing EPTC vapors above cone. Two on right were similarly grown without EPTC vapors. Plastic cone remains in place on center seedling.

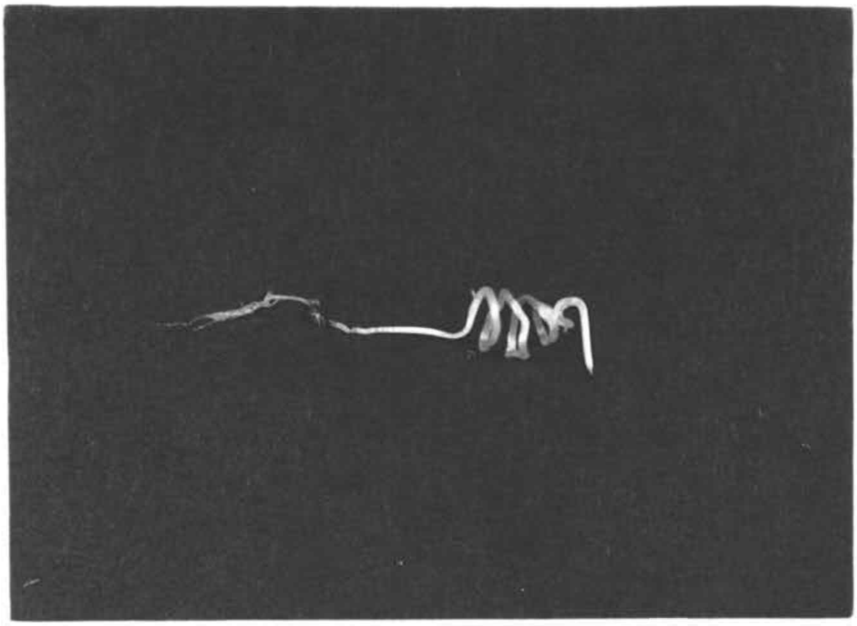


Fig. 16. Barnyard grass seedling grown in untreated soil under plastic cone having hole in apex too small for coleoptile to penetrate.

Progressive Development of First Internode Kinking

Materials and Methods. An effort was made to follow the progression of first internode kinking associated with EPTC injury. Barnyard grass seeds were planted 3/4 and 1 1/2 inches deep in four-inch pots in untreated soil and soil containing 3 ppm of EPTC. Seeds and/or seedlings were recovered from the soil by careful screening and washing 3, 4, 5, 6, 7, 8, 9, 10, 13 and 18 days after planting. Representative seedlings were photographed in an effort to provide a serial pictorial record of the development of kinking in the first internode during emergence.

Results. The periodic observations of growing barnyard grass seedlings failed to show how the kinking of the first internode progressed. The degree of kinking varied considerably at the different sampling dates (Figure 17). Apparently some condition peculiar to the individual pots of soil caused the plants to kink rather than EPTC exposure per se. Soil compaction seemed a likely possibility.

Kinking of the First Internode in Compacted EPTC-treated Soil

Materials and Methods. Air dry soil containing 3 ppm of EPTC was prepared by applying the appropriate amount of commercial EPTC in petroleum ether and mixing thoroughly after the solvent had evaporated. The soil was moistened approximately to field capacity. When the soil was no longer sticky, it was mixed until friable and used to fill 16 one-quart oil cans. Approximately 60 barnyard

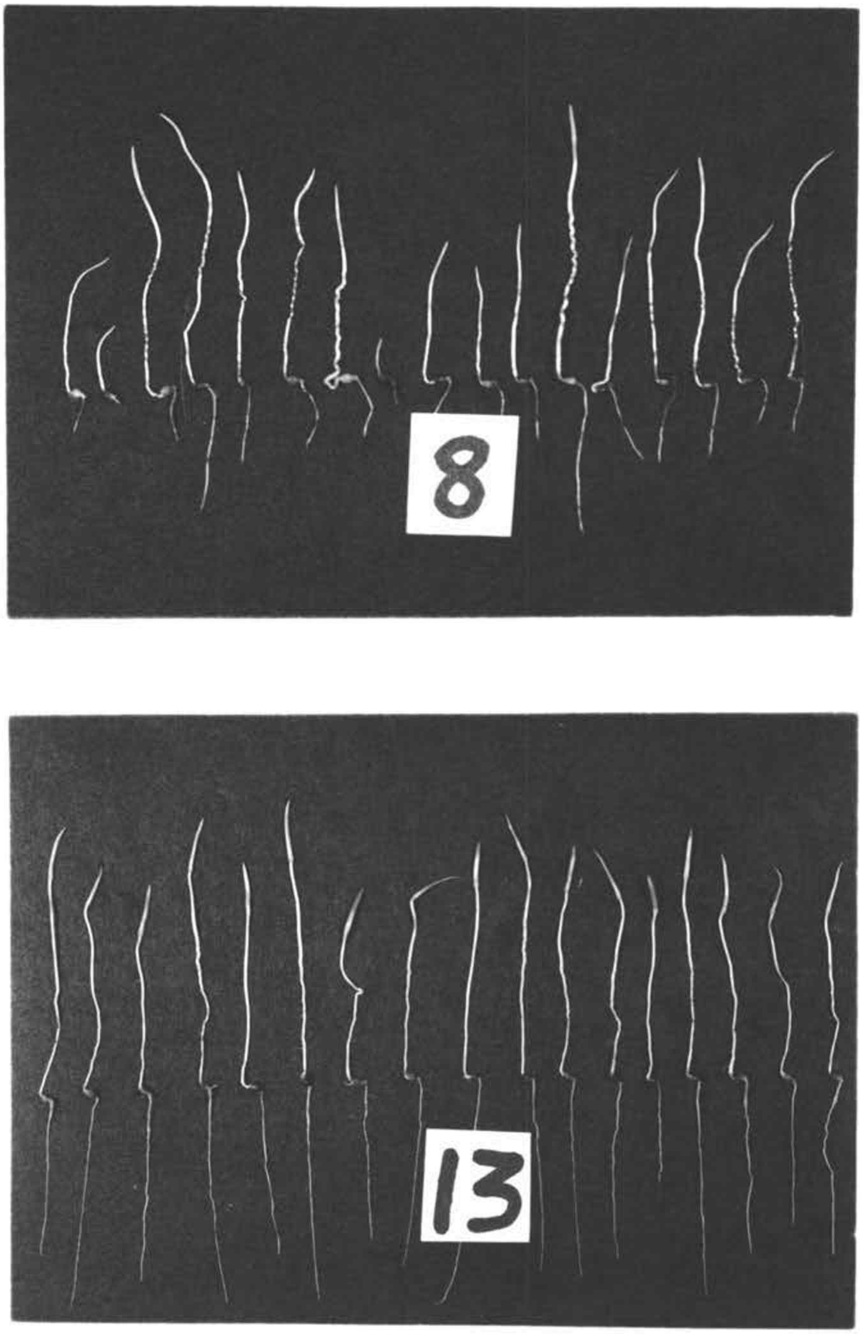


Fig. 17. Barnyard grass seedlings 8 and 13 days after seeds were planted 1 1/2 inches deep in soil containing 3 ppm of EPTC showing variableness of first internode kinking.

grass seeds were planted 2 inches deep in each can. Four treatments with four replications were established by applying 0, 6, 12 and 24 lb. of pressure per square inch to the soil surface in the cans. This was done by placing a circular piece of wood of known area on top of the soil in the can. The can was then placed on a platform scale and pressure applied until the scale registered a value equal to the product of the area of the disc in square inches times the desired pounds pressure per square inch to be applied. Each can was covered with a plastic bag to prevent drying and thus eliminated the need for watering. The covered cans were placed under a bench in a warm greenhouse. After seven days, the plastic bags were removed, and the emerged seedlings were counted. Emerged and unemerged seedlings were recovered by washing and screening. The percentage of the total seedlings in which the first internode showed kinking was determined.

<u>Results.</u> The seeds germinated uniformly in all the treatments. All showed typical coleoptilar symptoms of EPTC injury. The number of seedlings from approximately 60 seeds and the percentage of these which showed some degree of kinking of the first internode are shown in Table 3. Although all were exposed to the same concentration of EPTC and all were lethally injured, the seedlings in the loose soil showed very little kinking of the first internode. As the soil compaction increased, the amount of kinking increased, both in the percentage of seedlings kinked and the severity of kinking (Figure 18).

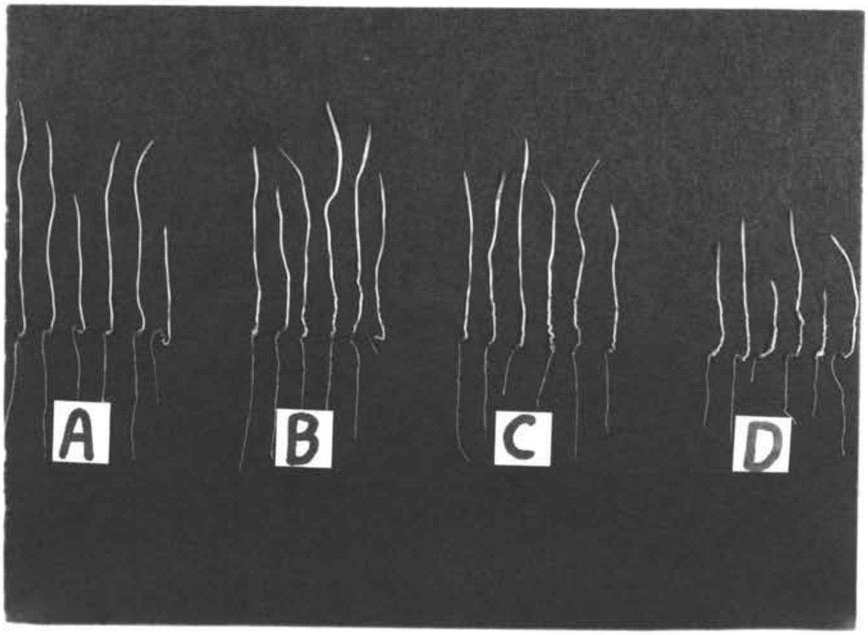


Fig. 18. Barnyard grass seedlings grown in soil containing 3 ppm of EPTC to which 0, 6, 12 and 24 lb. pressure per square inch (A, B, C and D, respectively) had been applied after planting seed 2 inches deep.

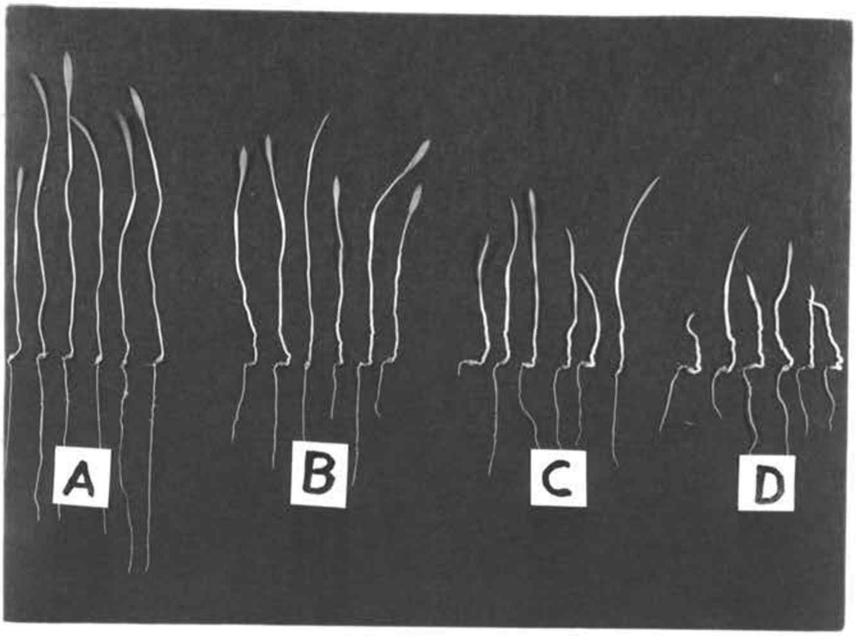


Fig. 19. Barnyard grass seedlings grown in soil containing no EPTC to which 0, 60, 120 and 240 lb. pressure per square inch (A, B, C and D respectively) had been applied after planting seeds 1 1/2 inches deep.

Table 3. Effect of soil compaction on first internode of EPTC-injured barnyard grass seedlings.

Pressure applied to soil surface	Total seedlings	Percent having kinked first internode
0 lb/in^2	36	6
6 lb/in^2	43	60
12 lb/in^2	38	82
24 lb/in^2	38	99

Kinking of the First Internode in Compacted Soil Without EPTC

Materials and Methods. A test similar to the foregoing was conducted using soil without EPTC. The pressures applied were 0, 60, 120 and 240 pounds per square inch. These pressures are ten times as great as those applied to the soil treated with EPTC.

Four additional cans of moist soil were prepared to which 0, 60, 120 and 240 pounds pressure per square inch were applied. The pounds of weight required to insert a dissecting needle of approximately the diameter of a barnyard grass shoot 1 1/2 inches into the soil was determined 10 times for each soil. This was done by placing the can on a scale and pushing the needle downward into the soil. The pounds registered when the needle penetrated 1 1/2 inches into the soil was recorded. This indicated the increased resistance to seedling emergence which compaction caused.

Results. The pounds of weight required to insert a dissecting needle 1 1/2 inches into the soil of the four treatments is shown in

Table 4. The force required to insert the needle increased considerably as soil compaction increased. The increased compaction probably made it increasingly difficult for the barnyard grass shoots to penetrate the soil also.

Table 4. Effect of compaction on the force required to insert a needle of 1 mm diameter into soil. Average of 10 trials.

Pressure applied to soil surface	Pounds weight required to insert needle 1 1/2 inches into soil
0 lb/in^2	0.10
60 lb/in^2	2.17
120 lb/in^2	3.16
240 lb/in^2	5.26

The seeds germinated uniformly in all treatments, but emergence was reduced under conditions of greatest compaction. The number of seedlings from approximately 60 seeds and the percentage of these which showed some degree of kinking of the first internode are shown in Table 5. Kinking of the first internode, similar to that which was observed in response to EPTC exposure, was present in all the compacted soil. It became somewhat more frequent and much more severe as the compaction increased (Figure 19). The amplitude of the kinking was less when induced by compaction than when induced by EPTC. This is reasonable because the compacted soil would restrict the lateral movement involved in kinking.

Table 5. Effect of soil compaction on first internode of barnyard grass seedlings grown in soil without EPTC.

Pressure applied to soil surface	Total seedlings	Percent having kinked first internode
0 lb/in^2	47	1
60 lb/in^2	41	82
120 lb/in^2	46	91
240 lb/in^2	38	95

Geotropism of Barnyard Grass Shoots Lethally Injured by EPTC

Materials and Methods. A number of EPTC-injured barnyard grass seedlings were washed free of soil and laid horizontally on wet porous paper at room temperature under very little light. After two days they were observed for geotropic response.

Results. The EPTC-injured seedlings responded normally to geotropism. The region of the intercalary meristem in the upper end of the first internode bent, raising the coleoptiles to a vertical position. Although the foliar tissue was lethally injured and incapable of further normal development, the stem tissue below it functioned normally. Seedlings after bending are shown in Figure 20.

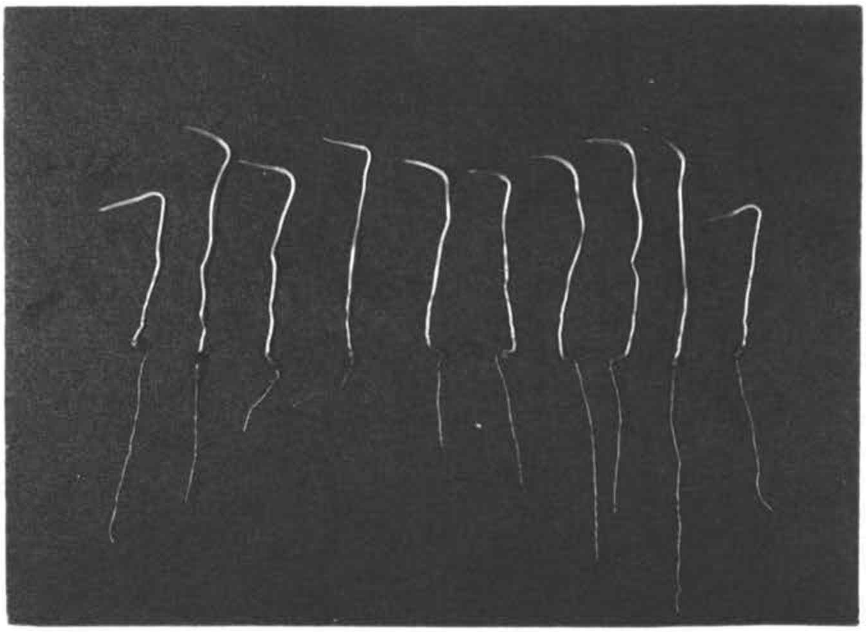


Fig. 20. Barnyard grass seedlings lethally injured by EPTC showing normal geotropic response after lying horizontally on moist paper for 2 days.

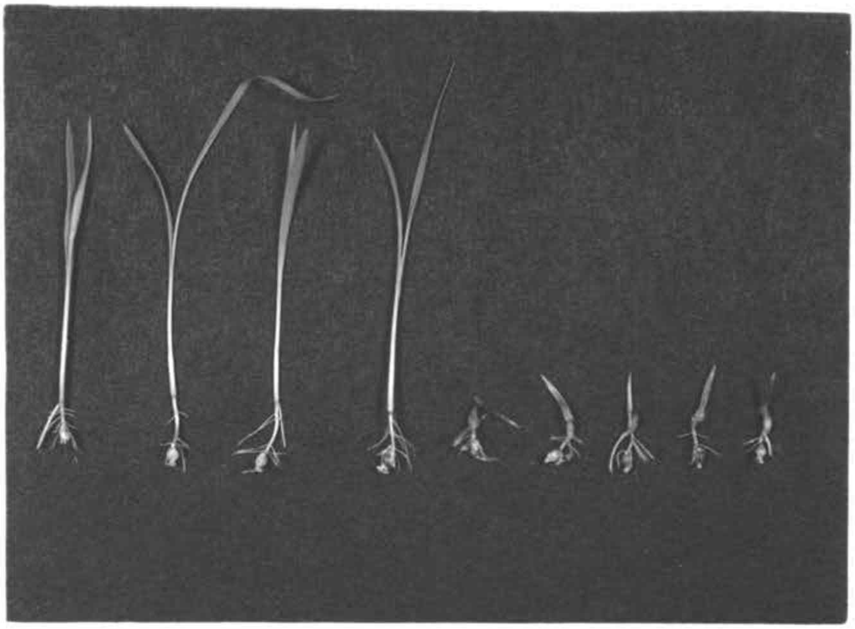


Fig. 21. Barnyard grass seedlings having an abundance of coronal and first internode adventitious roots. Seeds germinated on surface of firmly packed, moist soil under sealed plastic bag containing EPTC vapors (seedlings on right) and without EPTC (seedlings on left).

SITES OF UPTAKE AND LETHAL ACTION OF EPTC

The purpose of this portion of the investigations was to examine the effects of EPTC on leaf tissue in greater detail and to study the effect of EPTC on roots. The relationship between sites of injury and uptake was also studied. The effect of EPTC on seven other grasses was studied and compared to the effect on barnyard grass.

Effect of EPTC Vapors on Germination and Seedling Development

Materials and Methods. Four one-quart oil cans were filled with moist soil. Approximately 60 barnyard grass seeds were planted one inch deep in each can. A jelly mold and plastic bag were put on each can. Two bags contained EPTC vapors; two did not. When the seedlings emerged, they were observed periodically.

Four one-quart oil cans were filled to the brim with firmly packed, moist soil. Approximately 60 barnyard grass seeds were distributed on the soil surface in each can. A jelly mold and plastic bag were put on each can. Two bags contained EPTC; two did not. The seeds and resulting seedlings were observed periodically for three weeks and then discarded.

Results. Barnyard grass seedlings which emerged from soil under an atmosphere containing EPTC vapors were lethally injured. Symptoms were the same as those which develop in seedlings grown in soil containing EPTC.

The seeds on the surface of firm, moist soil in the presence of

EPTC vapors germinated as well as those which were untreated. Typical foliar symptoms of EPTC injury were present in the seedlings. The leaves within the coleoptile were very dark green and appeared water-soaked. These leaves did not develop normally beyond the coleoptile and the plants eventually died.

Under the conditions of high humidity within the plastic bags, adventitious roots developed on the first internodes and at the crowns of the barnyard grass seedlings as they normally do in soil (Figures 40-45). Both the coronal adventitious roots and the adventitious roots on the first internode of the EPTC-treated plants were identical in appearance and equal in number to those of the untreated check. Representative seedlings are shown in Figure 21. Injury to the leaf tissue had already taken place before the adventitious roots were produced. Therefore, the seedlings produced normal roots after they had been lethally injured by EPTC. Furthermore, this root growth occurred while the plants were still in the presence of EPTC vapors.

Differential Exposure of Shoot and Primary Root of Emerging Seedlings to EPTC in Soil

Materials and Methods. The primary root and shoot of barnyard grass were differentially exposed to EPTC during emergence. The plastic cone method was used to separate treated and untreated soil. The following four treatments involving exposure of selected seedling parts to EPTC were set up in five replications:

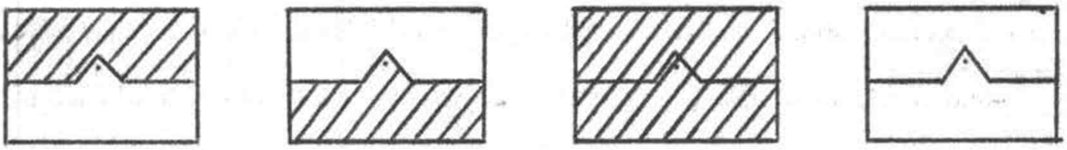
a. First internode and coleoptile exposed with the seed and primary root protected.

b. Seed and primary root exposed with the first internode and coleoptile protected.

c. Whole plant exposed (check).

d. Whole plant protected (check).

Each plot consisted of four seeds planted under cones in a six-inch flower pot. Each seed was placed in soil within 1/8 inch of the tip of the cone. Enough soil was placed over the cones and plastic sheet so the seeds were all planted one inch deep. The arrangement of the seed in the four treatments is shown below. The plastic barrier separated soil with 3 ppm of EPTC (cross-hatched) from untreated soil (blank).



a. b. c. d.

The pots were placed in saucers. Soil below the plastic barrier was watered from the saucers while the soil above the barrier was sprinkled.

The pots were observed periodically. One month after planting, seedlings from two replicates were washed free of soil and examined. Plants in the other three replicates were allowed to grow until they matured.

<u>Results</u>. Although four different treatments were involved in this study, only two different results were obtained. Wherever the shoot

was not exposed to EPTC, whether the root was exposed or not, the seedlings were normal. Wherever the shoot was exposed to EPTC, whether the root was exposed or not, the plants were killed (Figures 22 and 23). Emergence was very good in the treatments where the shoots were not exposed. Emergence was not as good in the treatments where shoots were exposed. The development of some seedlings was arrested when the coleoptile passed through the hole in the cone into EPTC-treated soil.

The plants whose shoots were exposed to EPTC died. The seedlings whose shoots were not exposed to EPTC continued to grow, flowered and produced seed. At the time of flowering, considerable variation was present among the plants. Some abnormal symptoms developed in some plants in which the roots were exposed to EPTC, such as twisting of the stem and rolling of the leaves. These are suggestive of EPTC injury. However, some of the plants from the untreated check showed similar effects. Representative mature plants from the two treatments in which the plants were not killed are shown in Figure 24. The mature seeds were collected and placed in a cold refrigerator for four months. The seeds were then tested for germinability but none germinated. Some mold had grown on the seeds in the refrigerator which perhaps had destroyed their viability.

Exposure of Coleoptiles to EPTC Vapors

Materials and Methods. Barnyard grass seeds were planted in untreated soil. The coleoptiles were exposed to EPTC vapors as they emerged.

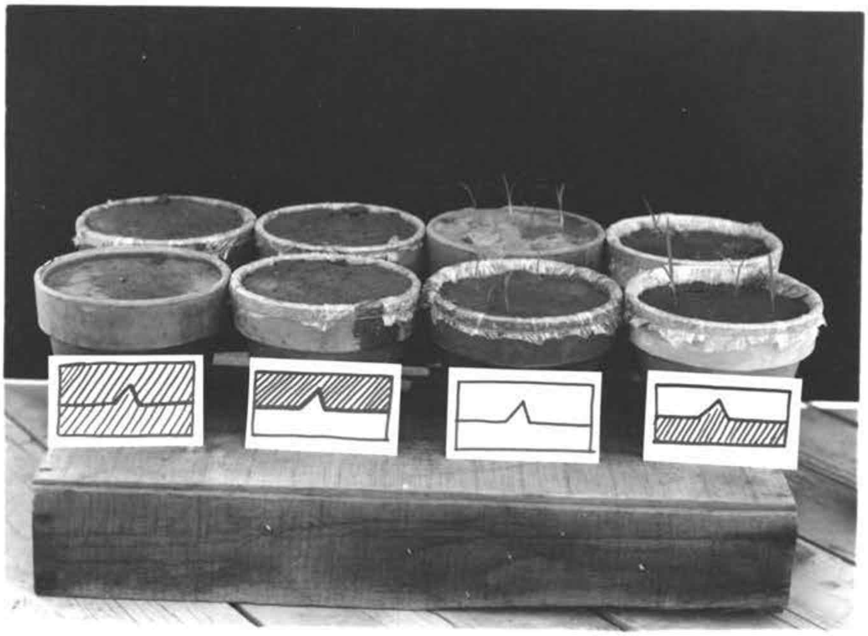


Fig. 22. Barnyard grass seedlings grown from seeds placed within plastic cones which formed part of a barrier between untreated soil (blank) and soil containing 3 ppm of EPTC (cross-hatched).

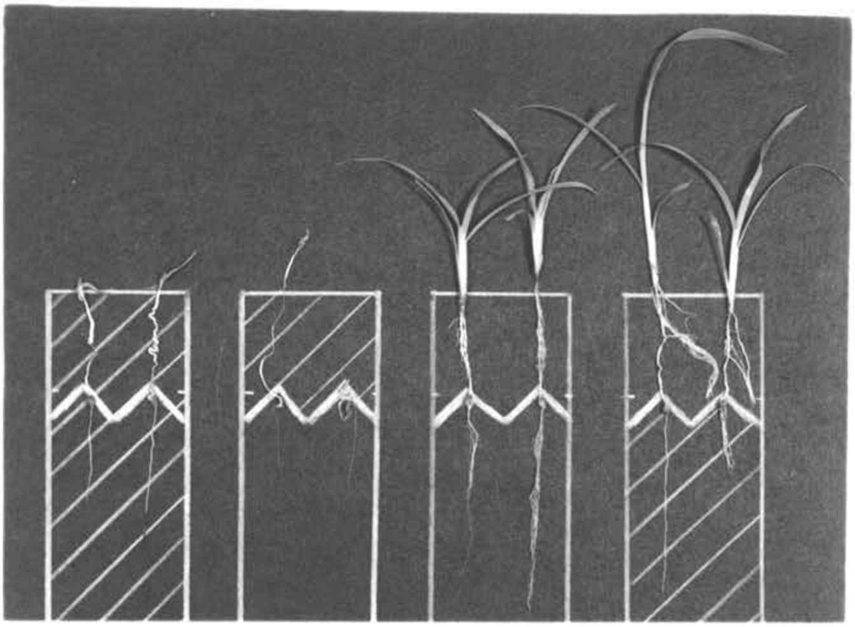


Fig. 23. Month-old barnyard grass seedlings showing effect of arrangement of plant parts during emergence in untreated soil (blank) and soil containing 3 ppm of EPTC (cross-hatched).

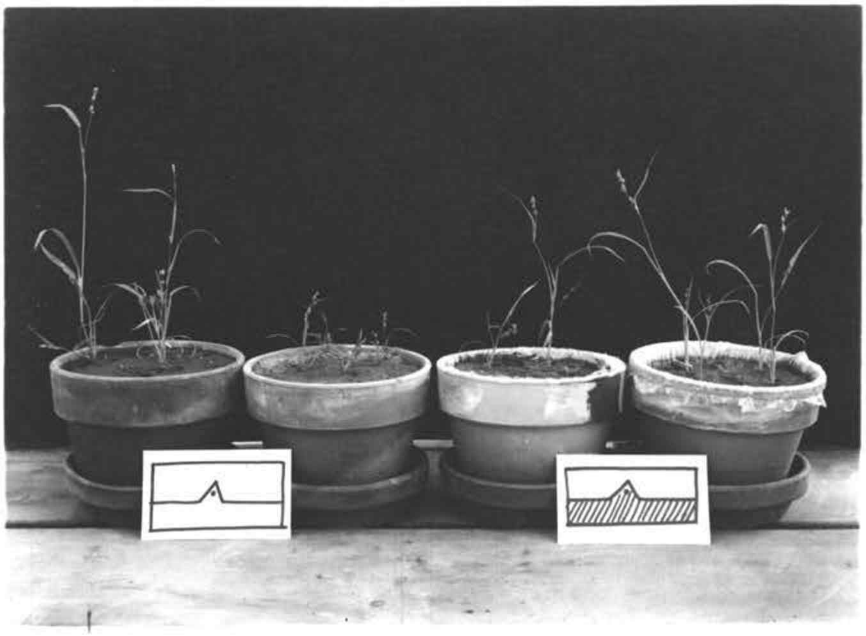


Fig. 24. Barnyard grass plants eight weeks after seeds were planted within plastic cones which formed part of barrier between untreated soil (blank) and soil containing 3 ppm of EPTC (cross-hatched).

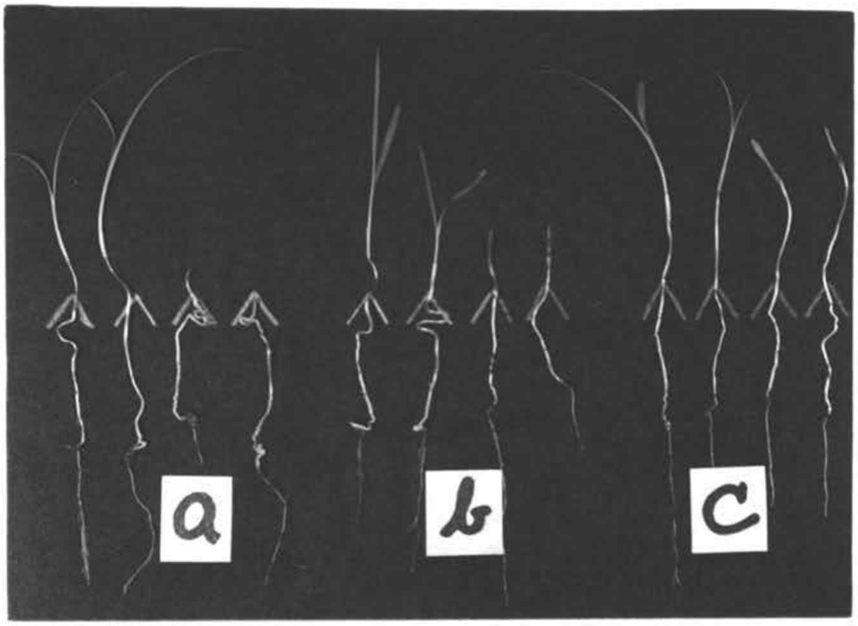


Fig. 25. Barnyard grass grown in untreated soil with the emerging shoots exposed to EPTC vapors. Pencil lines represent plastic barrier to EPTC through which seedlings emerged. Immediately (a), 3 days (b), and 5 days (c) after seeding the two seedlings on the right in each group were exposed to EPTC vapors while the two on the right were not.

Four barnyard grass seeds were planted in each of 12 oil cans. Each seed was placed under a plastic cone. Enough soil was placed on top the plastic sheet through which the cones protruded to effect a seal between the sheet and the cones. The tips of the cones were located right at the soil surface. A jelly mold and plastic bag were placed over four of the cans at three different times corresponding to the following developmental stages of the barnyard grass:

a. Immediately after planting.

b. Three days after planting, just prior to barnyard grass emergence.

c. Five days after planting, when seedlings had emerged. These four cans were covered with a pail to darken them from the fourth to fifth days to induce further elongation of the first internode and prevent foliar leaf expansion. Two seedlings already had foliar leaves out when the cans were darkened, however.

At each time of treatment, two of the covers contained EPTC while the other two did not. The plastic sheet through which the cones protruded was large enough to extend over the lip of the oil can. The jelly mold then fitted tightly over it, effecting a seal between the atmosphere within the plastic bag and the air of the soil in the can. The barnyard grass seedlings were observed for symptoms of EPTC injury. All seedlings were washed free of soil for examination 16 days after planting.

Results. The barnyard grass seedlings emerged from the cones satisfactorily. All of the untreated seedlings were normal in appearance and growth. All of the seedlings exposed to EPTC vapors exhibited symptoms of injury which were the same as those which develop when barnyard grass seedlings emerge in soil containing EPTC. The foliar leaves within the coleoptiles became dark green and appeared water-soaked and did not emerge normally from the coleoptile. Swelling in the region of the coleoptilar node which is often associated with EPTC injury was absent in these plants.

Vapors of EPTC contacting only the part of the shoot above ground killed barnyard grass. Sometimes only a part of the coleoptile emerged from the cone tip before elongation ceased. In these plants only the coleoptile was exposed to EPTC, and the plants were killed. Representative treated and untreated seedlings from the three times of exposure are shown in Figure 25.

In two seedlings exposed to EPTC vapors five days after planting, the first foliar leaf had already expanded beyond the coleoptile. These plants were killed by the EPTC just as the others which were not as far advanced in development when exposed. The expanded leaves became dark green and appeared water-soaked. They grew no more after exposure.

Exposure of Leaves to EPTC After Emergence

Materials and Methods. In this study, leaves of emerged barnyard grass plants were exposed to EPTC as vapor and as aqueous solution. Six one-quart oil cans were filled with moist soil. About 50 barnyard grass seeds were planted one inch deep in each can. When the resulting seedlings had two foliar leaves, the plants in two cans were exposed to EPTC vapors using the jelly mold-plastic bag method. At the same time, two cans were placed under the plastic bags without EPTC. When the seedlings in the two remaining cans had three or four foliar leaves, those in one can were exposed to EPTC vapors while the other can was placed under the plastic bag without EPTC. In all cases, the plastic cover was removed after 48 hours. The plants were observed periodically for two months and discarded.

In early July, 1960, barnyard grass seeds were planted out of doors in three beds 6 feet by 10 inches. When the barnyard grass was 12 inches tall and had 5 - 8 leaves, some plants were dug up and planted in four one-quart oil cans. After several days when the transplanted barnyard grass had recovered from the shock of moving, the plants in two cans were exposed to EPTC vapors for 48 hours. At the same time, half of each of the three beds was sprayed with EPTC at the rate of 9 pounds in 50 gallons of water per acre. All plants were observed periodically for symptoms of injury.

Results. When the barnyard grass plants were exposed to EPTC vapors in the two-leaf stage, further growth of the existing leaves ceased. The leaves became very dark green in color and appeared water-soaked. The plants remained in this condition unchanged in appearance or size for a few days. Subsequent foliar leaves of the treated plants did not emerge from the bud normally. Instead, they broke through the sheaths of the existing foliar leaves laterally and were twisted, tightly rolled, and very much distorted. The leaves which were already expanded when exposed to EPTC did not exhibit any of these symptoms of twisting and distortion. Except that they did not grow any more, and were abnormally dark green in color, they remained quite normal in appearance for several weeks. Large drops of guttation water were frequently observed on these leaves, more so than in the untreated checks.

In the untreated checks, the second foliar leaves continued to grow further since they were not fully grown at the time of treatment. Subsequent leaves also developed normally. Treated and untreated plants five days after exposure are shown in Figure 26.

The primary shoots of the plants exposed to EPTC died after several weeks. The plants then recovered by development of tillers which grew normally. The same plants shown in Figure 26 are shown in Figure 27 as they appeared two months later.

Results very similar to the above were seen where barnyard grass was exposed to EPTC vapors in the 3 - 4 leaf stage. Further growth of existing leaves stopped and subsequent leaves were very much distorted. Eventually the primary shoots died. Some plants developed tillers while others died completely.

When large barnyard grass plants (5 - 8 leaves present) were exposed to EPTC vapors, results were similar, except changes in leaf color were not so evident. The primary culm did not always die. When it survived and flowered, the inflorescence remained wrapped in leaf tissue and failed to expand normally. Abundant tillers developed from the crowns.

No typical EPTC symptoms developed in the emerged barnyard grass plants sprayed with EPTC in the field.

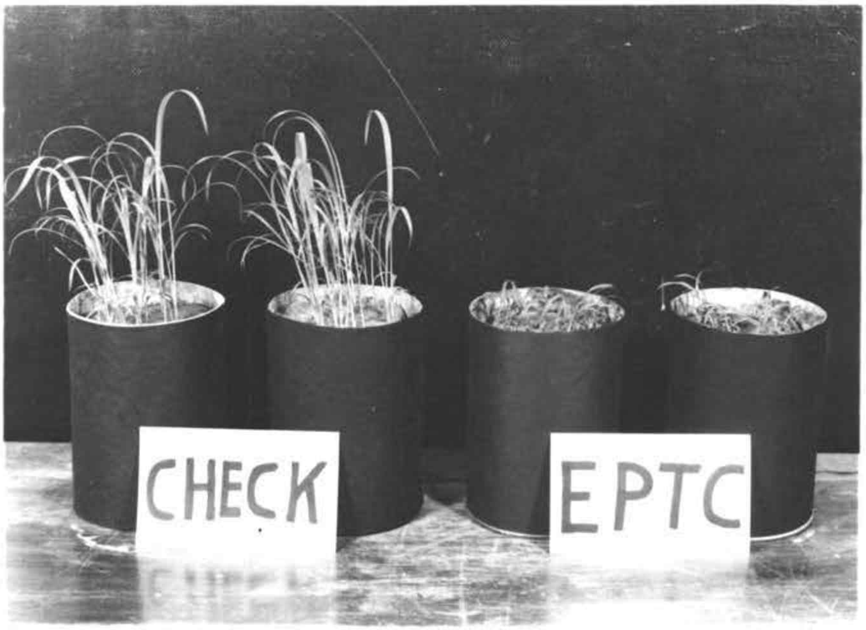


Fig. 26. Barnyard grass plants 5 days after being covered for 48 hours with plastic bags with and without EPTC vapors.

Fig. 27. Barnyard grass plants 2 months after being covered for 48 hours with plastic bags with and without EPTC vapors showing recovery of EPTC-injured plants from tiller buds.

Microscopic Examination of Normal and EPTC-injured Seedlings

Materials and Methods. Seeds of barnyard grass were planted in soil containing 0, 1/2 and 3 ppm EPTC. When seedlings had emerged they were collected and placed in Randolph's solution (chromic acid, acetic acid, and formalin) for preservation. They were then imbedded in paraffin, sectioned, mounted on glass slides and stained.[2] The stained material was then examined with the microscope in order to observe the effects of EPTC on barnyard grass at the cell and tissue level.

Results. Examination of stained and mounted sections of EPTC-treated and untreated barnyard grass seedling shoots revealed certain differences. The mesophyll of the undeveloped foliar leaves within the coleoptile was seriously affected. The chloroplasts became much more heavily stained than in the untreated plants. This abnormal staining indicated that a chemical change in the chloroplasts had occurred. In many cells in the treated plants, the chloroplasts were concentrated close to the periphery of the cells near the cell walls, which was not observed in the untreated material.

The physical arrangement of the mesophyll cells was also affected. In the untreated plants, large intercellular spaces were evident in

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2 The author is indebted to Mr. Thomas Newell, formerly a student at Oregon State College, for imbedding, sectioning, and mounting the slide material and to Dr. H. M. Hull, Plant Physiologist, Crops Research Division, U. S. Department of Agriculture, Tucson, Arizona, for clearing and staining the slides and assisting in interpreting the results.

the mesophyll of the foliar leaves. These spaces were absent in the treated plants. Furthermore, in some longitudinal sections the linear files of cells were somewhat buckled and kinked. Probably the absence of the intercellular spaces and/or the rearrangement of the chloroplasts were responsible for the dark green, water-soaked appearance of the foliar leaves which has already been described. Longitudinal sections of treated and untreated plants are shown in Figures 28 and 29.

No distinct cellular differences between the first internode tissue of treated and untreated plants were evident.

The bulging in the region of the coleoptilar node commonly associated with EPTC injury showed up well in the slides. No cell proliferation was involved in this bulging. Instead there was an outward folding of the coleoptile all around its base just above its point of attachment to the stem (Figures 30 and 31). This folding could have resulted from weakening of the cell walls and/or a differential rate of elongation between coleoptile and foliar leaves with adhesion between the two.

Comparative Effect of EPTC on Eight Grasses Differing in Developmental Morphology

Grass seedlings differ in developmental morphology. In some grasses, leaf tissue constitutes a minor part of the total length of the emerging shoot. In others, the entire length of the emerging shoot contains leaf tissue. Still others are intermediate between these two. Grasses representing these different groups were treated

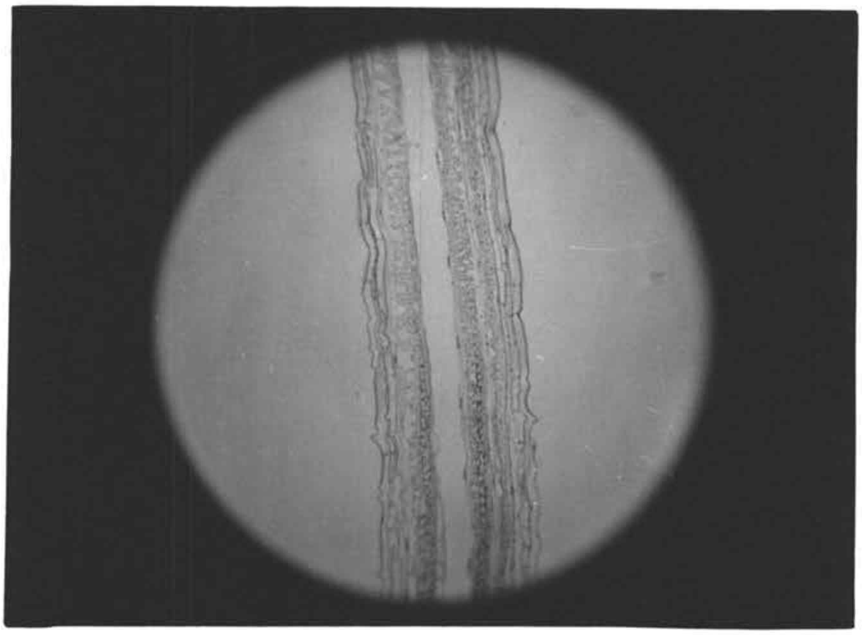

Fig. 28. Longitudinal section of normal coleoptile of barnyard grass with enclosed foliar leaves.

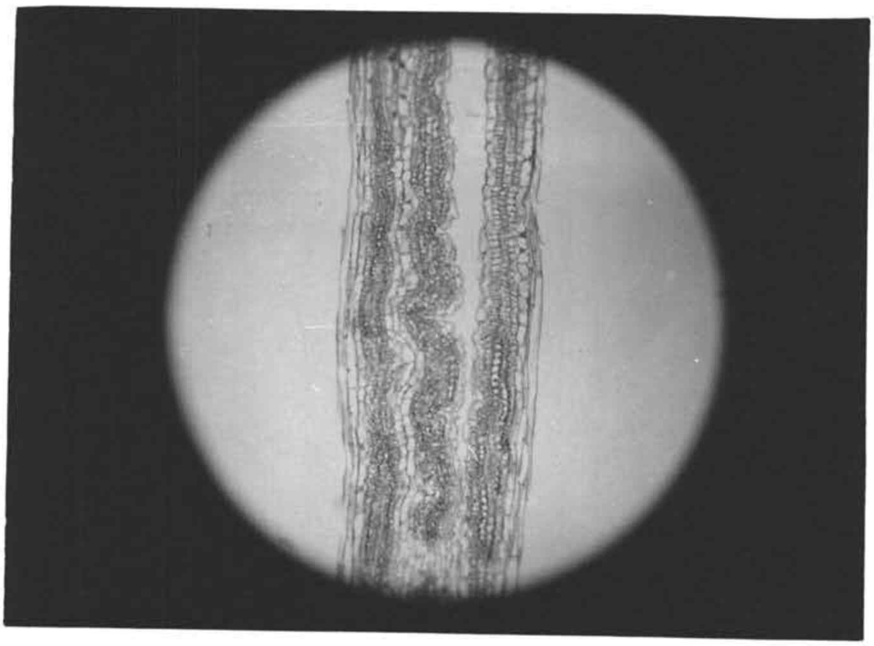

Fig. 29. Longitudinal section of coleoptile with enclosed foliar leaves of EPTC-injured barnyard grass.

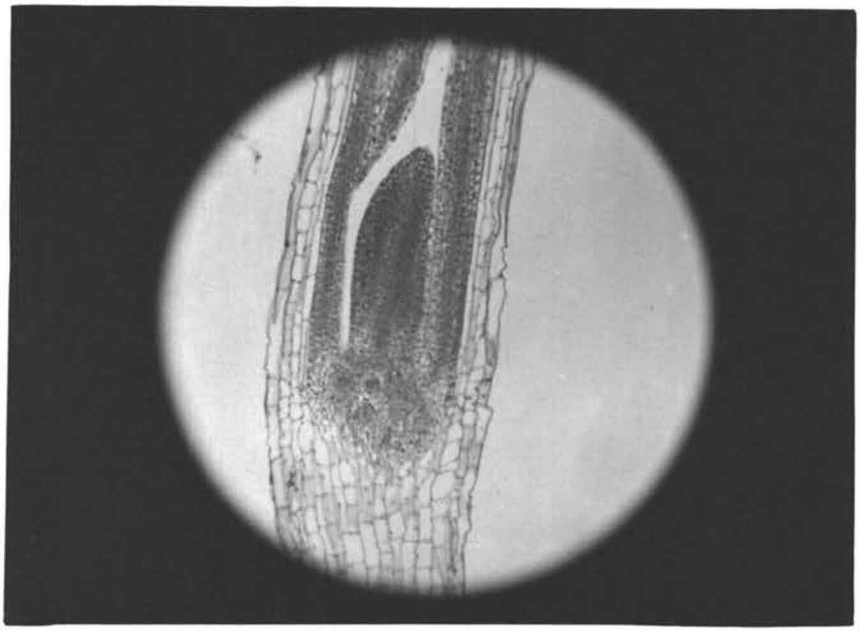

Fig. 30. Longitudinal section of normal barnyard grass seedling in region of coleoptilar node.

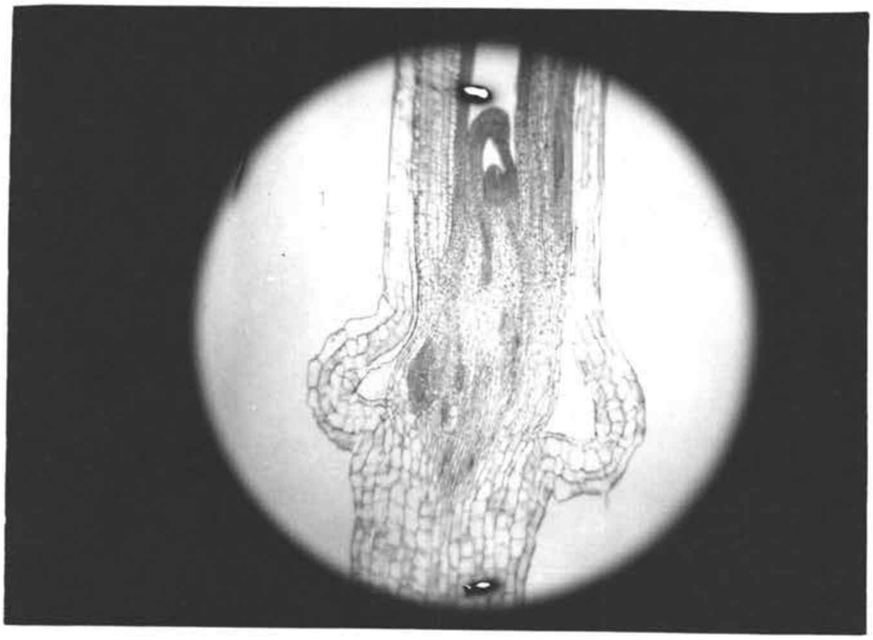

Fig. 31. Longitudinal section of EPTC-injured barnyard grass seedlings in region of coleoptilar node showing bulging near base of coleoptile.

with EPTC and their response to EPTC was compared.

Materials and Methods. Seeds of barnyard grass (*Echinochloa crusgalli* (L.) Beauv.), green foxtail (*Setaria viridis* (L.) Beauv.), yellow foxtail (*S. glauca* (L.) Beauv.), sudan grass (*Sorghum sudanense* (Piper) Stapf.), corn (*Zea mays* L.), oats (*Avena sativa* L.), wheat (*Triticum aestivum* L.) and rhizomes of quackgrass (*Agropyron repens* (L.) Beauv.) were planted in soil with and without 3 ppm of EPTC.

In barnyard grass, green foxtail, yellow foxtail, and sudan grass, most of the length of the elongating shoot consists of first internode, with the coleoptile being relatively short. In corn, both the first internode and the coleoptile elongate about equally. In oats, the coleoptile accounts for most of the elongation of the emerging shoot with the first internode elongating relatively little. In wheat, the first internode does not elongate at all. The coleoptile spans the whole distance from the seed through the soil surface, with the second internode elongating within it concurrently. New shoots grow from the buds on the rhizomes of quackgrass. These shoots consist almost entirely of leaf tissue. Very little stem tissue is involved in their early growth.

When seedlings began to emerge, and periodically thereafter, they were dug up and washed free of soil for examination. When shoots had emerged from the quackgrass rhizomes, the material from both the treated and untreated soil was washed free of soil and examined.

Results. Seeds of all species germinated equally well in the treated and untreated soil. All of the eight grasses studied were lethally injured by 3 ppm of EPTC except corn. Corn appeared to be tolerant to EPTC. The expression of injury symptoms was definitely related to the developmental morphology of the seedlings. The amount of growth the seedlings made before development stopped and death eventually ensued was dependent on the role played by leaf tissue in shoot elongation. The effect of EPTC on the grasses is shown by representative seedlings of different ages from treated and untreated soil in Figures 32 through 39.

Barnyard grass, green foxtail, yellow foxtail, and sudan grass, whose developmental morphology is similar, responded similarly to EPTC. The first internode, which constituted most of the shoot length, sometimes was kinked, but otherwise elongated quite normally causing most of the injured seedlings to emerge. Injury symptoms in these four grasses were seen in the coleoptile and enclosed foliar leaves. The foliar leaves became dark green, appeared water-soaked, and failed to develop normally beyond the coleoptile.

The development of wheat shoots, whose total length includes leaf tissue, was curtailed very shortly after germination. No injured seedlings emerged. The effect of EPTC on oats, whose shoots consist largely of leaf tissue, was very similar to that observed in wheat. Injured oat seedlings did not emerge either.

No shoots emerged from quackgrass rhizomes in the presence of EPTC. The shoots elongated very little before their growth was

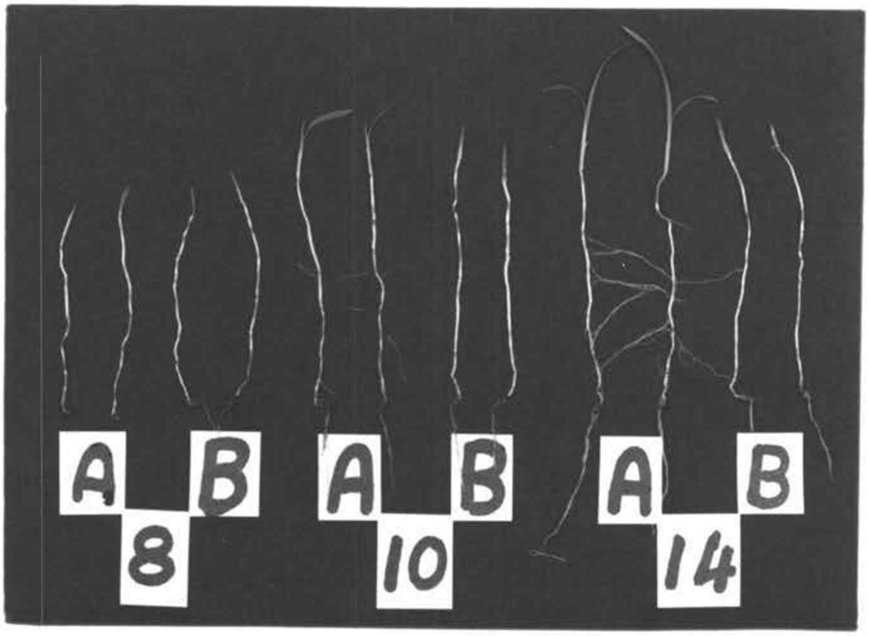

Fig. 32. Barnyard grass 8, 10 and 14 days after seeds were planted in untreated soil (a) and soil containing 3 ppm of EPTC (b).

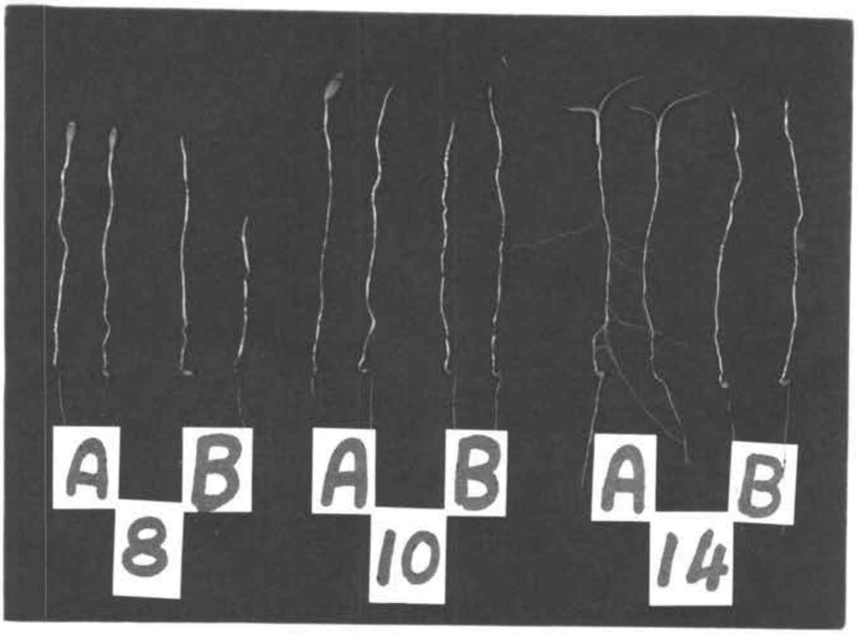

Fig. 33. Green foxtail 8, 10 and 14 days after seeds were planted in untreated soil (a) and soil containing 3 ppm of EPTC (b).

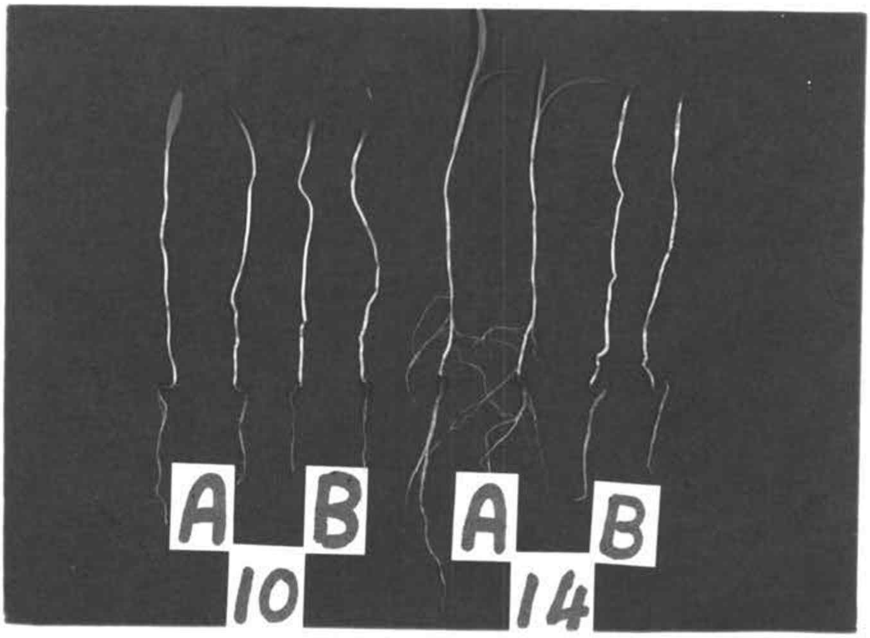

Fig. 34. Yellow foxtail 10 and 14 days after seeds were planted in untreated soil (a) and soil containing 3 ppm of EPTC (b).

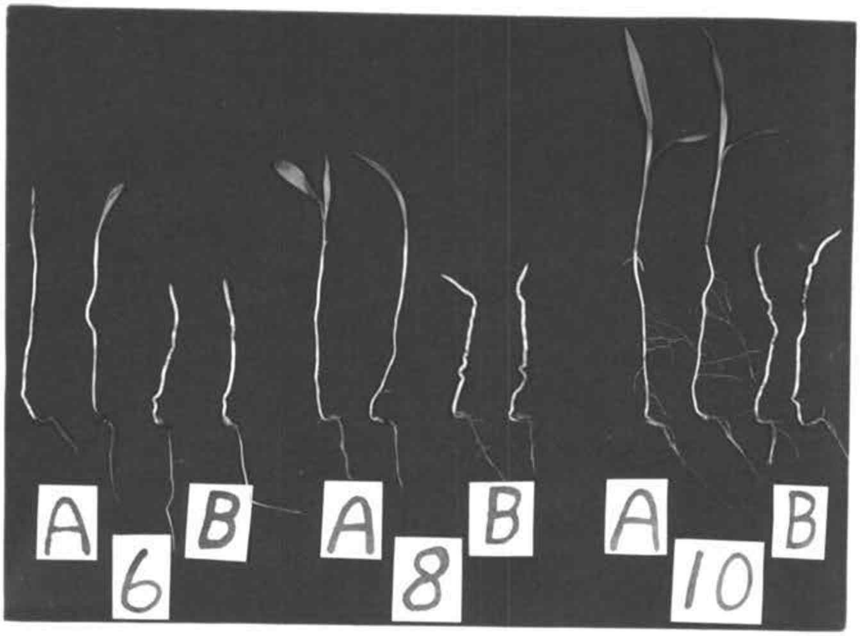

Fig. 35. Tift sudan grass 6, 8 and 10 days after seeds were planted in untreated soil (a) and soil containing 3 ppm of EPTC (b).

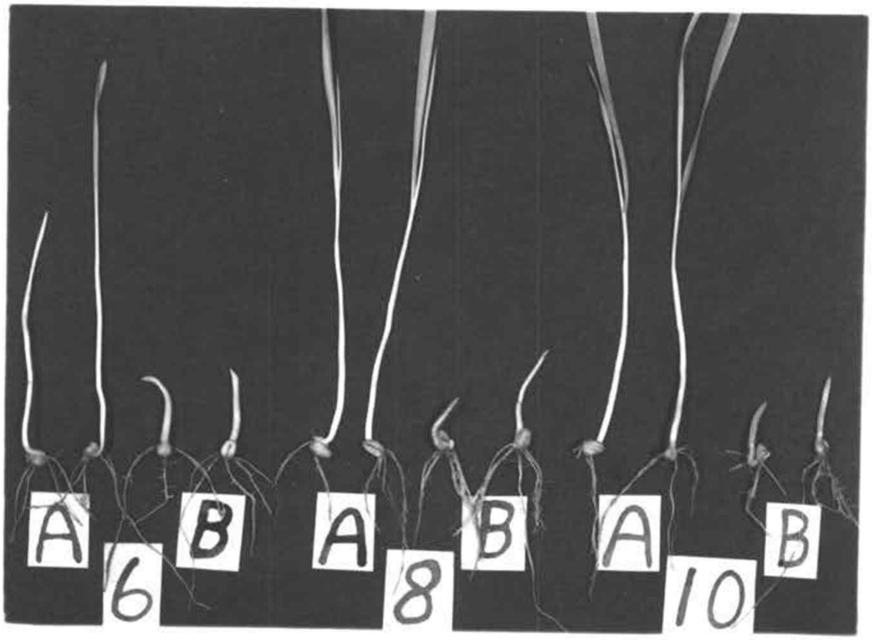

Fig. 36. Marfed wheat 6, 8 and 10 days after seeds were planted in untreated soil (a) and soil containing 3 ppm of EPTC (b).

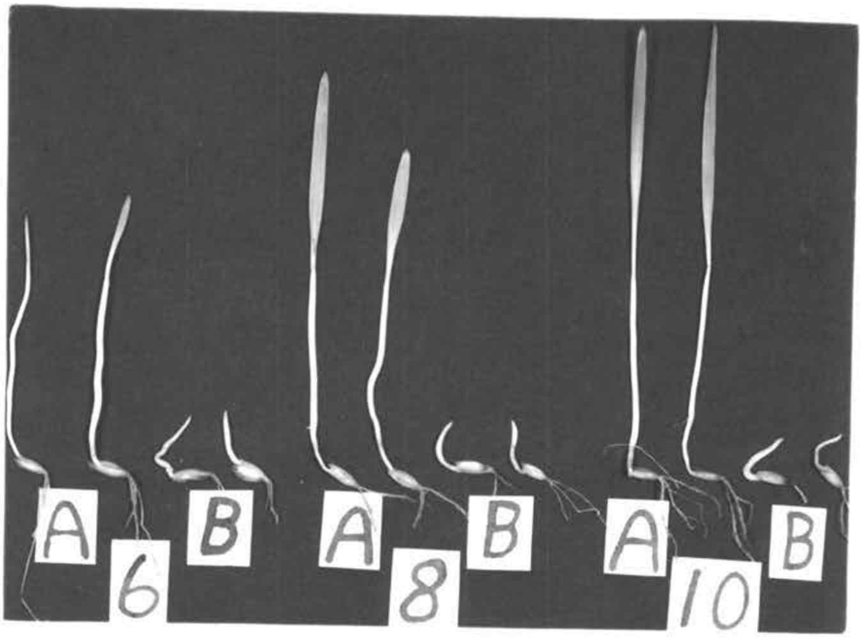

Fig. 37. Kanota oats 6, 8 and 10 days after seeds were planted in untreated soil (a) and soil containing 3 ppm of EPTC (b).

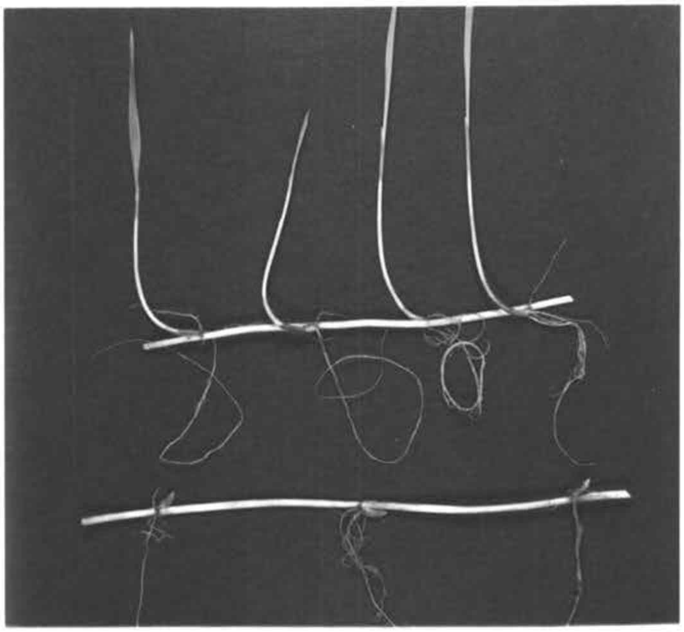

Fig. 38. Quackgrass two weeks after rhizomes were planted in untreated soil (upper) and soil containing 3 ppm of EPTC (lower).

Fig. 39. Corn 8, 10 and 14 days after seeds were planted in untreated soil (a) and soil containing 3 ppm of EPTC (b).

curtailed. Nearly all of the length of the emerging shoots from the rhizomes in untreated soil consisted of leaf tissue.

In summary, the elongation of emerging shoots whose length consisted largely of leaf tissue (wheat, oats, quackgrass) was much reduced in the presence of EPTC and the seedlings died without emerging. In grasses where stem tissue is responsible for most of the elongation of the emerging shoot (barnyard grass, green foxtail, yellow foxtail, sudan grass) the shoots attained their normal length, or nearly so, in spite of the fact that lethal injury of the leaf tissue had occurred which prevented further development of the plants and eventually caused their death. Leaf tissue appeared to be the prime site of lethal action in these grasses. Corn presented an interesting exception, being tolerant of concentrations of EPTC which killed the other grasses.

BARNYARD GRASS SEEDLING DEVELOPMENT IN THE FIELD

The purpose of this study was to gain information about the growth of barnyard grass in the field from which the progression of its development under representative conditions could be mapped. This information is needed in order to predict the location of EPTC-sensitive parts of the seedlings under different conditions. When the developmental patterns of barnyard grass seedlings are known, and when the sensitive parts of the seedling to EPTC has been determined, it should be possible to predict the application method which would provide the most efficient control of barnyard grass with EPTC.

Materials and Methods. Barnyard grass seeds were planted 1/2, 1 1/2, and 3 inches deep in Sagemoor fine sandy loam in beds 1 foot by 12 feet on April 18, 1960 and July 7, 1960. From shortly after planting until the plants tillered, seeds and/or seedlings were dug up periodically and washed free of soil. Fifty representative seedlings were collected from each depth on each sampling date for measurement and observation. The lengths of coleoptile, first internode and total shoot were measured. Leaves, tillers and coronal roots were counted. The presence and general size and number of primary roots and first internode adventitious roots were noted as well as any other general characteristics. From this information the progression of barnyard grass development was mapped. A representative plant was drawn to scale for each date of sampling.

A continuous record of soil temperature at 1/2, 1 1/2 and 3 inches was obtained by the use of thermographs.

Results. The barnyard grass seeds germinated uniformly and the seedlings grew well providing an abundance of material with which to work.

Temperatures were quite low following the April 18 planting. Temperatures in July following the second planting were much higher. The rate of emergence and growth was slower under the cooler temperatures, but otherwise the patterns of developmental progression were essentially the same for the two dates.

During germination the shoot emerged from the seed first, usually followed in a day by the primary root from the opposite end of the seed. The seed itself remained unmoved. The coleoptile and first internode elongated concurrently, and initially at about the same rate. Soon the rate of elongation of the first internode became much greater and that of the coleoptile decreased. Depth of seeding had little effect on coleoptile length. In seedlings which emerged from three inches, the coleoptile was only 1 - 1.5 mm longer than that of seedlings which emerged from 1/2 inch. Most of the length of young barnyard grass shoots consisted of first internode. Elongation continued until the coleoptile emerged from the soil. When the coleoptilar node was located at or about 1 mm below the soil surface, elongation of the first internode and coleoptile ceased.

Soon after emergence and the cessation of first internode elongation, the first foliar leaf grew out beyond the tip of the coleoptile. Subsequent leaves followed in order.

At about the time the first foliar leaf expanded beyond the coleoptile, adventitious roots appeared along the lower end of the first internode. More of these roots were produced as time passed, proceeding upward on the first internode until eventually adventitious roots were present on its whole length. These roots branched and re-branched, and became quite dense.

The primary root system also continued to grow and ramify. Most of the primary roots were broken when the seedlings were dug, so they were not measured.

When two or three foliar leaves had expanded from the coleoptile, coronal adventitious roots began to grow from the region of the coleoptilar node (crown). They eventually became very numerous.

After the plants were several inches tall and well supplied with coronal roots, tillers grew from buds at the crowns. The number of tillers per plant varied with the degree of crowding. Plants in the center of the beds had few tillers, while they were abundant on border plants.

Once the barnyard grass seedlings emerged, the plants from the three depths and two dates of planting appeared the same. All had the apical bud at the soil surface and all produced leaves, coronal roots and tillers in a similar manner. The only difference among seedlings from different depths of planting was in the length of the first internode which was not apparent without digging up the plants. Seedlings from the same depth at the two planting dates differed only in growth rate.

Serial scale drawings of seedlings from the six treatments are shown in Figures 40 through 45.[3]

[3] The scale drawings of barnyard grass were prepared by Mr. L. J. Barnhart, Agricultural Aide, Irrigation Experiment Station, Prosser, Washington.

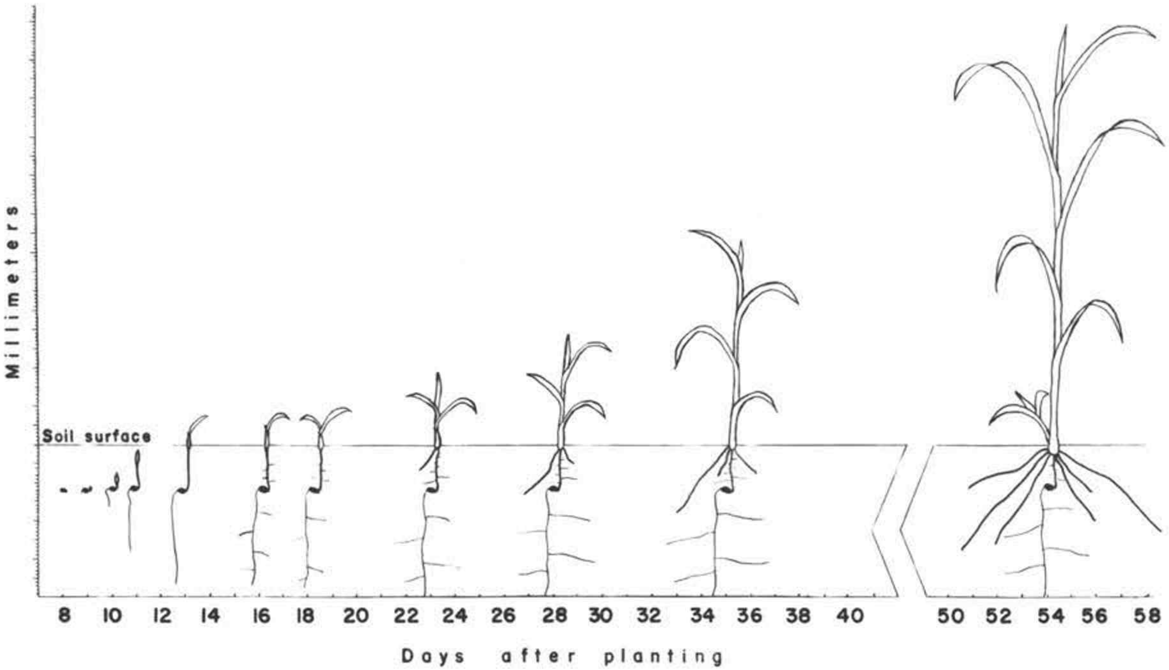

Fig. 40. Development of barnyard grass from seed planted $\frac{1}{2}$ inch deep on April 18, 1960.

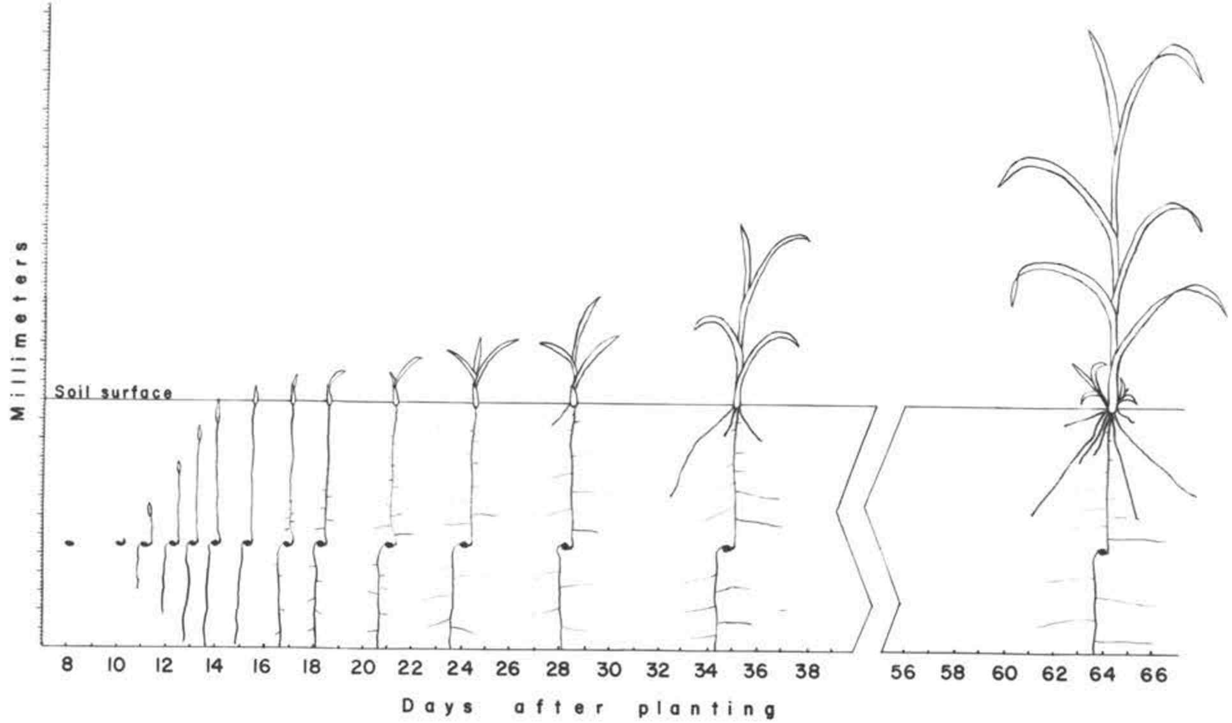

Fig. 41. Development of barnyard grass from seed planted 1½ inches deep on April 18, 1960.

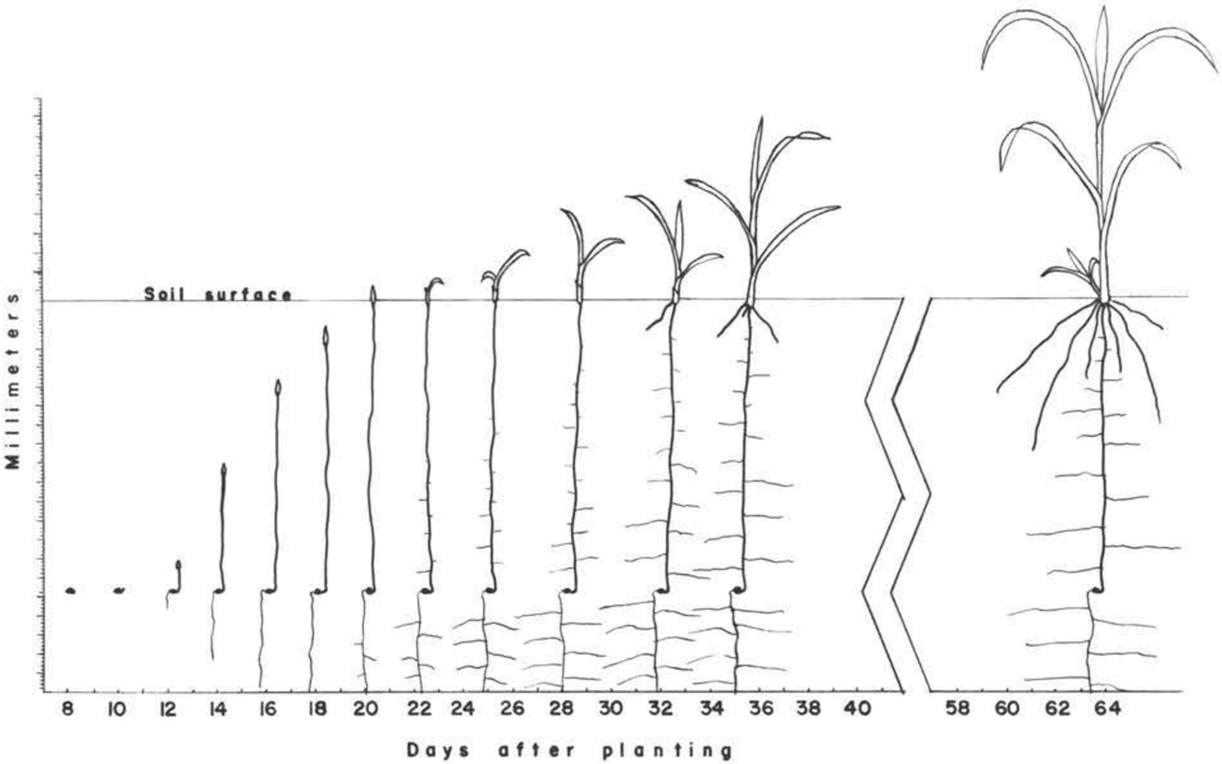

Fig. 42. Development of barnyard grass from seed planted 3 inches deep on April 18, 1960.

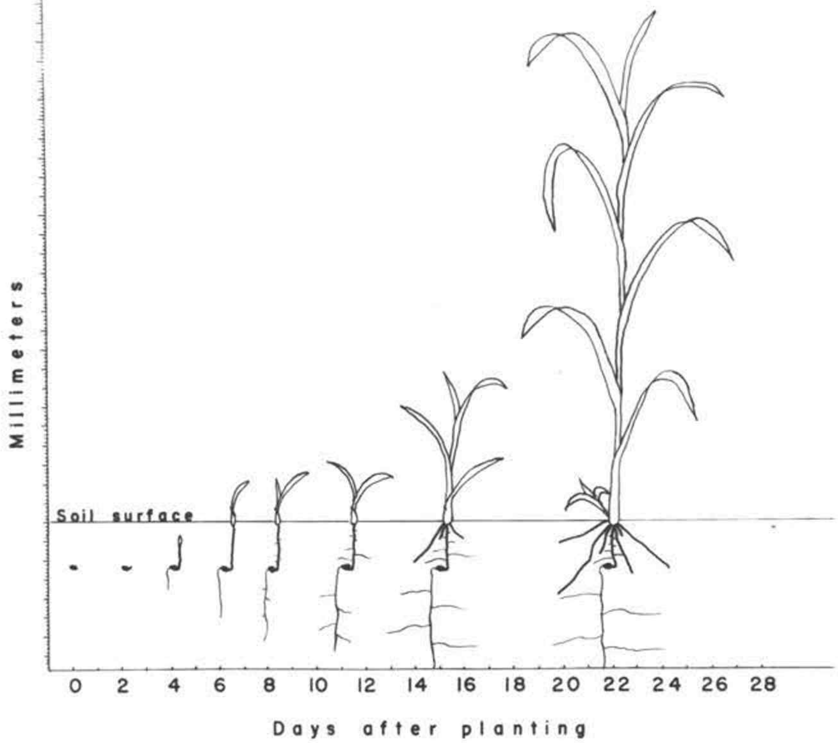

Fig. 43. Development of barnyard grass from seed planted 1/2 inch deep on July 7, 1960.

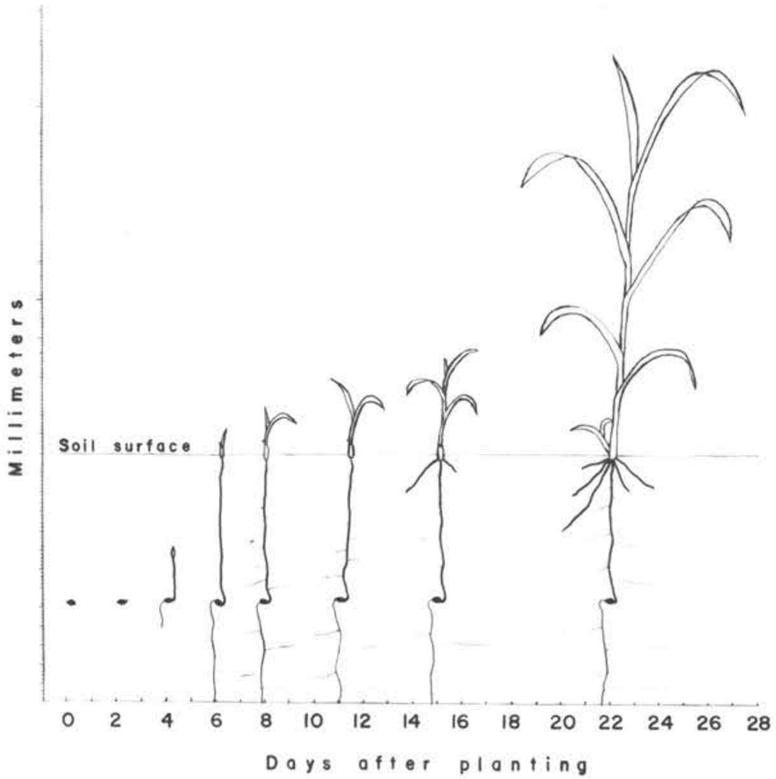

Fig. 44. Development of barnyard grass from seed planted 1 1/2 inches deep on July 7, 1960.

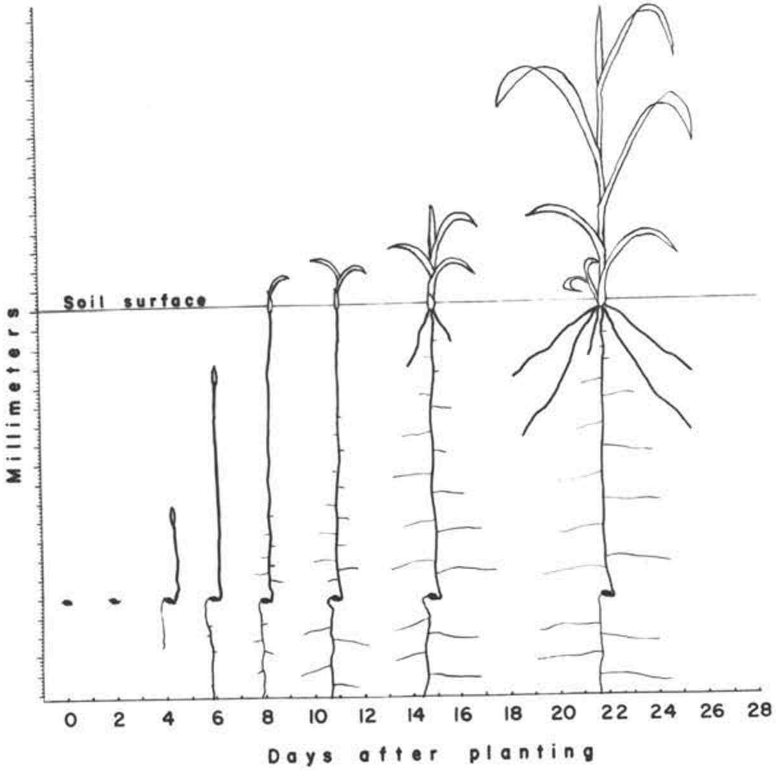

Fig. 45. Development of barnyard grass from seed planted 3 inches deep on July 7, 1960.

FIELD APPLICATIONS OF EPTC FOR BARNYARD GRASS CONTROL

Field applications of EPTC at different depths were made in order to compare results in the field with those obtained in the detailed greenhouse studies.

Materials and Methods. On May 18, 1960, EPTC was applied at 0, 1 and 3 pounds per acre in a split plot design with four replications. Each application was incorporated 1, 3 and 5 inches deep. A roto-tiller equipped with a depth control wheel mounted on a garden tractor was used to incorporate the EPTC. Main plots were 9 feet by 88 inches. Sub-plots were 3 feet by 88 inches. The experiment was set up in an unused portion of a bean field. The 88-inch width corresponded to four bean rows, which allowed the plots to be ditched and furrow irrigated with the beans. Barnyard grass seed had been sown and disked five inches deep in the fine sandy loam prior to application.

All broadleaved weeds were removed from the plots. The barn-yard grass plants in nine square feet of undisturbed soil between the irrigation furrows in each sub-plot were counted on July 1 and July 27.

Results. Excellent barnyard grass control resulted from EPTC at 1 and 3 pounds per acre at all depths of incorporation for about a month. At this time, a few barnyard grass plants appeared at both rates where the EPTC had been incorporated 1 inch deep. They were more numerous at the 1 pound per acre rate. There were no seedlings where either rate of EPTC had been incorporated 3 or 5 inches deep. Two months after planting, a few barnyard grass seedlings were present where both rates of EPTC had been incorporated 3 and 5 inches deep. However, many more were present where incorporation had been only 1 inch deep (Table 6).

Table 6. Average number of barnyard grass in 9 square feet of undisturbed soil between irrigation furrows in study of rate and depth of incorporation of EPTC.

Treatments	July 1, 1960	July 21, 1960
1. EPTC @ 0 lb/A		
Incorporated 1 inch	19.3	19.3
Incorporated 3 inches	16.3	16.5
Incorporated 5 inches	16.3	16.3
2. EPTC @ 1 lb/A		
Incorporated 1 inch	1.8	4.5
Incorporated 3 inches	0.0	0.3
Incorporated 5 inches	0.0	0.3
3. EPTC @ 3 lb/A		
Incorporated 1 inch	0.5	1.8
Incorporated 3 inches	0.0	0.3
Incorporated 5 inches	0.0	0.3

DISCUSSION

General

The results of this investigation are important because they provide basic information concerning the effect of EPTC, an important herbicide, on barnyard grass, a serious weed. In addition to these direct results, certain implications of the investigation have a bearing on the whole area of weed control with soil-applied herbicides. A common assumption among chemical weed control specialists is that soil-applied herbicides which injure weeds or crops enter the plant via the root system. This is reasonable because roots are the plant's main region of water and mineral absorption from the soil, and no contrary information with regard to herbicide uptake has been available. Exposing barnyard grass roots to EPTC did not cause lethal injury to the plant. Instead, lethal injury resulted from exposing the shoot or just the coleoptile. Therefore, in the case of EPTC and barnyard grass the chemical which kills the plant enters the shoot directly. Thus the classical assumption does not apply.

Further investigation is needed to determine the portions of other plants responsible for the uptake of injurious amounts of various other soil-applied herbicides besides EPTC. Conceivably, the efficiency of chemical weed control could be improved thereby. Herbicides could be applied in a manner to increase their effectiveness in killing weeds and decrease the danger of injuring crop plants. For example, when beans (*Phaseolus vulgaris* L.) are injured by EPTC, leaf tissue is the site of injury as it is in barnyard grass. The author has observed indirect evidence which suggests that EPTC enters the bean plant by direct foliar uptake. It is possible that additional research will confirm that injurious amounts of EPTC enter beans and other crops via shoots rather than roots. If this proves to be true, the safety to the crop should be increased by planting the seeds shallow in order to minimize the time the shoot is exposed to treated soil before emergence.

In this study, rates of EPTC used were in the range of concentrations which are used for commercial weed control in the field. No effort was made to determine the effect of excessive rates of EPTC on barnyard grass, which could be quite different from the lower rates used. It must be borne in mind that the discussion of results which follows is intended to explain what occurs when barnyard grass seedlings are killed by rates of EPTC which might be used for weed control by growers.

Effect of EPTC on Seed Germination

Seed germination was not affected by EPTC in any of the tests conducted. The percentage emergence was sometimes reduced, but this was due to failure of seedlings to emerge after germination rather than a direct effect on germination. Even when seeds were placed on the surface of moist soil under high humidity in the presence of EPTC vapors, they germinated as well as the checks.

Effect of EPTC on Barnyard Grass Leaves

Whenever barnyard grass seedlings were injured by EPTC, injury symptoms were seen in the young leaf tissue. The developing foliar leaves within the coleoptile turned dark green and appeared water-soaked. Often the injured foliar leaves did not develop at all beyond the coleoptile, and if they did they were very much distorted and abnormal.

Similar foliar symptoms developed in emerged barnyard grass plants which were enclosed in a plastic bag containing EPTC vapors after leaves had grown beyond the coleoptile. Leaves which were full grown when treated became dark green and appeared water-soaked. Younger leaves which were still growing when exposed to EPTC were similarly affected. In addition, further growth of these leaves was curtailed. When new leaves developed from the affected shoots, they were very much distorted and abnormal. Lack of injury to emerged barnyard grass sprayed with EPTC in the field was probably due to the rapid vapor loss of the herbicide.

Microscopic comparison of EPTC-injured and normal barnyard grass seedlings revealed that physical and chemical changes within the mesophyll of the injured seedlings had occurred. Injured plants did not have the large intercellular spaces common in the mesophyll of non-injured plants. Chloroplasts of injured plants had an increased affinity for the stains used indicating a biochemical change. Furthermore, these chloroplasts were noticeably more concentrated near the cell walls. Microscopic examination confirmed the observation that leaf tissue suffered severe injury when barnyard grass was exposed to EPTC.

When the effect of EPTC on the emergence of barnyard grass and six other annual grasses from seed and quackgrass from perennial rhizomes was studied, it was found that in all the plants except corn, leaf tissue was injured. The normal emerging shoots of these grasses differ in developmental morphology. Leaf tissue constitutes varying proportions of the total shoot in the different grasses and the effect of EPTC on the emerging shoot was governed largely by these differences. The amount of elongation made by the emerging shoots of plants exposed to EPTC was inversely proportional to the amount of leaf tissue of which the shoot consisted. Corn was conspicuously different from all the other grasses in that it was not visibly injured by 3 ppm of EPTC.

Considerable evidence was accumulated which indicated that not only was leaf tissue the prime site of EPTC injury, it was also an important site of EPTC uptake by the barnyard grass seedling. When only the shoot (first internode and coleoptile) was exposed to EPTC either as vapor or within the soil, the plants were lethally injured, just as they were when the whole plant was exposed. Furthermore, when only the coleoptile was exposed to EPTC the plants were killed. It was also found that barnyard grass seedlings grew quite normally when the germinating seed and the roots were in soil having a lethal concentration of EPTC, but the shoot was protected.

This evidence indicates that the susceptible part of the seedling, the leaf tissue, itself, is subject to lethal injury from direct contact by EPTC. The lack of injury to the plant from root exposure suggests that direct exposure to the leaf tissue may be the main mode of uptake of EPTC and that translocation from the roots is unimportant.

The nature of EPTC-injury and the way injured plants eventually recovered also suggest that direct foliar contact is the effective mode of exposure. EPTC-injury was progressive. When barnyard grass seedlings were injured, the first foliar leaf always showed symptoms. If injury was slight, it was limited to this first leaf and subsequent leaves were normal. As injury became more severe, more leaves were affected. The photo of recovering plants which had grown in soil containing 1/4 ppm of EPTC shown in Figure 5 demonstrates this progression of injury.

The developing leaves and leaf primordia are arranged concentrically in the bud with the first one to expand being external. Possibly the progression of injury from outside inward which occurred as the rate of EPTC increased was due to deeper penetration by higher concentrations of EPTC. EPTC diffusion through leaf tissue reported by Yamaguchi et al (37, p. 91-92) supports this possibility.

If it is true that exposure of developing leaves within the coleoptile of grass seedlings occurs by direct penetration of EPTC, is it not possible that the tolerance of corn to 3 ppm of EPTC was due to more efficient EPTC exclusion by its heavier coleoptile? Here is an interesting problem for further research.

Actually, the progression of EPTC injury was two-fold. More severe injury from higher rates of EPTC progressed to involve more leaves, as was just mentioned. At the same time, injury to individual leaves (most obvious in the first foliar leaf) became more severe as the rate of EPTC increased (Figure 4).

In these studies, it was shown that EPTC vapors were very effective in entering the coleoptile of barnyard grass and killing the plant. No information was obtained which would indicate whether the entrance of EPTC into seedlings in moist soil is in the form of vapors or aqueous solution.

No effort was made in the current investigation to study the biochemistry involved in the action of EPTC on leaf tissue. This phase of the problem deserves further intensive research.

The coleoptile, being the leaf preceding the first foliar leaf in the grass phyllotaxy, did not show the extreme symptoms of EPTC injury that the foliar leaves did. This may be due to the lack of chlorophyll in the coleoptile. It was in the chlorophyllous cells of the foliar leaf mesophyll that severe symptoms of EPTC injury were seen. However, certain signs of injury to the coleoptile were observed. First, the characteristic bulging near the coleoptilar node often associated with EPTC injury involved an abnormal outfolding of the base of the coleoptile. Furthermore, browning, shriveling, and shortening of the coleoptile were caused by EPTC in the barnyard grass germinated in paper towels in the presence of EPTC. There was, therefore, some effect of EPTC on the colorless leaf tissue of the coleoptile. However, the most obvious effect was seen in the mesophyll of the foliar leaves. Apparently plants die from EPTC exposure because of injury to the leaf mesophyll.

Effect of EPTC on the First Internode of Barnyard Grass

In addition to the foliar symptoms already discussed, the first internode of barnyard grass injured by EPTC often showed symptoms, being very much kinked. This kinking was invariably limited to the portion of the first internode below the soil surface. This suggested that the kinking may have resulted from direct contact of the first internode in the soil. However, certain other evidence suggested that the first internode functioned quite normally.

For example, the first internode of EPTC-injured seedlings elongated quite normally during emergence. Furthermore, plants which recovered after being injured by EPTC often remained in a static condition for several weeks before producing any normal leaves. During this time the first internode, the only connection between the root system and the apical meristem and leaves, must have remained functional. It transported water and resisted attack by decay organisms which might be expected to destroy injured plant tissue within the soil.

It seemed possible that the kinking of the first internode might be a secondary effect of the injury to the leaf tissue above it. The results of several tests indicated this was true. When EPTC-injured barnyard grass elongated in loose soil or in paper towels, where resistance to elongation was slight, the first internode did not become kinked. The resistance of firm soil caused EPTC-injured seedlings to develop the kinking symptom. This indicated the kinking was a secondary effect of EPTC injury rather than a direct effect. The lack of kinking in the first internode above ground was due to the lack of resistance to elongation there.

It seemed that injury to the coleoptile may have impaired its ability to penetrate the soil during emergence. Stem elongation, which is due to cell division and elongation in the region of the intercalary meristem in the upper part of the first internode, continued to push against the coleoptile. Because the coleoptile could no longer penetrate the soil efficiently in response to the push from below, the first internode became kinked to accommodate its own increase in length. Further evidence supporting this theory was obtained when similar kinking symptoms were induced without EPTC. When barnyard grass was made to germinate and emerge in tightly compacted soil without EPTC, the resistance of the firm soil caused the first internode to become kinked. Similar kinking of the first internode was observed when the coleoptile of an emerging barnyard grass seedling in the absence of EPTC became lodged while trying to penetrate the hole in the tip of a plastic cone. Kinking and coiling accommodated the elongation of the first internode when it could not push the coleoptile forward.

Further evidence that the function of the first internode was not harmed by EPTC was obtained when lethally injured barnyard grass seedlings showed normal geotropic response. They bent into an upright position when laid horizontally on wet paper for two days. Also, adventitious roots developed on the first internodes of EPTC-injured seedlings as they do in untreated seedlings. The lack of observable ill-effects at the cellular level in the first internode of barnyard grass further supported the theory that this part of the plant is not injured by EPTC.

When barnyard grass seedlings elongated in paper towels moistened with water containing EPTC, the length of the first internode decreased as the rate of EPTC increased. This could suggest a direct effect of EPTC on the first internode. Again, it seems more logical to explain this reduction in length as a secondary effect of the foliar injury. It is known that auxin produced in the coleoptile of grasses stimulates shoot elongation, and that auxin destruction by light upon emergence causes elongation to cease. It seems reasonable that injured coleoptiles would produce less auxin than normal coleoptiles. If this is true, it would account for the reduced shoot length.

Credible evidence has been presented which indicates the kinking of the first internode is a secondary effect and suggests that this stem tissue continues to function quite normally after the foliar tissue suffers lethal EPTC injury. The possibility of some minor direct effects on the first internode has not been precluded, however. It is possible that EPTC induces a softening of the cell walls which facilitates kinking. The kinking of the first internode and the bulging of the base of the coleoptile are somewhat similar, and may be related in cause.

Effect of EPTC on Roots of Barnyard Grass

In the different tests conducted in the investigation of the effect of EPTC on barnyard grass, detrimental effects of EPTC on roots were never observed. In fact, rooting appeared to be enhanced by EPTC in some cases. The length of the primary roots of barnyard grass seedlings which germinated in paper towels was not reduced by increasing concentrations of EPTC.

The production of normal coronal and first internode adventitious roots in the presence of EPTC vapors by barnyard grass seedlings which had already suffered lethal injury to the foliar tissue (Figure 21) must be considered as very substantial evidence that root tissue is not a site of EPTC injury in barnyard grass. Lack of injury to roots exposed to EPTC was also indicated by the normal growth made by plants grown with the primary roots exposed to EPTC and the shoots protected.

The lack of injury to the barnyard grass plants from root exposure indicated the roots were not a site of uptake of EPTC for transport to the sensitive leaf tissue. Either the EPTC was not absorbed by the roots, it was adsorbed but not transported, or it was absorbed and chemically changed before transport.

Considering the distribution of radioactivity throughout the plant from an application of tagged EPTC reported by Yamaguchi et al (37, p. 91-92) and Fang and Theisen (16, p. 295-298) and the rapid breakdown of EPTC in plants reported by Fang and Yu (17, p. 91-92) the latter possibility seems most likely.

The persistence of injured plants for several weeks with no normal leaves followed by rapid recovery once a normal leaf was produced, suggested that the roots in the soil remained functional during the time when normal activity of the plant was impossible due to the lack of normal leaves.

EPTC Application as Influenced by Seedling Development

Observation of barnyard grass seedlings from seeds planted at three depths in the soil in April and July showed that a consistent pattern of emergence was followed. The coleoptile began to elongate first. Further elongation of the shoot was largely due to elongation of the first internode with the coleoptile becoming about 4 - 8 mm in length, regardless of the depth in the soil from which the seedling emerged. Elongation of the first internode always continued until all or nearly all of the coleoptile emerged. The apical meristem, which is just above the coleoptilar node was always located at or just below the soil surface. This was true whether seedlings emerged from 1/2, 1 1/2 or 3 inches.

Based on the observations that the site of lethal uptake of EPTC is the coleoptile, the susceptible stage of the barnyard grass seedling to EPTC exposure is from seed germination until the coleoptile emerges from the soil. The deeper the seeds were planted, the longer it took for the coleoptile to emerge. Emergence took longer in cool weather than when temperatures were high. Seedlings emerged from 1/2 inch in July in about 4 days. Other things being equal, one would expect EPTC to be more effective in killing plants in cool weather than in warm because of the greater time of exposure resulting from the slower emergence.

From whatever depth barnyard grass seedlings emerged, the sensitive tissue (coleoptile and enclosed foliar leaves) always had to pass through the same surface soil. It would seem that the most effective application of a given rate of EPTC in the field would be a shallow incorporation of perhaps 1 inch. A lethal concentration would then be present to expose the coleoptiles of any emerging shoots. Deeper incorporation would dilute the concentration in the surface soil, possibly allowing seedlings from seeds near the soil surface to escape injury. However, in the field application of EPTC at different depths, barnyard grass seedlings were most numerous at the shallowest (1 inch) incorporation.

A rate of 3 pounds per acre incorporated 1 inch deep gives a concentration in the surface inch of soil of approximately 9 ppm. This is at least 9 times the concentration needed to kill barnyard grass in the greenhouse. It seems likely that rapid loss was responsible for the poor barnyard grass control obtained when the EPTC was incorporated shallowly. EPTC is known to be a very volatile compound (1, p. 88) and the shallow incorporation probably encouraged rapid vapor loss. More research is needed to determine the method of placement of EPTC in the soil which will maintain a lethal concentration near the surface for the longest time. A recently described method of EPTC application (34, p. 6-7) which the author has personally found very effective for barnyard grass control involves layering the EPTC at some depth in the soil without actually mixing it with the soil. This application method appears very promising for efficient use of EPTC. Probably a lethal concentration is maintained in the surface soil by diffusion from the layer. Thus, a concentration sufficient to kill barnyard grass is present to contact emerging shoots, and at the same time a high concentration very near the surface which would lead to rapid loss is avoided.

CONCLUSIONS

Barnyard grass seedlings are subject to lethal injury by EPTC at concentrations of 1 - 6 parts per million by weight in fine sandy loam soil. EPTC at these concentrations does not affect seed germination. Death results from injury to the young foliar leaves and leaf primordia contained within the coleoptile of the developing seedling. In addition to being the site of lethal action of EPTC, the coleoptile (with the enclosed foliar leaves) is an important and perhaps the main site of EPTC uptake. The roots appear to take up little, if any, of the EPTC which kills the barnyard grass plant. Root and stem tissue is not injured by rates of EPTC which cause serious injury to leaf tissue. The first internode (stem tissue) often becomes kinked into a zig-zag pattern in EPTC-injured barnyard grass seedlings. This appears to be a secondary response due to the direct injury of the leaf tissue rather than a direct effect of EPTC.

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APPENDIX

Detailed data are presented in the Appendix. These data are presented in summary form in the body of the thesis as summary tables, figures or summary statements.

Table A. Number of seedlings of barnyard grass from approximately 60 seeds 2 weeks after planting in soil having various concentrations of EPTC.

ppm EPTC	I	II	III	IV	Total	Average
0	47	63	54	63	227	57
1/4	54	59	65	60	238	60
1/2	63	64	52	57	236	59
1	60	44	63	50	217	54
1 1/2	50	57	50	58	215	54
2	60	51	53	49	213	53
2 1/2	38	58	46	52	194	49
3	65	55	41	48	209	52
4	46	35	42	46	169	42*
5	43	24	53	52	172	43*
6	29	38	45	29	141	35**

* Means significantly different from check at 5% level of probability.

** Means significantly different from check at 1% level of probability.

LSD (5%) = 11.8 LSD (1%) = 15.6

Table B. Lengths in mm of barnyard grass seedling parts 5 days after placing seeds in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

0 ppm of EPTC

	Rep. I					Rep. II			
	Primary root	First internode	Coleoptile	Total shoot		Primary root	First internode	Coleoptile	Total shoot
	15	92	5	97		2	71	3	74
	2	73	4	77		1	76	4	80
	2	90	5	95		4	73	3	76
	2	76	4	80		1	60	3	63
	3	88	4	92		1	75	5	80
	1	93	4	97		2	79	4	83
	8	83	5	88		1	83	4	87
	1	72	5	77		1	70	4	74
	1	63	4	67		1	64	4	68
	1	77	3	80		0	62	3	65
	4	99	4	103		1	79	4	83
	1	71	4	75		2	77	3	80
	0	78	4	82		1	52	3	55
	4	74	4	78		1	61	4	65
	11	62	5	67		3	71	4	75
	3	63	4	67		1	70	4	74
	1	71	4	75		1	58	3	61
	13	59	3	62		11	66	4	70
	1	59	4	63		2	59	6	65
	9	59	5	64		1	50	5	55
Ave.	4.2	75.1	4.2	79.3	Ave.	1.9	67.6	3.9	71.7
Averages of 2 replications						3.1	71.4	4.1	75.5

Table B (continued). Lengths in mm of barnyard grass seedling parts 5 days after placing seeds in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

5 ppm of EPTC

	Rep. I				Rep. II			
	Primary root	First internode	Coleoptile	Total shoot	Primary root	First internode	Coleoptile	Total shoot
	8	49	4	53	9	86	4	90
	10	89	4	93	9	57	4	61
	1	65	2	67	14	87	3	90
	1	71	4	75	13	67	3	70
	15	69	4	73	1	79	2	81
	1	47	3	50	1	56	5	61
	10	67	3	70	6	72	3	75
	0	68	4	72	17	96	3	99
	1	68	3	71	0	72	3	75
	1	71	4	75	2	88	3	91
	1	62	3	65	7	77	3	80
	2	66	3	69	8	77	3	80
	5	68	4	72	1	64	3	67
	1	65	3	68	1	71	3	74
	1	59	4	63	0	56	2	58
	1	65	4	69	0	65	3	68
	2	58	3	61	3	59	3	62
	1	60	3	63	1	61	4	65
	1	51	3	54	0	53	2	55
	4	54	4	58	1	52	3	55
Ave.	3.4	63.6	3.5	67.1	4.7	69.8	3.1	72.9
Averages of 2 replications					4.1	66.7	3.3	70.0

Table B (continued). Lengths in mm of barnyard grass seedling parts 5 days after placing seeds in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

15 ppm of EPTC

	Rep. I					Rep. II			
	Primary root	First internode	Coleoptile	Total shoot		Primary root	First internode	Coleoptile	Total shoot
	1	58	2	60		15	52	2	54
	15	60	3	63		2	55	2	57
	0	59	3	62		0	60	2	62
	1	53	2	55		22	78	4	82
	5	70	3	73		6	73	3	76
	8	87	3	90		1	73	3	76
	22	70	3	73		3	73	4	77
	1	63	3	66		25	59	3	62
	1	63	3	66		1	61	4	65
	1	53	2	55		3	64	3	67
	1	60	3	63		1	61	2	63
	0	56	2	58		0	55	2	57
	11	67	3	70		20	80	4	84
	1	60	2	62		1	69	3	72
	0	54	3	57		10	57	3	60
	10	62	3	65		15	57	3	60
	2	59	3	62		1	50	2	52
	16	53	3	56		1	46	2	48
	0	51	3	54		2	48	2	50
	1	52	3	55		5	39	3	42
Ave.	3.9	60.5	2.8	63.3	Ave.	6.7	60.5	2.8	63.3
Averages of 2 replications						5.3	60.5	2.8	63.3

Table B (continued). Lengths in mm of barnyard grass seedling parts 5 days after placing seeds in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

30 ppm of EPTC (measurements made on the 6th. day)

	Rep. I				Rep. II			
	Primary root	First internode	Coleoptile	Total shoot	Primary root	First internode	Coleoptile	Total shoot
	18	80	3	83	30	49	3	52
	1	66	4	70	3	36	4	40
	1	62	3	65	2	61	4	65
	0	61	4	65	4	57	3	60
	9	68	3	71	5	53	3	56
	8	54	4	58	1	39	3	42
	2	59	3	62	11	58	4	62
	2	67	3	70	3	36	4	40
	8	69	3	72	0	44	2	46
	3	42	2	44	11	71	4	75
	0	78	3	81	0	46	4	50
	1	47	3	50	3	68	1	69
	12	55	5	60	1	51	4	55
	8	52	3	55	1	52	3	55
	4	49	3	52	15	31	4	35
	0	42	5	47	2	47	3	50
	2	51	4	55	4	51	4	55
	1	32	3	35	0	20	5	25
	1	37	3	40	1	31	4	35
	1	35	5	40	2	36	4	40
Ave.	4.1	55.3	3.5	58.8	5.0	46.9	3.5	50.4
Averages of 2 replications					4.6	51.1	3.5	54.6

Table C. Lengths in mm of barnyard grass seedling parts 7 days after placing seeds in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

0 ppm of EPTC

	Rep. I				Rep. II			
	Primary root	First internode	Coleoptile	Total shoot	Primary root	First internode	Coleoptile	Total shoot
	8	66	4	70	13	82	8	90
	15	98	6	104	1	91	6	97
	7	98	7	105	1	80	4	84
	34	93	7	100	2	85	6	91
	4	100	6	106	23	96	7	103
	1	95	5	100	1	103	7	110
	16	106	9	115	5	90	5	95
	28	106	9	115	0	89	5	94
	0	97	7	104	3	86	9	95
	1	75	5	80	1	97	6	103
	0	98	5	103	4	63	5	68
	32	117	9	126	1	116	6	122
	0	85	5	90	0	82	3	85
	1	81	6	87	0	98	5	103
	22	78	5	83	25	79	5	84
	2	71	4	75	0	81	4	85
	0	88	3	91	10	66	4	70
	32	60	5	65	3	87	3	90
	11	60	4	64	0	79	4	83
	4	37	5	42	5	68	4	72
Ave.	10.9	85.5	5.8	91.3	4.9	85.9	5.3	91.2
Averages of 2 replications					7.9	85.7	5.6	91.3

Table C (continued). Lengths in mm of barnyard grass seedling parts 7 days after placing seeds in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

5 ppm of EPTC

	Rep. I					Rep. II			
	Primary root	First internode	Coleoptile	Total shoot		Primary root	First internode	Coleoptile	Total shoot
	2	70	4	74		25	98	9	107
	10	51	4	55		8	84	6	90
	2	76	5	81		2	80	5	85
	1	89	4	93		5	80	6	86
	2	57	3	60		0	60	5	65
	0	82	3	85		1	71	5	76
	4	73	2	75		4	90	5	95
	1	96	4	100		15	83	4	87
	1	93	4	97		1	85	7	92
	0	71	3	74		5	90	5	95
	0	66	4	70		3	80	5	85
	30	51	5	56		3	74	4	78
	0	61	4	65		14	96	4	100
	0	51	4	55		6	85	5	90
	0	95	5	100		0	81	4	85
	1	70	5	75		1	75	5	80
	2	72	3	75		1	82	5	87
	0	69	5	74		2	74	4	78
	3	76	4	80		0	75	5	80
	1	77	3	80		11	90	3	93
Ave.	3.0	72.3	3.9	76.2	Ave.	5.4	81.6	5.1	86.7
Averages of 2 replications						4.2	77.0	4.5	81.5

Table C (continued). Lengths in mm of barnyard grass seedling parts 7 days after placing seeds in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

15 ppm of EPTC

	Rep. I				Rep. II			
	Primary root	First internode	Coleoptile	Total shoot	Primary root	First internode	Coleoptile	Total shoot
	1	84	3	87	22	100	5	105
	1	87	3	90	4	86	4	90
	2	64	4	68	1	90	3	93
	1	80	4	84	1	80	3	83
	13	55	3	58	0	57	4	61
	0	65	5	70	18	83	4	87
	2	67	3	70	0	73	3	76
	2	56	2	58	1	79	5	84
	45	62	3	65	0	74	3	77
	10	88	4	92	4	97	6	103
	24	88	4	92	0	66	4	70
	16	76	4	80	1	74	6	80
	15	75	3	78	1	74	6	80
	0	66	4	70	8	67	3	70
	1	82	4	86	7	65	5	70
	1	78	4	82	0	69	4	73
	1	66	4	70	6	62	3	65
	1	51	4	55	2	39	3	42
	0	59	3	62	1	44	3	47
	20	70	3	73	1	36	4	40
Ave.	7.8	70.9	3.6	74.5	3.9	70.7	4.1	74.8
Averages of 2 replications					5.7	70.8	3.9	74.7

Table C (continued). Lengths in mm of barnyard grass seedling parts 7 days after placing seeds in paper towels moistened with water containing 0, 5, 15 and 30 ppm of EPTC.

30 ppm of EPTC

	Rep. I					Rep. II			
	Primary root	First internode	Coleoptile	Total shoot		Primary root	First internode	Coleoptile	Total shoot
	1	55	3	58		38	52	5	57
	10	56	5	61		23	74	3	77
	2	68	4	72		5	36	4	40
	2	67	5	72		4	54	4	58
	3	59	3	62		2	58	3	61
	3	58	4	62		9	60	3	63
	22	71	4	75		22	51	3	54
	2	63	4	67		20	70	4	74
	0	51	4	55		9	45	5	50
	1	61	4	65		1	72	5	77
	32	64	4	68		1	59	3	62
	27	51	4	55		18	62	5	67
	2	71	4	75		15	61	4	65
	18	66	4	70		0	51	4	55
	0	50	3	53		1	59	4	63
	11	57	3	60		1	46	2	48
	3	59	6	65		0	61	4	65
	1	58	2	60		4	45	5	50
	8	46	4	50		0	51	4	55
	21	44	3	47		7	58	4	62
Ave.	8.5	58.7	3.9	62.6	Ave.	9.0	56.3	3.9	60.2
Averages of 2 replications						8.8	57.5	3.9	61.4

Table D. Number of barnyard grass seedlings and percent showing some degree of first internode kinking 7 days after planting in soil containing 3 ppm of EPTC and applying various pressures to the soil surface.

Lb/in.^{2} applied to soil surface	Replication I	II	III	IV	Weighted Average
0					
Total	32	47	32	34	36
Percent kinked	6	6	6	6	6
6					
Total	44	42	43	41	43
Percent kinked	52	74	60	54	60
12					
Total	36	36	36	43	38
Percent kinked	94	92	86	58	82
24					
Total	39	45	31	38	38
Percent kinked	100	100	100	95	99

Table E. Number of barnyard grass seedlings and percent showing some degree of first internode kinking 7 days after planting and applying various pressures to the soil surface.

Lb/in.^{2} applied to soil surface	Replication I	II	III	IV	Weighted Average
0					
No. germinated	52	39	46	51	47
Percent kinked	0	3	0	0	1
60					
No. germinated	42	42	39	42	41
Percent kinked	55	81	95	100	82
120					
No. germinated	47	41	47	49	46
Percent kinked	79	93	96	98	91
240					
No. germinated	43	37	30	41	38
Percent kinked	84	97	100	100	95

Table F. Pounds weight required to insert a needle of 1 mm diameter 1 1/2 inches into soil to which pressures of 0, 60, 120, 240 lb/in.^{2} had been applied.

Trials	Treatments -- Lb/in.^{2} 0	60	120	240
1	.10	2.0	3.1	4.9
2	.08	2.0	3.1	5.4
3	.15	1.9	2.8	5.3
4	.15	2.1	3.2	5.3
5	.10	2.0	3.1	5.2
6	.10	2.1	2.9	5.4
7	.07	3.3	3.5	5.2
8	.12	2.1	3.2	5.2
9	.08	2.1	3.4	5.5
10	.09	2.1	3.3	5.2
Average	.10	2.17	3.16	5.26

Table G. Periodic counts and measurements taken on developing barnyard grass seedlings from seeds planted at three depths on April 18, 1960. Averages of 50 seedlings.

Measurements	Depth inches	4/25	4/26	4/27	4/28	4/29	4/30	5/1
Coleoptile	1/2	0	0.2	0.8	1.6	3.4	3.4	4.4
length in mm	1 1/2	0	0.1	0.3	0.9	2.3	2.9	3.8
	3	0	0.0	0.1	0.4	1.3	1.7	3.0
First inter-	1/2	0	0.1	0.9	3.5	9.2	11.6	13.2
node length	1 1/2	0	0.0	0.1	1.4	8.7	18.4	27.7
in mm	3	0	0.0	0.0	0.3	2.3	7.9	21.5
Total shoot	1/2	0	0.3	1.7	5.1	12.6	16.2	20.0
length in mm	1 1/2	0	0.2	0.3	2.3	11.0	21.5	31.5
	3	0	0.0	0.1	0.6	3.6	9.7	24.8
Number of	1/2	0	0	0	0	0	0.7	0.8
foliar leaves	1 1/2	0	0	0	0	0	0	0.1
per plant	3	0	0	0	0	0	0	0
Percent of	1/2	0	22	60	96	100	100	100
seeds	1 1/2	0	18	36	76	100	100	100
germinated	3	0	0	18	36	84	100	100
Percent of	1/2	0	50	67	96	100	100	100
seedlings having	1 1/2	0	11	28	87	82	100	100
primary root	3	0	0	0	44	55	100	100
Percent with	1/2	0	0	0	0	0	0	0
adventitious roots	1 1/2	0	0	0	0	0	0	0
on first internode	3	0	0	0	0	0	0	0
Number of coronal	1/2	0	0	0	0	0	0	0
roots per plant	1 1/2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
Number of	1/2	0	0	0	0	0	0	0
tillers per	1 1/2	0	0	0	0	0	0	0
plant	3	0	0	0	0	0	0	0

Table G (continued). Periodic counts and measurements taken on developing barnyard grass seedlings from seeds planted at three depths on April 18, 1960. Averages of 50 seedlings.

Measurements	Depth inches	5/2	5/3	5/4	5/5	5/6	5/7	5/9
Coleoptile	1/2	4.9	4.5	4.3	4.3	4.6	-	4.4
length in mm	1 1/2	5.7	5.4	5.6	5.4	4.6	-	5.2
	3	3.3	4.0	4.7	4.5	4.7	5.1	5.5
First inter-	1/2	13.1	11.4	12.2	12.0	12.6	-	13.3
node length	1 1/2	30.4	33.9	34.0	34.7	33.6	-	38.0
in mm	3	30.8	47.8	50.6	55.4	63.7	68.5	75.0
Total shoot	1/2	23.6	23.7	23.9	25.0	28.5	-	27.0
length in mm	1 1/2	38.6	44.2	45.4	45.0	45.7	-	50.8
	3	34.3	52.0	55.4	60.2	69.6	74.8	82.1
Number of	1/2	1.0	1.1	1.3	1.5	1.8	-	2.0
foliar leaves	1 1/2	0.9	0.9	0.8	1.0	1.4	-	2.0
per plant	3	0	0	0	0.1	0.3	0.3	0.5
Percent of	1/2	100	100	100	100	100	100	100
seeds	1 1/2	100	100	100	100	100	100	100
germinated	3	100	100	100	100	100	100	100
Percent of	1/2	100	100	100	100	100	-	100
seedlings having	1 1/2	100	100	100	100	100	-	100
primary root	3	100	100	100	100	100	100	100
Percent with	1/2	0	0	30	52	88	-	100
adventitious roots	1 1/2	0	0	0	4	40	-	100
on first internode	3	0	0	0	0	0	0	42
Number of coronal	1/2	0	0	0	0	0	-	0.3
roots per plant	1 1/2	0	0	0	0	0	-	0.1
	3	0	0	0	0	0	-	0.0
Number of	1/2	0	0	0	0	0	-	0
tillers per	1 1/2	0	0	0	0	0	-	0
plant	3	0	0	0	0	0	-	0

Table G (continued). Periodic counts and measurements taken on developing barnyard grass seedlings from seeds planted at three depths on April 18, 1960. Averages of 50 seedlings.

Measurements	Depth inches	5/11	5/13	5/16	5/20	5/23	6/21
Coleoptile	1/2	4.3	4.2	4.4	-	-	-
length in mm	1 1/2	5.1	4.9	5.1	-	-	-
	3	5.7	5.3	5.6	-	-	-
First inter-	1/2	13.7	12.5	13.9	-	-	-
node length	1 1/2	37.7	36.1	36.9	-	-	-
in mm	3	77.6	74.5	81.7	-	-	-
Total shoot	1/2	37.0	35.9	48.4	42.9	72.3	220.5
length in mm	1 1/2	58.1	58.0	63.7	72.2	84.9	140.7
	3	87.2	89.3	103.9	103.4	125.1	150.0
Number of	1/2	2.8	3.0	3.5	-	-	-
foliar leaves	1 1/2	2.6	2.7	3.0	-	-	-
per plant	3	1.0	2.0	2.1	-	-	-
Percent of	1/2	100	100	100	100	100	100
seeds	1 1/2	100	100	100	100	100	100
germinated	3	100	100	100	100	100	100
Percent of	1/2	100	100	100	100	100	100
seedlings having	1 1/2	100	100	100	100	100	100
primary root	3	100	100	100	100	100	100
Percent with	1/2	100	100	100	100	100	100
adventitious roots	1 1/2	100	100	100	100	100	100
on first internode	3	50	68	86	100	100	100
Number of coronal	1/2	0.6	0.8	2.0	1.7	3.0	8.5
roots per plant	1 1/2	0.3	0.4	0.9	1.5	2.7	6.8
	3	0.0	0.0	0.3	0.6	2.5	6.4
Number of	1/2	0	0	0	0	0	1.9
tillers per	1 1/2	0	0	0	0	0	1.8
plant	3	0	0	0	0	0	1.6

Table H. Periodic counts and measurements taken on developing barnyard grass seedlings from seeds planted at three depths on July 7, 1960. Averages of 50 seedlings.

Measurements	Depth inches	7/9	7/11	7/13	7/15
Coleoptile length in mm	1/2	0.5	1.6	4.0	4.5
	1 1/2	-	1.8	4.4	4.6
	3	0.5	-	4.3	5.4
First internode length in mm	1/2	0.2	6.2	15.1	16.0
	1 1/2	-	12.2	40.8	45.5
	3	0.1	-	55.3	76.5
Total shoot length in mm	1/2	0.7	8.1	24.5	29.5
	1 1/2	-	14.0	47.2	56.0
	3	0.6	-	60.6	85.1
Number of foliar leaves per plant	1/2	0.0	0.1	1.0	1.7
	1 1/2	-	0.0	0.8	1.6
	3	0.0	-	0.0	0.9
Percent of seeds germinated	1/2	36	66	100	100
	1 1/2	-	86	100	100
	3	38	-	100	100
Percent of seedlings having primary root	1/2	-	79	100	100
	1 1/2	-	91	100	100
	3	-	-	100	100
Percent with adventitious roots on first internode	1/2	0	0	2	92
	1 1/2	-	0	34	100
	3	0	-	8	62
Number of coronal roots per plant	1/2	0.0	0.0	0.0	0.0
	1 1/2	-	0.0	0.0	0.0
	3	0.0	-	0.0	0.0
Number of tillers per plant	1/2	0.0	0.0	0.0	0.0
	1 1/2	-	0.0	0.0	0.0
	3	0.0	-	0.0	0.0

Table H (continued). Periodic counts and measurements taken on developing barnyard grass seedlings from seeds planted at three depths on July 7, 1960. Averages of 50 seedlings.

Measurements	Depth inches	7/18	7/22	7/29	8/10
Coleoptile length in mm	1/2	4.5	3.5	-	-
	1 1/2	4.7	4.6	-	-
	3	5.4	5.1	-	-
First internode length in mm	1/2	12.9	10.7	-	-
	1 1/2	45.1	41.3	-	-
	3	78.8	76.8	-	-
Total shoot length in mm	1/2	29.1	55.7	147.8	443.2*
	1 1/2	57.9	66.7	121.5	470.1*
	3	93.4	103.9	101.9	469.6*
Number of foliar leaves per plant	1/2	2.2	4.2	-	-
	1 1/2	2.0	3.7	-	-
	3	1.7	3.7	-	-
Percent of seeds germinated	1/2	100	100	100	100
	1 1/2	100	100	100	100
	3	100	100	100	100
Percent of seedlings having primary root	1/2	100	100	100	100
	1 1/2	100	100	100	100
	3	100	100	100	100
Percent with adventitious roots on first internode	1/2	92	100	100	100
	1 1/2	100	100	100	100
	3	96	100	100	100
Number of coronal roots per plant	1/2	0.4	3.0	6.5	15.7
	1 1/2	0.0	2.1	5.4	14.5
	3	0.0	1.9	5.4	18.1
Number of tillers per plant	1/2	0.0	0.4	1.3	2.0
	1 1/2	0.0	0.1	0.8	1.5
	3	0.0	0.1	0.7	3.0

* Height above coleoptilar node.

Table I. Maximum, minimum and mean daily temperature (degrees F.) from April 18 to June 21, 1960 at three depths in the soil where barnyard grass was grown.

Date	1/2 inch depth Max.	Min.	Mean	1 1/2 inch depth Max.	Min.	Mean	3 inch depth Max.	Min.	Mean
4/18/60	64	37	50	56	41	48	--	--	--
19	64	38	51	57	41	49	--	--	--
20	62	42	52	58	46	52	57	50	53
21	69	39	54	61	39	50	58	45	51
22	70	38	54	61	38	49	56	43	49
23	74	41	57	66	43	54	--	--	--
24	76	44	60	70	44	57	--	--	--
25	84	39	61	77	43	55	70	45	57
26	78	40	59	68	46	57	66	49	57
27	83	45	64	77	46	61	70	50	60
28	82	51	66	77	52	64	73	57	65
29	92	45	68	87	49	68	81	55	68
30	96	46	71	90	51	70	85	54	69
5/1/60	92	50	71	85	54	69	78	58	68
2	94	50	72	87	53	70	84	58	71
3	86	48	67	79	54	66	--	--	--
4	90	47	68	85	48	66	--	--	--
5	90	45	67	86	49	67	--	--	--
6	92	57	74	86	58	72	--	--	--
7	74	53	63	69	55	62	--	--	--
8	90	44	67	86	45	65	--	--	--
9	94	49	71	88	52	70	--	--	--
10	99	53	76	91	56	73	--	--	--
11	106	58	82	92	61	76	95	66	80
12	70	46	58	66	52	59	69	67	68
13	74	43	58	69	46	57	69	53	61
14	84	41	62	80	46	63	74	51	62
15	92	42	67	88	48	68	82	51	66
16	79	51	65	76	55	65	--	--	--
17	84	45	64	80	50	65	--	--	--
18	87	43	65	83	49	66	81	53	67
19	80	45	62	75	50	62	73	54	63
20	57	42	49	56	50	53	60	51	55

Table I (continued). Maximum, minimum and mean daily temperature (degrees F.) from April 18 to June 21, 1960 at three depths in the soil where barnyard grass was grown.

Date	1/2 inch depth			1 1/2 inch depth			3 inch depth		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
5/21/60	73	37	55	67	43	55	66	46	56
22	82	37	59	87	44	65	68	57	57
23	91	42	66	97	48	72	82	50	66
24	82	47	64	82	53	67	76	56	66
25	83	42	62	80	48	64	75	51	63
26	82	47	64	78	52	65	73	55	64
27	93	48	70	88	51	69	86	55	70
28	96	49	72	88	52	70	88	57	72
29	104	55	79	92	56	74	93	60	76
30	100	61	80	88	62	75	92	67	79
31	96	55	75	89	62	75	91	66	78
6/1/60	92	50	71	89	54	71	86	60	73
2	104	54	79	100	59	79	96	63	79
3	106	59	82	95	63	79	98	65	81
4	107	58	82	97	62	79	98	66	82
5	114	60	87	98	65	81	100	68	84
6	84	50	67	80	58	69	80	71	75
7	87	46	66	83	50	66	82	56	69
8	88	47	67	84	49	66	80	56	68
9	98	49	73	90	54	72	90	58	74
10	102	54	78	95	58	76	94	62	78
11	103	60	81	93	63	78	98	67	82
12	110	60	85	90	64	77	100	67	83
13	104	63	83	92	60	76	96	70	83
14	82	59	70	78	62	70	80	66	73
15	92	57	74	84	57	70	82	63	72
16	90	57	73	86	63	74	89	67	78
17	99	49	74	93	54	73	94	60	77
18	104	56	80	95	60	77	96	64	80
19	98	54	76	88	60	74	89	63	76
20	94	51	72	86	56	71	86	60	73
21	100	51	75	90	54	72	91	60	75

Table J. Maximum, minimum and mean daily temperatures (degrees F.) from July 7 to July 29, 1960 at three depths in the soil where barnyard grass was grown.

Date	1/2 inch depth			1 1/2 inch depth			3 inch depth		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
7/7/60	97	60	78	92	62	77	91	69	80
8	105	57	81	100	59	79	96	65	80
9	109	62	85	101	63	82	99	67	83
10	108	62	85	101	64	82	100	69	84
11	110	61	85	102	63	82	100	69	84
12	116	65	90	105	67	86	104	73	88
13	96	64	80	91	68	79	90	76	83
14	96	58	77	90	60	75	89	68	78
15	107	60	83	101	60	80	98	66	82
16	113	66	89	105	66	85	104	71	87
17	120	71	95	106	71	88	107	76	91
18	122	72	97	110	74	92	109	79	94
19	122	72	97	110	74	92	110	80	95
20	117	68	92	105	71	88	105	78	91
21	103	65	84	93	69	81	93	76	84
22	91	58	74	86	60	73	87	68	77
23	98	52	75	92	54	73	87	62	74
24	105	56	80	100	56	78	97	62	79
25	103	61	82	98	62	80	96	68	82
26	108	72	90	100	73	86	98	76	87
27	115	69	92	105	70	87	104	76	90
28	105	67	86	96	70	83	94	76	85
29	92	60	76	97	61	79	84	69	76

Table K. Number of barnyard grass in 9 square feet of undisturbed soil between irrigation furrows in study of rate and depth of incorporation of EPTC on July 1, 1960.

Treatments	I	II	III	IV	Total	Average
1. EPTC @ 0 lb/A						
Incorporated 1 inch	27	15	20	15	77	19.3
Incorporated 3 inches	17	14	13	21	65	16.3
Incorporated 5 inches	20	12	16	17	65	16.3
2. EPTC @ 1 lb/A						
Incorporated 1 inch	3	1	0	3	7	1.8
Incorporated 3 inches	0	0	0	0	0	0.0
Incorporated 5 inches	0	0	0	0	0	0.0
3. EPTC @ 3 lb/A						
Incorporated 1 inch	0	0	2	0	2	0.5
Incorporated 3 inches	0	0	0	0	0	0.0
Incorporated 5 inches	0	0	0	0	0	0.0

Table L. Number of barnyard grass in 9 square feet of undisturbed soil between irrigation furrows in study of rate and depth of incorporation of EPTC on July 21, 1960.

Treatments	I	II	III	IV	Total	Average
1. EPTC @ 0 lb/A						
Incorporated 1 inch	27	15	20	15	77	19.3
Incorporated 3 inches	18	14	13	21	66	16.5
Incorporated 5 inches	20	12	16	17	65	16.3
2. EPTC @ 1 lb/A						
Incorporated 1 inch	6	4	3	5	18	4.5
Incorporated 3 inches	0	0	0	1	1	0.3
Incorporated 5 inches	0	0	0	1	1	0.3
3. EPTC @ 3 lb/A						
Incorporated 1 inch	0	4	3	0	7	1.8
Incorporated 3 inches	0	1	0	0	1	0.3
Incorporated 5 inches	0	0	0	1	1	0.3