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Rapid Bioassessment Methods for Assessing Vegetation Toxicity at the Savannah River Site - Germination Tests and Root Elongation Trials

by
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RAPID BIOASSESSMENT METHODS FOR ASSESSING VEGETATION TOXICITY AT THE SAVANNAH RIVER SITE-GERMINATION TESTS AND ROOT ELONGATION TRIALS

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FINAL REPORT

GERMINATION TESTS AND PRELIMINARY ROOT ELONGATION TRIALS

By

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INTRODUCTION

Plants form the basis of all ecosystems including wetlands. Although they are the most abundant life form and are the primary producers for all other organisms, they have received the least attention when it comes to environmental matters (Fletcher, 1991). Higher plants have rarely been used in ecotoxicity testing (Wang and Williams, 1988), and may not respond in the same manner as algae, which have been used more frequently. The introduction of hazardous waste materials into wetland areas has the potential to alter and damage the ecological processes in these ecosystems. Measuring the impact of these contaminants on higher plants is therefore important and needs further research.

Higher plants are useful for detecting both herbicidal toxicity and heavy metal toxicity (Wang and Williams, 1988). For phytotoxicity tests to be practical they must be simple, inexpensive, yet sensitive to a variety of contaminants. A difference between seed germination and root elongation tests is that seed germination tests measure toxicity associated with soils directly, while root elongation tests consider the indirect effects of water-soluble constituents that may be present in site samples (Linder et al, 1990).

There are seven basic classes of plant phytotoxicity tests available; enzyme assays, process measurements, tissue culture growth, life cycle, seedling growth, seed germination, and root elongation. Of these seven, only the last three are currently required to be used by the EPA, FDA, and the OECD . The plant species recommended for use in these tests include no native species (Fletcher, 1991). In areas such as the southeastern United States, where agroecosystems exist as a patchwork of crops and native woodlots, alongside industry, there is a real question as to whether the surrogate species recommended by these agencies adequately protect native plant communities (Fletcher et al, 1990). Virtually no toxicology data exists for most native plant families (Fletcher et al, 1985), and it is an aim of the current project to begin to address this issue for native wetland species.

The main effects of metal ions on living systems result from the role of metals in enzyme expression and regulation (Wang and Elseth, 1990). The uptake by plants of phytotoxic amounts of metal can result in the inhibition of several enzymes and an increase in the activity of others. There are two main mechanisms of enzyme inhibition, 1) the metal binds to sulfhydryl groups that are involved in the catalytic action or structural integrity of enzymes, and 2) a deficiency of an essential metal in metalloproteins or metal-protein complexes occurs as a result of substitution of that metal by the toxic metal(s) (Van Assche and Clijsters, 1990).

Jones and Sharitz (1990) found that cohorts of seedlings in bottomland hardwood forests that emerged earlier in the growing season had a greater survival than those that emerged later, both at the end of the first growing season and by the fall of the next year. Seedlings that emerged before rather than after simulated leaf-out could grow a magnitude larger, and thus it is possible that early germination can affect the fitness of individual genotypes (Jones and Sharitz, 1989). Thus, a delay in germination as a result of exposure to a contaminant could have effects later on in the life of that seedling. Probably the most vulnerable time in a plant's life cycle is the establishment of the newly germinated seedling (Egley, 1986).

OBJECTIVE

The objective of the current study was to measure the seed germination response of a number of wetland species native to the Savannah River Site, S.C., to five representative contaminants: cadmium, nickel, anthracene, atrazine, and tetrachloroethylene (PCE). Root elongation work was begun and will be completed in Part 2 of this project. Native species used were *Cephalanthus occidentalis* (button bush), *Saururus cernuus* (lizard's tail), *Liquidambar styraciflua* (sweetgum), and *Quercus falcata* (cherrybark oak). Three agricultural species, *Lactuca sativa* (lettuce), *Raphanus sativus* (radish), and *Panicum miliaceum* (white millet) were also tested as reference species.

LITERATURE REVIEW

The two endpoints measured in this study, seed germination, and root elongation, have been used in other studies. The vast majority of these studies have dealt with commercially important agricultural species, or with weed species with the purpose for the study being better control through herbicides. However, there are a few studies where the objective has been biomonitoring of contaminants. Wang and Williams (1988) used cabbage (*Brassica oleracea*), cucumber (*Cucumis sativus)*, millet (*Panicum miliaceum*), Japanese millet (*Echinochloa crusgalli*) , rice (*Oryza sativa*), and wheat (*Triticum aestivum*) seeds to screen and biomonitor complex effluent samples. Of these species, millet, Japanese millet, and rice inhabit wetland and riverine ecosystems. Seeds were incubated in the dark for 120 hrs which was sufficient to allow these species enough time to germinate. It was found that cabbage, cucumber, and millet were able to detect phytotoxicity in all the samples, and were thus concluded to be promising test species.

Millet root elongation was used to test the toxicity of phenol and seven chlorophenols (Wang, 1985b). Toxicity generally increased with increasing chlorination of the compound. Root elongation was found to be more sensitive than the biomass method used on this species in an earlier study (see below in "other tests"). However the results were more variable (SD=30% or more) due to the fact that root elongation is a measure of individual plants. Interestingly, when the concentration of the phenolic compounds was low, root growth was stimulated. Root growth stimuation in response to low levels of toxicants has been found in other studies. In tests with collards (*Brassica oleracea*) concentrations of vanadium less than 1mg/L stimulated radicle elongation while concentrations greater or equal to 3mg/L caused severe toxicity (Kaplan et al, 1990).

The millet study by Wang (1985b) was expanded to include cucumber and lettuce seeds tested alongside millet in exposures to these same compounds (Wang, 1986). Millet was found to show a more regular and predictable response to the phenolics than the other two species, which are species recommended by the U.S. EPA and the OECD. Although the lettuce controls showed the most uniform root elongation, millet was as sensitive or more sensitive than the other two species and had the most predictable response.

Wang (1987) continued his development of the root elongation test by exposing lettuce, cucumber, and millet seeds to heavy metals (Cd, Cr(IV), Cu, Mn, Ni, and Zn). Lettuce seeds were found to have the highest germination rate, the least variability, and the greatest sensitivity to heavy metal exposure. Millet seeds showed the most consistent response to toxicity. Cu or Ni were found to be the most toxic of the metals tested to cucumber and millet seeds, while Ni was the most toxic to lettuce. Cd was generally the third most toxic heavy metal to all three species. High variability was found as for the previous study, and is considered a characteristic of the root elongation test, since each seed can vary independently from 0 to more than 100mm, in contrast to the dichotomy of lethality tests.

In a test using root elongation of millet exposed to a series of heavy metals, Wang and Elseth (1990) found the three most toxic metals to be Cu, Ni, and Cd, in that order. The NOEC values were 0.6, 0.9, and 2.6 mg/L respectively. In comparisons of these values with those found in other toxicity tests in the literature, the rye grass tests of Wong and Bradshaw (1982) were more sensitive than millet, duckweed, and fish.

Using root elongation tests in rye grass (*Lolium perenne*) as an endpoint of exposure to 10 metals, (Wong and Bradshaw, 1982) found that the most toxic metal was Cu and the least toxic was Fe . Nickel was the second most toxic metal. Root elongation was more sensitive to metals than shoot growth in all cases because heavy metals must pass through the roots before they can have an effect on the shoot portion of the plant. No clear relationship was found between seed germination and the primary effects of metals on rooting, except that effects seen were seen only at concentrations above those critical for rooting.

The root system of *Asparagus officinalis* was also more sensitive than the shoots to diuron (Castanon, 1990).

In a study evaluating the effects of beryllium and vanadium on collards, it was found that 97% of the Be taken up by the plants remained in the roots while only only 3% was translocated into the above ground parts of the plant (Kaplan et al, 1990). Be had a detrimental effect on germination but V did not.

As seen in the present study, in petri dishes, roots do not grow straight but rather they become intertwined and twisted. Many researchers have germinated seed on an inclined or vertical plane to encourage straighter root growth. Edwards and Ross-Todd (1980) used plexiglass chambers with depressions to hold the seeds. The vertical surface allowed straight radical growth and even spacing of seeds allow the roots to grow separately, allowing for easy measurement. Many more seeds were able to be accomodated than in dishes. Gorsuch et al (1990) developed a similar method for allowing roots to germinate in the vertical plane, using separator racks and seed-pack growth pouches. They found lettuce to be the most sensitive species (of lettuce, radish, and ryegrass), and root elongation to be the most sensitive endpoint of those tested. Germination was not noticeably affected by the exposure to 26 commercial chemicals. In another study acrylic plastic boxes were partioned and filled with soil (Teem et al, 1973). Boxes were tilted at 18° and covered with aluminum foil. Seeds were germinated in petri dishes and added to the compartments radicle side down.

The Neubauer technique, a method often used for evaluating the effect of fertilizers and to evaluate seed germination and growth has been modified for use in assessing contaminated soils (Thomas and Cline, 1985). Essentially the setup consists of petri dishes which are filled with soil, to which seeds are added and then watered with the treatment liquids. The whole system is then surrounded by a polyethylene bag filled with air and closed at the top. Germination and shoot measurements are taken through the bag, minimizing researcher exposure to the contaminants. In a study using samples from an abandoned waste pond, these researchers found germination to be slightly more sensitive than shoot growth.

Shoot growth has been measured in some studies, although it has generally been found to be less sensitive than root growth. Plant height of sorghum (*Sorghum bicolor*) and pinto bean (*Phaseolus vulgaris*), was used as an indicator of exposure to soil contaminated with jet fuel or the herbicide Krovar. In the jet fuel tests, plant height was stimulated in the dicotyledon (pinto bean) but not in the monocotyledon (sorghum) (Lillie and Bartine, 1990). They suggested that it may be important to include both types of plant in a bioassay.

In a study of the effect of nickel on rye grass, it was found that nickel depressed shoot yield at all levels except the lowest (30ug Ni/g soil) (Khalid and Tinsley, 1980). The increase of nickel concentration in the shoots was not proportional to the reduction in yield, nickel uptake being highest at the middle level and decreasing on both sides.

In tests using millet , radish (*Raphanus sativus*), and velvetleaf (*Abutilon theophiasti*) exposed to phenolic compounds, Wang (1985a) found that millet was generally the most sensitive. However, in comparison with daphnid, fathead minnows, bacteria, millet was found to be approximately one order of magnitude less sensitive. The endpoint used in the seed tests was growth rate.

There are a variety of other methods of plant bioassay including chlorophyll content, ion accumulation, and delayed fluorescence (Velagaleti et al, 1990) but they will not be discussed here. In addition to tests with xenobiotics bioassays similar to these can be used in tests using toxic metabolites from fungi (Wedge et al, 1993), allelochemics (Patterson, 1986), and other naturally occurring phytotoxic compounds (Duke, 1986).

Bioassays using seeds have in general been found to be simple and economical, making them ideal for screening large numbers of samples and compounds (Wang, 1985a). Seeds are usually dry and dormant and thus have a long shelf life yet are readily available. There are benefits and disadvantages to using each of the endpoints. The biomass method of seed germination is less time consuming and shows less variation than the root elongation method but the latter is more sensitive (Wang, 1985b, Edwards and Ross-Todd, 1980). Measuring of roots and shoots is the most time consuming part of most germination and root elongation studies (Gorsuch et al, 1990), however inhibition of root growth is one of the most rapid resposes to heavy metal exposure (Wong and Bradshaw, 1982). Root elongation will be tested in part two of this study and promises to be a sensitive endpoint of contaminant exposure in wetland species.

CONTAMINANTS USED IN THIS STUDY

Five contaminants (atrazine, anthracene, tetrachlorolethlene, nickel, and cadium) were used in the initial screening tests. Their effects are summarized separately below.

Atrazine (6-chloro-N-ethyl--N'-[1-methylethyl]-1,3,5-triazine-2,4-diamine) is an inhibitor of photosynthetic electron transport among susceptible plants(Kleier and Gardner 1993). Some species such as corn (*Zea mays*) are able to metabolically detoxify atrazine. For this reason atrazine is commonly used to selectively control dicotyledonous weeds in corn (Bartley, 1993). In fact, atrazine is the most heavily used agricultural pesticide in North America. In the USA more than 50 million kg are applied annually to more than 25 million ha. Residues in runoff from fields has been found in groundwater, lakes, and streams, sometimes at phytotoxic concentrations (Eisler, 1989).

Anthracene is a polycyclic aromatic.hydrocarbon consisting of three annelated aromatic rings. It occurs from the incomplete burning of a number of substances including petroleum, coal, soot, and tar. Anthracene itself is not carcinogenic but many of its derivatives are (Williams and Weisburger, 1986).

Tetrachloroethylene is a halogenated hydrocarbon and is used for dry cleaning fabrics and for metal-degreasing operations. It is also used as an intermediate in the production of other chemicals. It has been found on at least 714 of the 1300 sites on the EPA's national priority list (USDHHS,1990).

Cadmium is used in a number of industrial processes including electroplating and galvanizing. It is used as a color pigment in paints and plastic and as a cathode material in batteries. As a byproduct of zinc and lead mining and smelting it has become an important source of environmental contamination (Goyer, 1986). Compared with other metals cadmium is relatively mobile in the aquatic environment, and is transported in solution as either hydrated cations or organic or inorganic complexes. It is strongly accumulated by organisms at all trophic levels (USEPA, 1979).

Nickel is a metal whose properties make it very useful for combining with other metals to make alloys. It is used for nickel plating, to color ceramics, to make some batteries, and as a catalyst in chemical reactions. Release into the atmosphere occurs as a result of oil and coal burning power plants and incinerators (USDHHS, 1989). Nickel is discharged into waters through municipal wastewaters, smelting and refining of nonferrous metals, manufacturing processes, and atmospheric fallout (Nriagu and Pacyna, 1988).

METHODS

There were three main components to this study. The first was the collection and identification of herbaceous and woody species growing in Carolina Bays at the Savannah River Site. Seeds from these species were either collected or ordered from commercial sources as appropriate. Finally five toxicants were selected and the seeds were exposed to seven concentrations of each toxicant . Seed germination and root elongation were the endpoints measured. In addition to the wetland species, radish (*Raphanus sativus*), lettuce (*Lactuca sativa*), and white millet (*Panicum miliaceum*) were used in these tests. Radish and lettuce have been frequently used in seed germination and root elongation tests previously and served as control species, while millet, a native wetland species has previously been found to show a predictable response to contaminants (Wang, 1985b).

SEED COLLECTION AND IDENTIFICATION

Herbaceous species seeds were collected from various locations on the Savannah River Site and elsewhere from late July to mid-September of 1994. At SRS a number of Carolina Bays were visited. At each bay a survey of species present was made, using the references listed below. In some cases the help of experts in plant identification were enlisted. Especially helpful were Dr. Gary Wein at the Savannah River Ecology Laboratory and Phil Hyatt from the Forest Service station at SRS. The following lists the specific bays visited and the species found there (woody species included). An asterisk indicates seeds were collected.

Thunder Bay (Bay 83) 07/12/94 and 07/13/94

Acer rubrum
Nymphaea odorata
Quercus nigra
Panicum anceps
Cornus spp.
Persea borbonia
Panicum hemitomon
Prosepinaca pectinata
Lersia hexandra
Juncus spp. (immature)
Eleocharis quadrangulata
Eleocharis spp.(englemannis/ambigens) *
Cyperus spp.
Pinus taeda
Brasenia schrekeri
Liquidambar styraciflua
Scirpus cyperinus *
Utricularia spp.

Dry Bay (Bay 31) 07/12/94 and 07/13/94

Juncus effusus *
Hydrocotyl umbellata
Cephalanthus occidentalis *
Taxodium distichum

Craig's Pond (Bay 77) 07/28/94 and 07/28/94

Scirpus cyperinus
Xyris caroliniana
Lachnanthes caroliniana *
Rhexia mariana
Rhyncospora tracyi *

Ellenton Bay (Bay 176) 07/19/94 and 07/20/94

Polygala spp.
Rhexia spp.
Scirpus cyperinus
Panicum anceps
Carex glaucescens
Lycopus spp.
Acer rubrum
Juncus effusus
*Eleocharis quadrangulata**
Nymphea odorata
Panicum hemitomon
Brasenia schreberi
Quercus nigra
Liquidambar stryaciflua
Proserpinaca pectinata
*Leersia hexandra**

Compound 3 Bay #1 (unable to ascertaine SRS Bay #) 07/19/94 and 07/20/94

Cephalanthus occidentalis *
Rhyncospora inundata *
Panicum hemitomon *
Utricularia spp
Rhexia virginica
Juncus validus
Salix nigra
Utricularia purpurea
Smilax rotunidfolia
Scirpus cyperinus
Pontedaria cordata

Compound 3 Bay #2 07/19/94 and 07/20/94

Rhexia virginica
Scirpus cyperinus

*Species tested in laboratory

Seeds of herbaceous species were considered to be mature and were collected when they were dry, brown, and falling off of the plant. However, in many cases the seeds collected from SRS did not germinate, either because they were not ripe yet or we did not know the correct method for germinating them. While at a Wetland Horticulture course at Environmental Concern, St Michaels, MD, a number of seeds were obtained from species that were used in germination exercises during the course. Seeds from the following species were obtained from Environmental Concern:

Scirpus pungens
Verbena hastata
Scirpus validus
Carex crinata
Carex stricta
Scirpus robustus
Scirpus cyperinus
Pontedaria cordata

We were not able to germinate all of these seeds either.

Seeds of *Nuphar luteum* were obtained from Dr. Larry Dyck of the Biological Sciences Department in Clemson on 09/21/94.

Tree seeds were ordered from the International Forest Seed Company, PO Box 490, Simpson Rd., Odenville, AL, 35120. The following species were ordered:

Fraxinus pennsylvanica	(green ash)
Quercus falcata var pagodifolia	(southern red oak)
Taxodium distichum	(bald cypress)
Nyssa aquatica	(water tupelo)
Diospyros virginiana	(common persimmon)
Quercus lyrata	(overcup oak)

The overcup oak seeds germinated in the refrigerator and were therefore unusable. These seeds came preidentified by the Company.

Cephalanthus occidentalis seeds were collected on 09/24/94 from Lake Hartwell in Clemson, SC. These seeds were air dried for two days and then stored in the refrigerator as described below.

Saururus cernuus seeds were collected from Guntersville Reservoir, AL, on 09/16/94.

Lettuce, radish, and millet seeds were obtained from Griff's, a local feed and seed store in Pendleton, S.C.

After collection or receipt of seeds they were air dried and stored in plastic bags at 4^{o}C (except radish and lettuce which were stored at room temperature). Some seeds were moist stratified in order to increase their germinability. Germination tests were carried out using filter paper in petri dishes in the germination chamber or a growth chamber. Specific germination enhancement treatment of the seeds of each species is detailed in the results section.

INITIAL STOCK SOLUTION AND DILUTION PREPARATIONS

Stock Solution

Stock solutions of each of the five compounds were made to a concentration of 1000mg/L and 100mg/L. For nickel and cadmium (metalic state; zero valence state) atomic absorption spectrophotometer standards (AAS) were used at 1000mg/L. 100mg/L stocks were made by adding 5ml of the AAS solutions to 45ml of double distilled water. Although the metals were in the zero valence state when they were applied to the filter pater they probably oxidized to the plus two state when they were exposed to air.

For the other three compounds, atrazine, anthracene, and tetrachloroethylene all stocks had to be made. All three of these substances have low solubility in water and thus the stock was made in methanol instead. Methanol controls were added in the experiment to test for the effects of methanol alone. Stocks were made in 100ml batches using volumetric flasks. The purity of each compound was taken into account in preparing the stock solutions.

Dilution

Concentrations to be tested were 0, 0.1, 0.5, 1.0, 5.0, 10.0, and 50.0mg/L. Originally lower concentrations were used but preliminary results indicated it would be better to test some higher concentrations in order to have definite responses.

Each day fresh stock solution of 10ml of 10mg/L stock were prepared. *The following chart shows how the dilutions were made:*

Final Conc. (mg/L)	Conc. of Stock Used (mg/L)	ml stock in 250ml milliQ water
0.1	10	2.5
0.5	100	1.25
1.0	100	2.5
5.0	100	12.5
10	1000	2.5
50	1000	12.5

To make the 10mg/L temporary stock 1ml of 100mg/L was added to a 10ml volumetric flask and brought to volume with milliQ (water that meets 18 ohm resistance criteria) water.

Each of the dilutions was made up by adding the required amount of stock to a 250ml volumetric flask which was then brought to volume with milliQ water. After mixing well the solutions were poured into 250ml jars with lids and then refrigerated. The volumetric flasks were washed well between each use and rinsed with dilute nitric acid or acetone as required.

An exception to the above was anthracene. It was not possible to dissolve it to a concentration of 1000mg/L and therefore a 500mg/L stock was made and 5ml and 25ml of this in 250ml milliQ water used to make the 10 and 50mg/L solutions respectively.

Methanol controls were made as follows:

For the 0.5mg/L standard, 1.25ml of methanol was added to the 250ml volumetric flask. This was brought up to 250ml with milliQ water. For the 5.0 standard, 12.5ml methanol was pipetted into the 250ml volumetric flask, and this was brought to volume (250ml) with milliQ water. For the highest methanol standard (25mg/L) which was necessary for the anthracene only (due to the fact that we had to use 500mg/L stock instead of 1000mg/L), 25ml of methanol was pipetted into the 250ml volumetric flask, which was then brought up to volume with milliQ water. Each of these was mixed well and decanted into 250ml jars for storage in the refrigerator.

Note that for all compounds except anthracene the 5.0mg/L methanol standard is representative of the greatest amount of methanol the test solutions would have been exposed to, and this would have occurred in the 5mg/L and 50mg/L exposures.

The methanol controls were used as follows:

ml MeOH in 250ml milliQ water	%MeOH	control for
1.25	0.5%	0.5ppm atr,anth,PCE
12.5	5.0%	5.0ppm atr,anth,PCE
		50.0 ppm atr,PCE
25.0	10.0%	50.0ppm anth

REVISED STOCK SOLUTION AND DILUTION PREPARATIONS

The original method of using the methanol carrier had an effect on seed germination and root elongation, thus it confounded the results. Therefore, a revised method of mixing the chemicals was used to get the organic compound into solutions. A switch from the use of milliQ water to moderately hard water was made at this point also, to increase environmental representativeness.

All chemicals were made up in moderately hard water (MHW). MHW was made by autoclaving 12L of MilliQ water and the following chemicals (wrapped separately in aluminum foil): $CaSO_4.2H_20$ (0.72g), $NaHCO_3$ (1.152g), $MgSO_4$ (0.72g) and KCl (0.048g). After the water had cooled the chemicals were added to the water in a 20L carboy and mixed vigorously.

All bottles were washed appropriately and labelled with the date, chemical and its concentration, project number, and contact name.

The two metals (nickel and cadmium) were diluted from 1000ppm atomic absorption spectrophotometer standard solutions. No carrier was involved. The following dilutions were made:

Solution wanted (ppm)	Stock used(ppm)	ml stock added to 250ml MHW
0.5	1000	0.125
1.0	1000	0.25
5.0	1000	1.25
10.0	1000	2.5
25.0	1000	6.25
50.0	1000	12.5

Each dilution was made using a 250ml volumetric flask.

Anthracene (99% pure) stock was made up to a 1000ppm concentration (0.025g in 25ml methanol). It was attempted to make a 2000ppm stock but it would not dissolve, even with sonication. Dilutions to the various solutions were made as for the metals.

Atrazine stock was made up to a 10,000ppm concentration by adding 0.257g of 97.1%pure atrazine to 25ml methanol and sonicating.

Dilutions were made as follows:

Solution wanted (ppm)	Stock used (ppm)	ml stock added 250ml MHW
0.5	1000	0.05
1.0	1000	0.1
5.0	10000	0.05
10.0	10000	0.1
25.0	10000	0.25
50.0	10000	0.5

The 1000ppm stock was created by adding 1ml of the 10000ppm stock to a 10ml volumetric flask and bringing it to volume with MHW.

Tetracholorethylene (PCE) stock was made up to 10,000ppm by adding 1.0g to a 100ml volumetric and bringing to volume with methanol. Dilutions were made as for atrazine.

The following methanol controls were made:

ml MeOH in 250ml MHW	%MeOH	control for
0.25	0.1	25ppm atr, PCE 1.0ppm anth
0.5	0.2	50ppm atr, PCE
1.25	0.5	5ppm anthr
2.5	1.0	10ppm anthr
6.25	2.5	25ppm anthr
12.5	5.0	50ppm anthr

Treatment Design (For All Wetland Species Tests)

Five petri dishes of each contaminant at each concentration were labelled by species, date, contaminant, and concentration. Autoclaved filter paper was folded in quarters and laid in the dish, and 2.5ml of the toxicant was pipetted onto it. Seeds were surface sterilized with a 10% solution of bleach for 10 minutes then rinsed 5 times with distilled water. Floating seeds were removed, as were any that looked discolored or otherwise abnormal. Seeds were handled with tweezers. Five seeds of each species were placed in each dish with the following exceptions: 3 seeds each of *Quecus falcata*, 5 seed pairs of *Cephalanthus occidentalis* (since the seeds are paired).

Five replicates of each of the solutions were created, along with 5 replicates of milliQ water as a control. A separate set of 20 petri dishes containing one seed per dish treated with milliQ water was used to determine percent germination. Petri dishes were sealed with parafilm to prevent evaporation and petri dishes were randomly placed in the growth chamber. Growth chamber temperature measurements were taken with a portable thermometer and also continuously via chart recorder. The photoperiod was 14 hours light (27^oC) and 10 hours dark (22^oC).

Lettuce, Radish, and Millet Tests

Seeds of these three species were obtained from Griffs (Pendleton, SC). The seeds were bleached for 10 min in 10% bleach solution. Floating seeds were removed, as were any that were discolored. Five replicates of each of the solutions listed above were made as well as five replicates of MHW as a control. Each contained 5 seeds in a petri dish on filter paper that had been dosed with 5ml of each solution. In addition, 20 replicates of 5 ml MHW were made with one seed per petri dish in order to determine germination percent. Petri dishes were sealed with parafilm, and petri dishes were placed randomly in the growth chamber . Owing to space limitations the petri dishes were double stacked in a staggered fashion, such that light to the bottom layer of petri dishes was not blocked. The growth chamber was set for 27^oC during the day (14hrs) and 22^oC at night (10hrs).

Measurements

Germination was recorded on the first day that radicles were seen and every second or third day afterwards depending on the rate of germination. Cotyledon presence was also recorded. Cotyledons were counted as present after they had emerged from the seed coat and had separated from each other (sometimes the seed coat was still attached to the tip of one cotyledon). Presence of fungi or algae was noted. Root lengths were estimated in incremental categories during germination. At the end of the test root lengths were measured with a ruler to obtain actual measurements. With some species additional developments were noted and measured, such as the length of the first shoot in *Quercus falcata* which has hypogeal germination, rather than epigeal germination as was seen in the other species (Young and Young, 1986).

Temperature in the growth chambers was recorded on a chart recorder and also at intervals on a portable thermometer during the tests.

Statistics

Data were entered into a computer using the Excel spreadsheet program. A second person double checked that data entry was correct. Graphs were made on Cricket Graph III. Means and standard deviations of each treatment were calculated using SAS. One way ANOVA and Tukey's Studentized Range (HSD) tests were also run using SAS.

RESULTS

The following species used in this study occur naturally on the Savannah River Plant site: *Quercus falcata, Liquidambar styraciflua, Saururus cernuus, Cephalanthus occidentalis*(Batson et al, 1985). Germination procedures of these species are detailed at the end of this section, along with those of some other species we have worked with.

Seed Germination

Sweetgum (*Liquidambar styraciflua*)

A significant decrease in germination was seen in seedlings exposed to 50 ppm of both metals (Table 1 and Figures 1-5). With the three organic compounds, a significant decrease was seen at 5 and 50 ppm. This same decrease was seen in the MeOH control. As discussed under methods, in this test the 5 and 50 ppm had the same concentration of MeOH carrier (5%), whereas the 10 ppm organics had only 1% MeOH and did not show a significant decrease in seed germination.

White millet (*Panicum miliaceum*)

In this species no significant effect on seed germination was seen with exposure to PCE, nickel, and atrazine (T 2 and Figures 6-10). A significant decrease was seen with 50 ppm cadmium and anthracene. The toxicity in the 50 ppm anthracene exposure could be due to MeOH since a significant decrease was seen in the 5% MeOH control, which was the amount of MeOH in the 50 ppm anthracene treatment.

Cherry Belle radish (*Raphanus sativus*)

No effect on seed germination was seen from exposure to any of the contaminants (Table 3 and Figures 11-15).

Lizard's tail (*Saururus cernuus*)

A significant increase in seed germination was seen in seedlings exposed to 5 and 10 ppm nickel (Table 4 and Figures 16-20). Increases were also seen in 10 ppm anthracene, 10 ppm PCE, and the 0.5 ppm MeOH control (which corresponds to the amount of MeOH in 0.5 ppm atrazine, anthracene, and PCE). A significant decrease in germination was found in seedlings exposed to 50 ppm atrazine.

Buttercrunch lettuce (*Lactuca sativa*)

No significant difference in seed germination was seen except in the 5% MeOH where a decrease was seen (Table 5 and Figures 21-25).

Cherrybark oak (*Quercus falcata*)

No significant changes in germination were seen except in the 50 ppm nickel where a significant increase in germination was seen (Table 6 and Figures 26-30).

Buttonbush (*Cephalanthus occidentalis*)

Seedlings of this species exposed to 50ppm anthracene, 50ppm atrazine, 50ppm cadmium, and 50ppm nickel showed a significant decrease in germination (Tables 7 and 8 and Figures 31-35). In the 50ppm nickel and cadmium exposures no seedlings germinated.

<u>Root Elongation</u>

Preliminary results are presented here. The rest will be presented with the final report of Part 2 of this study, along with the relevant statistics.

Radish (Raphanus sativus)

With exposure to nickel an overall decrease in root length was seen, with a slight increase at 1 and 5ppm (Table 9 and Figures 36-40). A similar pattern was seen with exposure to atrazine. An increase at 1ppm was seen with exposure to anthracene, followed by a sharp decrease in root length at the higher concentrations. Root length showed a steady decrease in response to cadmium exposure, while exposure to tetrachloroethylene resulted in a variable pattern of root length.

Cherrybark oak (Quercus falcata)

In seedlings exposed to tetrachloroethylene, nickel, and anthracene a general decreasing trend was seen, however the decrease in root length in anthracene exposed seedlings could have been due at least in part to the methanol carrier (Table 10 and Figures 41-45). Atrazine seemed to have little effect on germination except at the highest dose where a decrease was seen. In the cadmium exposure an increase in root length was seen at 25ppm.

Buttercrunch lettuce (*Lactuca sativa*)

Roots of lettuce seedlings exposed to nickel and cadmium showed a decrease in root length at 5 and 10ppm respectively (Table 11 and Figures 46-50). No change in root length was seen in seedlings exposed to tetrachloroethylene. Atrazine and anthracene exposure resulted in a trend of decreasing root length. In the atrazine test, root lengths were less than in the methanol controls suggesting that atrazine was the cause of the decrease.

Root elongation of buttonbush *Cephanalthus occidentalis* a appeared to be reduced by the highest concentrations of herbicides but the results were confounded by methanol effects at these concentrations (Tables 12 ; see page 16 of this report). Because of the confounding effects ,it was not possible to clearly assess the toxic effects of these chemical on buttonbush root elongation. In contrast, root elongation of white millet *Panicum miliaceum*, was reduced by concentrations of nickel and cadmium at 25 ppm and higher (Table 13). However, the effects of the herbicides on root elongation of white millet were less clear. Perchlorolethylene appeared to have no toxic effect at the concentrations tested whereas anthracene appeared to have toxic effects at 10 ppm and higher. The effect at 50 ppm was again confounded with methanol effects (Table 13). Atrazine, on the other hand, showed inconsistent responses on white millet. It appeared to reduce root elongation slightly at 5 ppm and greater but the effect at 5 ppm were more pronounced than at 10 and 25 ppm.

Comparison of Wild Species to Domestic Species

Germination. Figures 51 and 52 show that germination of sweetgum (SG), buttonbush (BB), and lizard's tail (Liz-T) were affected more dramatically by 50 ppm of nickel and cadmium than cherrybark oak (CBO), radish (RAD), and millet (MILL). Of the domestic species, only millet (MILL) showed a significant effect of nickel and cadmium on germination. Both 10 and 50 ppm of nickel and cadmium had an effect on germination of millet (MILL) whereas sweetgum (SG) and buttonbush (BB) appeared to respond only to 50 ppm of either toxin. The response of lizard's tail (Liz-T) was not clear.

Root Elongation. Data were collected on only one wild species, cherrybark oak (CBO) and the results were unclear (Figures 53 and 54). In contrast, root elongation of millet (MILL) and lettuce (LET) was reduced by 5 ppm or higher of nickel and 10 pmm or higher of cadmium.

DISCUSSION

The results of Part 1 of this study suggest that seed germination is not very responsive to contaminant exposure except at high concentrations. It is also apparent that the agricultural species tested were more uniform in response, showed a higher percent germination, and germinated more quickly thus reducing problems with fungal contamination. However since agricultural species are not representative of species living in wetland environments and have been subjected to years of genetic manipulation they are not deemed appropriate as bioassay species for wetlands. Great care must be taken when using wetland species seeds in bioassays to assure that the seeds are as uniform as possible, have been properly stored and stratified if necessary, contain minimal fungus, and are viable. Young and Young (1986) is an excellent reference for most aspects of seed collection, storage, and germination in general. For specific species available information is often mimimal or non-existent; an exception to this are wetland trees species important to the forestry industry.

Factors that may play a role in seed tests other than that of the contaminants being tested include seed size, presence of and distance to neighbouring seeds, and maternal source. In *Ludwigia leptocarpa* seed size was found to have a significant effect on percentage germination and time of seed germination but not on dry weight or leaf area of seedlings (Dolan, 1984). When seeds of this species were grown together in pots, plants from larger seeds developed into larger plants. Plant size was significantly influenced not only by seed size but by the distance to three nearest neighbours. Thus seeds

for toxicity tests need to be carefully chosen to be of similar size and appearance, and placed equidistant from each other in the test containers.

We recommend using more than one endpoint and more than one species when conducting phytotoxicity assays. Fletcher et al (1990) reported that taxonomic differences among plants had a much greater influence on plant response to chemical exposure than the difference between testing in the laboratory and the field . Wong and Bradshaw (1982) found from their and others results that the level at which the metals they tested became toxic varied greatly with species and appear to be related to specific ecological differences. In a computer search study using the PHYTOTOX database, Fletcher et al (1985) found oat and wheat to be the most sensitive species to the widest range of herbicides in comparison with 21 other commercial species. Radish was the third most sensitive dicotyledon. They concluded from their review of the literature that a species that is sensitive to one class of chemicals may not be sensitive to another, and therefore if the purpose of testing is to screen chemicals it is necessary to test a number of different species.

Using as many replicates as practical will increase statistical sensitivity. Edwards and Ross-Todd (1980) found a minimum of 150 seeds to be necessary to demonstrate a statistically significant difference in root growth at the lower concentrations that they tested.

We found that species with moderate sized seeds are generally easier to work with in toxicity tests. With small seeds, especially if a fine mist of condensation had formed on the petri dish lid, it was often very difficult to tell when germination had occurred. Large seeds (eg *Quercus lyrata* , a test that was aborted due to chamber malfunction) required larger petri dishes and took up more space in the chambers. In addition, it was difficult to maintain a high moisture content in the large pertri dishes with large seed. Even when sealed with parafilm, the large petri dishes tended to dry out and stop germination prematurely. If root elongation is categorized during the test as opposed to just at the end, as was done for several species (results not shown), it may be easier if a color other than white is used for the filter paper, as it makes seeing the roots much easier. Also in some species (eg *Raphanus sativus*), there was a tendency (not quantified) for a decrease in main root length to be compensated for by longer and more side roots. It was important in conducting a good test to apply sufficient sterilant to the seed to prevent fungus growth during the test without killing the seed and to start with seeds that were healthy and not contaminated with fungus, again to prevent fungus growth during the test. It may be useful to test stratifying the seeds in the various toxin combinations as this would more accurately simulate what would occur in field, and may increase the sensitivity of the germination test. Another way to more accurately represent field conditions is to test the seeds in various sand, vermiculite, and soil combinations, which is planned in Part 2 of this study.

Germination of wild species appeared to be more sensitive to nickel and cadmium than the domestic species. Of the domestic species, millet germination showed sensitivity to both nickel and cadmium whereas radish and lettuce showed no significant difference in germination at any toxin concentration. Under the test conditions of this experiment, millet was the only domestic species that could be used as a surrogate for wild species.

There was insuffcent data to evaluate the test conditions on root elongation of wild species. However, root elongation of millet and lettuce were very sensitive to concentrations of both nickel and cadmium of 5 and 10 ppm respectively. These results suggest that root elongation may be a better method of testing for toxins than germination, at least with domestic species.

The Fagaceae family (oaks, beeches, chestnuts) was represented in the test we conducted by only one species, cherrybark oak. This family is on the EPA and OECD's lists of recommended surrogate species and contains species that are abundant, widely distributed, and of economic importance (Fletcher et al, 1990). Attempts will be made to include *more members of this family in Part 2 of this study.*

**PRELEMINARY FINAL REPORT PART 2:
DEFINITIVE SEED GERMINATION
AND ROOT ELONGATION BIOASSAYS**

METHODS

SPECIES

Eight species were used in Part two of this study. Four tree species were used; *Liquidambar styraciflua* (sweetgum), *Fraxinus pennsylvanica* (green ash), *Pinus taeda* (loblolly pine), and *Quercus falcata var. pagodaefolia* (cherrybark oak). One shrub, *Cephalanthus occidentalis* (buttonbush) was tested. These five species are all indigenous to wetlands of the southeastern United States. In addition, three agricultural species were tested; *Lactuca sativa* (lettuce), and *Raphanus sativus* (radish), and *Panicum miliaceum* (white millet). Radish and lettuce have been used in seed germination and root elongation tests previously and served as control species, while millet, a native wetland species, has previously been found to show a predictable response to contaminants (Wang, 1985b).

Tree seeds were ordered from the International Forest Seed Company, PO Box 490, Simpson Rd., Odenville, AL, 35120. *Cephalanthus occidentalis* seeds were collected on 09/24/94 from Lake Hartwell in Clemson, SC. These seeds were air dried for two days and stored in the refrigerator as described below. Lettuce, radish, and millet seeds were obtained from Griff's, a local feed and seed store in Pendleton, S.C. After collection or receipt of seeds they were air dried and stored in plastic bags at $4^{O}C$. Some seeds (loblolly pine, sweetgum, green ash) were moist stratified in order to increase their germination.

TOXICANTS AND TREATMENT OF SAND

Stock solutions of cadmium and nickel were made using $CdCl_2$ and $NiCl_2 \cdot 6H_20$. 1.64g of $CdCl_2$ or 4.05g of $NiCl_2 \cdot 6H_20$ were disolved in 1L of double distilled water in a 1L volumetric flask and mixed well to make a 1000mg/L solution. This solution was transferred to storage jars and stored in a refrigerator until used for treating the sand.

The growth media was sand that had been acid washed in 10% HNO_3 for at least 24 hours. The acid washed sand was rinsed in distilled water until the pH was equivalent to the pH of the distilled water. It was then autoclaved, and dried in a drying oven at 80°C for 24hours.

Sand was treated using hand held sprayers containing a solution of toxicant in double distilled water. The amount of toxicant in the sprayer was calculated based on the weight of sand to be sprayed. Enough double distilled water was added to the sprayer such that the sand was completely wetted. Sand to be treated was spread evenly across a plastic sheet. After spraying, it was then transferred into a rubber tub and dried in an oven at 30°C until completely dry.

The concentrations of each metal used were 0, 0.1, 0.5, 1.0, 5.0, 10.0, 20.0, and 40.0mg/L.

An example of calculations done for treating sand is as follows:

eg. You have 49lbs of sand available for treating, and want to make 4 different concentrations.

$\frac{49\text{lbs}}{2.2\text{ lbs/kg}} = 22.3\text{ kg}$ $\quad \frac{22.3\text{kg}}{4\text{ concs to be made}} = 5.57\text{kg per conc}$

5.57 kg/conc. X 2.2 lbs/kg =12.25lb per concentration available (the large scale measured in pounds).

To make sand at, for example, 10mg/L=10000ng/g, you

want 10000ng metal/g sand in 5570g sand = 55,700,000ng metal needed

The stock is 1000ng/ul=1000mg/L

$\frac{55{,}700{,}000\text{ng}}{1000\text{ng/ul}} = 55700\text{ul} = 55.7\text{ml}$

Therefore, add 55.7ml stock to 5.57kg sand (12.25lb) for 10ppm metal in sand.

For other concentrations:

conc	ml stock needed
0.1	0.57
0.5	2.79
1	5.57
5	27.9
10	55.7
20	111.4
40	222.8

In each case the volume in the sprayer was brought up to 1L with double distilled water. Control sand was sprayed with 1L of double distilled water.

GERMINATION

Seeds were germinated in sand containing the same concentration of contaminant as would be present in the root elongation tube to which they were to be transferred. For each concentration of each contaminant, 10 seeds were placed in each of 3 replicate petri dishes. The one exception to this was *Quercus falcata*, in which case only 7 seeds were placed per dish. The sand was watered with 10% Hoaglands nutrient medium to field capacity prior to placement of the seeds in the dish. Dishes were wrapped with parafilm and placed in a germination chamber set at 15°C for 12hrs of darkness and 30°C for 12 hours of light. Germination was recorded daily for up to 10 days. Once enough plants had germinated in most of the treatments (ie at least 10 per treatment for most treatments) they were transferred to root elongation tubes. In the case of *Cephalanthus occidentalis* not enough plants germinated in the 20 and 40mg/L treatments to transfer.

ROOT ELONGATION

The root elongation tube consisted of a 200x25mm test tube with the top 4 cm painted with black paint to prevent light penetration down the glass. This tube was inserted into a 10 inch section of pvc pipe that had also been painted black. The bottom of the pvc pipe was closed with a rubber stopper. Ten such tubes were bundled together for stability. Each of two growth chambers contained 53 of these bundles. Each bundle was given a letter or double letter designation. Each tube in each bundle was given a number from one to ten. This together with the growth chamber number made it possible to locate any given plant. The tubes were placed in the chambers at 30° angles.

Each test tube was filled with sand to within 3 cm of the top. The sand was then watered with 20mL of 10% Hoagland's plant nutrient medium, pH 6.6. This medium had been tested with the treated sand to ensure the pH would be between 5.5 and 6.5. One seed per test tube was then placed in the tube on the side opposite the label. About 1cm of autoclaved vermiculite was then placed over the seed. Randomization was accomplished by pulling from a beaker pieces of paper on which each location in the growth chamber had been written. This location was recorded both on the test tube and on data sheets. The test tubes were then placed in the appropriate location in the chambers with the label side up, such that the root would grow along the bottom side of the test tube.

At weekly intervals after being planted in the root elongation tubes, each species was checked for growth and appearance, and watered with 5ml of 10% Hoagland's.

At the end of three weeks each species was harvested. Each plant was carefully washed free of the sand and verimiculite using distilled water and transferred to a labelled plastic bag. Notes were taken on whether the plant was alive or dead, and whether it appeared healthy or was chlorotic or necrotic.

Root length and shoot length were measured. Root and shoot were separated, placed in separate paper bags and placed in a drying oven at 30°C ro 48 hours and weighed.

RESULTS

SEED GERMINATION

Six species were evaluated using the germination bioassay procedures described in Part 1. Species tested included buttonbush (CEOC), white millet (PAMI), sweetgum (SG), cherrybark oak (QUFA), loblolly pine (PITA), and green ash (FRPE). Each species was tested against eight concentrations of Cd and Ni (0, 0.1, 0.5, 1.0, 5.0, 10.0, 20.0, and 40.0 mg/L). Germination data were collected daily; the bioassay lasted ten days.

No evidence of a dose-response relationships were seen for QUFA, PITA, or FRPE to either Cd or Ni (Figures 55 - 60). Data from these tests suggest that seed germination is not significantly affected by the concentrations of Cd and Ni under these experimental conditions. The best dose-response relationship was seen with CEOC (Figures 61 & 62). At concentrations greater than 10 mg/L, both Cd and Ni significantly reduced seed germination during the 10-day bioassay. This reduction was statistically significant as measured using ANOVA ($P < 0.001$).

The response of LIST to metal burden was dose dependent for Cd (Figure 63). The results of this bioassay were not as apparent statistically as those with CEOC due to less seed germination in the controls than in the lower Cd concentrations. The trend, however, is apparent.. A similar, but not statistically significant, trend was observed for Ni (Figure 64).

These results support our earlier conclusions that seed germination may be a useful bioassay but that response differs widely among both species and toxicants. Statistical analyses of the data suggest that the overall performance of the bioassay may be improved by significantly increasing the number of seeds used in each treatment (eg. n=50).

STEM AND ROOT ELONGATION

The results for stem and root elongation were for seed germinated in petri dishes on filter paper at seven dose concentrations and grown in test tubes filled with acid washed sand with the same dose concentration as they were germinated.

Preliminary results of stem and root elongation responses to nickel and cadmium chloride salts are shown in Tables 14 -17 and Figures 65 - 68. The tables for green stem and root lengths give the number of observations per dose and standard deviations for mean values. They also contain ANOVAs for stem and root measurements.

Stem and root elongation of CBO and PAMI varied significant between dose responses (Tables 14 & 15) but there were no differences in these parameter between dose responses for LASA and FRPE (Tables 16 & 17). The final stem lengths of cherrybark oak (CBO) and white millet (PAMI) were very sensitive to nickel and cadmium (Figures 65 & 66). Concentrations of nickel and cadmium at 5 ppm reduced the final stem lengths of these two species by 30 to 40%. For instance, cherrybark oak (CBO) stem lengths at 5 ppm nickel were 58%, at 10 ppm 32%, at 20 ppm 40%, and at 40 ppm 33% of the control. Cadmium had similar effects: at 5 ppm stem lengths were 61%, at 10 ppm 43%, at 20 ppm 40%, and at 40 ppm 24% of the control lengths. Stem lengths of letttuce (LASA) and green ash (FRPE) showed no response to the metals. Perhaps this was because there was little or no stem growth with controls or any concentration of metals for this species.

Root elongation responses occurred in cherrybark oak (CBO) and white millet (PAMI; Figures 67 & 68). Although cherrybark oak (CBO) showed a significant reduction in root elongation with increased concentrations of nickel and cadmium in the sand, the differences were small and therefore less easy to discern. In contrast, white millet (PAMI) had almost 10 cm of root lengths in the control but only 3.4 cm with 5 ppm nickel or higher concentration and 5.8 cm of length or less with 5 ppm cadmium or higher concentrations. Roots of lettuce (LASA) and green ash (FRPE) did not respond to the metals. Again this lack of response appears to be a lack of root growth in controls and at any concentration of metals for these species. In this preliminary run, stem and root lengths of a wild species (cherrybark oak--CBO) and a domestic species (white millet--PAMI) were both very sensitive to 5 ppm metal concentrations or higher.

LITERATURE CITED FOR PLANT IDENTIFICATION

Aulbach-Smith, C.A. and S. J. de Kozlowski. 1990. Aquatic and Wetland Plants of South Carolina. South Carolina Aquatic Plant Management. Council. USA.

Army Corps of Engineers. 1977 Wetland Plants of the Eastern United States. North Atlantic Division, 90 Church St. New York, NY 10007. NADP 200-1-1.

Batson, W.T., J.S. Angerman, and J. T. Jones. 1985. Flora of the Savannah River Plant. An inventory of the vascular plants on the Savannah River plant, South Carolina. SRO-NERP-15.

Godfrey , R.K. and J.W. Wooten. 1979. Aquatic and Wetland Plants of the Southeastern United States: Monocotyledons. UGA Press, Athens, GA.

Godfrey, R.K. and J.W. Wooten. 1981. Aquatic and Wetland Plants of the Southeastern United States. Dicotyledons. UGA Press, Athens, GA.

Schalles, J.F., R.R. Sharitz, J. W. Gibbons, G.J. Leversee, and J.N. Knox. 1989. Carolina Bays of the Savannah River Plant. SRO-NERP-18

Radford, A.E., Ahles, H.E., Bell, C.R. 1968. Manual of the Vascular Flora of the Carolinas. UNC Press, Chapel Hill.

GENERAL LITERATURE CITED

Bartley, M.R. 1993. Assessment of herbicide selectivity. IN: Herbicide bioassays. J.C. Streibig and P. Kudsk, Eds. CRC Press, Boca Raton, pp57-74.

Batson, W.T., J.S. Angerman, and J.T. Jones. 1985. Flora of the Savannah River Plant. An Inventory of the Vascular Plants on the Savannah River Plant, South Carolina. SRO-NERP-15

Castanon, M.L.G. 1990. Early flowering in seedlings of asparagus promoted by diuron and atrazine. IN: Plant Aging: Basic and Applied Approaches. R. Rodriguez et al, Eds. Plenum Press, New York. pp445-447.

Dolan,R.W. 1984. The effect of seed size and maternal source on individual size in a population of *Ludwigia leptocarpa* (Onagraceae). Amer. J. Bot. 71: 1302-1307.

Duke, S.O. 1986. Naturally occurring chemical compounds as herbicides. IN: Research Methods in Weed Science. N.D. Camper, Ed. 3rd Edition, pp17-44.

Edwards, N.T. and B. M. Ross-Todd. 1980. An improved bioassay technique used in solid waste leachate phytotoxicity research. Environ. and Expt. Bot. 20: 31-38.

Egley, G.H., 1986. Weed seed germination and seedling establishment. IN: Research Methods in Weed Science. N.D. Camper, Ed. 3rd Edition. pp47-70.

Eisler, R. 1989. Atrazine hazards to fish, wildlife, and invertebrates: a synoptic review. US Fish Wild. Serv. Biol. Rep. 85(1.18). 53pp.

Fletcher, J.S, M.J. Muhitch, D.R. Vann, J.C. McFarlane, and F.E. Benenati. 1985. Phytotox database evaluation of surrogate plant species recommended by the U.S. Environmental Protection Agency and the Organization for Economic Cooperation and Development. Environ. Toxicol. Chem. 4:523-532.

Fletcher, J.S., F.L. Johnson, and J.C. McFarlane. 1990. Influence of greenhouse versus field testing and taxonomic differences on plant sensitivity to chemical treatment. Environ. Toxicol. Chem. 9:769-776.

Fletcher, J. 1991. Keynote speech: A brief overview of plant toxicity testing. IN: Plants for Toxicity Assessment: Second Volume. ASTM STP 1115, J.W. Gorsuch, W.R. Lower, W. Wang, and M.A. Lewis Eds. American Society for Testing and Materials, Philadelphia, pp 5-11.

Gorsuch, J.W., R.O. Kringle, and K.A. Robillard. 1990. Chemical effects on the germination and early growth of terrestrial plants. IN: Plants for Toxicity Assessment, ASTM STP 1091, W.Wang, J.W. Gorsuch, and W.R. Lower, Eds. American Society for Testing and Materials, Philadelphia, pp49-58.

Goyer, R.A. 1986. Toxic effects of metals. IN: Casarett and Doull's Toxicology. The Basic Science of Poisons. C.D. Klassen, M.O. Amdur, and J. Doull, Eds. Macmillan Publishing Co. New York. pp582-635.

Jones, R.H. and R.R. Sharitz. 1989. Potential advantages and disadvantages of germinating early for trees in floodplain forests. Oecologia, 81:443-449.

Jones, R.H. an R.R. Sharitz. 1990. Dynamics of advance regeneration in four South Carolina bottomland hardwood forests. Proc. of the 6th Biennial Southern Silviculture Research Conference. S.S. Coleman and D.G. Neary, Eds., pp567-578.

Kaplan, D.I., K.S. Sajwan, D.C. Adriano, and S. Gettier. 1990. Phytoavailability and toxicity of beryllium and vanadium. Water, AIr, and Soil Pollutl 53:203-212.

Khalid, B.Y. and J. Tinsley. 1980. Some effects of nickel toxicity on rye grass. Plant and Soil 55:139-144.

Kleier, D. A. and G. Gardner. 1993. Quantitiative structure activity relationships: Adding value to herbicide bioassays. In Herbicide Bioassays. (eds.) J. C. Streibig and P. Kudsk. p 75-98. CRC Press. Ann Arbor. 270 pp.

Lillie, T.H., and R.W. Bartine. 1990. Protocol for evaluating soil contaminated with fuel or herbicide. IN: Plants for Toxicity Assessment, ASTM STP 1091, W. Wang, J.W. Gorsuch, and W.R. Lower, Eds. American Society for Testing and Materials, Philadelphia. pp 198-203.

Linder, G., J.C. Greene, H. Ratsch, J. Nwosu, S. Smith, and D. Wilborn. 1990. Seed germination and root elongation toxicity tests in hazardous waste site evaluation: methods development and applications. IN: Plants for Toxicity Assessment, ASTM STP 1091, W. Wang, J.W. Gorsuch, and W.R. Lower, Eds. American Society for Testing and Materials, Philadelphia, p177-187.

Nriagu, J.O. and Pacyna, J.M. 1988. Quantitative assessment of worldwide contamination of air, water, and soil by trace metals. Nature, 333:134.

Patterson, D.T. 1986. Allelopathy. IN: Research Methods in Weed Science. N.D. Camper, Ed. 3rd Edition, Chapter IV

Teem, D.H., C. S. Hoveland, and G.A. Buchanan. 1973. Primary root elongation of three weed species. Weed Science 22: 47-50.

Thomas, J.M. and J. F. Cline. 1985. Modification of the Neubauer technique to assess toxicity of hazardous chemicals in soils. Environ. Toxicol. Chem. 4: 201-207.

USEPA, 1979. Water Related Fate of 129 Priority Pollutants. Ch. 9. Cadmium. Vol. 1. EPA 440/4-79-029a. U.S. Environmental Protection Agency, Washington, D.C.

USDHHS, 1989. Toxicological profile for nickel. U.S. Department of Health and Human Services. TP-92/14. Atlanta, GA.

USDHHS, 1990. Toxicological profile for tetrachloroethylene. U.S. Department of Health and Human Services. TP-92/18. Atlanta, GA.

Van Assche, F. and H. Clijsters. 1990. Effects of metals on enzyme activity in plants. Plant, Cell, and Environ. 13:195-206.

Velagaleti, R.R., D. Kramer, S.S. Marsh, N.G. Reichenbach, and D.E. Fleischmann. 1990. Some approaches to rapid and pre-symptom diagnosis of chemical stress in plants. IN: Plants for Toxicity Assessment, ASTM STP 1091, W. Wang, J.W. Gorsuch, an d W.R. Lower. Eds, American Society for Testing and Materials, Philadelphia pp. 333-345.

Wang, W. 1985a. The use of plant seeds in toxicity tests of phenolic compounds. Environ. Int. 11;49-55.

Wang, W. 1985b. Use of millet root elongation for toxicity tests of phenolic compounds. Environ. Int. 11:95-98.

Wang, W. 1986. Comparative toxicology of phenolic compounds using root elongation method. Environ. Toxicol. Chem. 5:891-896.

Wang, W. 1987. Root elongation method for toxicity testing of organic and inorganic pollutants. Environ. Toxicol. Chem. 6:409-414.

Wang, W. and J.M. Williams. 1988. Screening and biomonitoring of industrial effluents using phytotoxicity tests. Environ. Toxicol. Chem. 7:645-652.

Wang, W. and G. Elseth. 1990. Millet root elongation in toxicological studies of heavy metals: a mathematical model. IN: Plants for Toxicity Assessment, ASTM STP 1091, W. Wang, J.W. Gorsuch, and W.R. Lower, Eds., American Society for Testing and Materials, Philadelphia, pp280-294.

Wedge, D.E., S.D. McElreath, and F.H. Tainter. 1993. Bioassay of toxic metabolites from fungi associated with dogwood anthracnose.38th Annual Southern Nurserymen's Association Research Conference Report.

Williams, G.M. and J.H. Weisburger. 1986. Chemical carcinogens. IN:Casarett and Doull's Toxicology. The Basic Science of Poisons. C.D. Klassen, M.O. Amdur, and J. Doull, Eds. Macmillan Publishing Co. New York. pp99-173.

Wong, M.H. and A.D. Bradshaw. 1982. A comparison of the toxicity of heavy metals, using root elongation of rye grass, *Lolium perenne*. New Phytol. 91:255-261.

Young, J.A. and C.G. Young. 1986. Collecting, Processing, and Germinating Seeds of Wildland Plants. Timber Press, Portland, OR. 236pp.

Table 1. Seed germination response of sweetgum (*Liquidambar styraciflua*) to a range of concentrations of various toxins. (*Original methanol carrier levels.)

SWEETGUM

TOXIN	DOSE	GERMINATION			
		TUKEY'S		MEAN	STD DEV
Nickel	0.0	a		4.4	0.5
	0.1	a		4.8	0.4
	0.5	a		4.6	0.5
	1.0	a		5.0	0.0
	5.0	a		5.0	0.0
	10.0	a		4.8	0.4
	50.0		b	2.6	1.1
Cadmium	0.0	a		4.4	0.5
	0.1	a		4.6	0.5
	0.5	a		4.6	0.5
	1.0	a		4.6	0.5
	5.0	a		5.0	0.0
	10.0	a		4.8	0.4
	50.0		b	2.4	0.9
Atrazine *	0.0	a		4.4	0.5
	0.1	a		4.6	0.5
	0.5	a		5.0	0.0
	1.0	a		4.6	0.9
	5.0		b	0.0	0.0
	10.0	a		5.0	0.0
	50.0		b	0.8	1.8
Perchloroethylene *	0.0	a		4.4	0.5
	0.1	a		5.0	0.0
	0.5	a		4.4	0.5
	1.0	a		5.0	0.0
	5.0		b	0.8	1.8
	10.0	a		4.0	1.4
	50.0		b	0.8	1.3
Anthracene *	0.0	a		4.4	0.5
	0.1	a		4.6	0.9
	0.5	a		4.6	0.5
	1.0	a		4.8	0.4
	5.0		b	0.8	1.3
	10.0	a		4.4	0.5
	50.0		b	0.0	0.0
Methanol	0.0	a		4.4	0.5
	0.5	a		4.6	0.5
	5.0		b	0.0	0.0
	10.0		b	0.0	0.0

Table 2. Seed germination response of white millet (*Panicum miliaceum*) to a range of concentrations of various toxins. (* Methanol carrier levels minimized.)

WHITE MILLET

TOXIN	DOSE	GERMINATION			
		TUKEY'S		MEAN	STD DEV
Nickel	0.0	a		3.8	0.8
	0.5	a		4.8	0.4
	1.0	a		3.8	0.4
	5.0	a		3.6	1.5
	10.0	a		3.2	0.8
	25.0	a		3.8	0.8
	50.0	a		3.0	1.2
Cadmium	0.0	a	b	3.8	0.8
	0.5	a	b	3.8	1.3
	1.0	a	b	3.8	1.6
	5.0	a		4.4	0.9
	10.0	a		4.0	0.7
	25.0	a	b	3.2	1.9
	50.0		b	1.8	0.8
Atrazine *	0.0	a		3.8	0.8
	0.5	a		4.2	0.8
	1.0	a		3.2	1.6
	5.0	a		2.8	0.8
	10.0	a		3.0	1.0
	25.0	a		3.4	1.1
	50.0	a		3.0	1.4
Perchloroethylene *	0.0	a		3.8	0.8
	0.5	a		4.0	1.0
	1.0	a		3.6	0.5
	5.0	a		3.4	1.5
	10.0	a		3.8	1.6
	25.0	a		3.4	1.1
	50.0	a		3.8	1.3
Anthracene *	0.0	a		3.8	0.8
	0.5	a	b	3.4	1.1
	1.0	a		3.6	1.1
	5.0	a		3.6	1.7
	10.0	a	b	2.8	0.8
	25.0	a	b	2.8	0.8
	50.0		b	1.2	1.3
Methanol	0.0	a		3.8	0.8
	0.1	a		4.2	1.1
	0.2	a		3.0	1.0
	0.5	a		3.2	1.5
	1.0	a		3.0	1.4
	2.5	a		2.8	1.3
	5.0		b	0.2	0.4

Table 3. Seed germination response of Cherry Belle radish (*Rhaphanus sativus* var. Cherry Belle) to a range of concentrations of various toxins. (* Methanol carrier levels minimized.)

CHERRY BELLE RADISH

		GERMINATION		
TOXIN	DOSE	TUKEY'S	MEAN	STD DEV
Nickel	0.0	a	4.6	0.5
	0.5	a	4.0	1.2
	1.0	a	3.6	2.1
	5.0	a	4.8	0.4
	10.0	a	4.4	0.5
	25.0	a	4.4	0.9
	50.0	a	4.0	0.7
Cadmium	0.0	a	4.6	0.5
	0.5	a	5.0	0.0
	1.0	a	4.6	0.5
	5.0	a	3.6	2.2
	10.0	a	4.6	0.9
	25.0	a	5.0	0.0
	50.0	a	4.0	1.0
Atrazine *	0.0	a	4.6	0.5
	0.5	a	4.4	0.5
	1.0	a	4.6	0.5
	5.0	a	4.8	0.4
	10.0	a	4.6	0.9
	25.0	a	4.2	0.8
	50.0	a	4.6	0.5
Perchloroethylene *	0.0	a	4.6	0.5
	0.5	a	5.0	0.0
	1.0	a	4.0	1.0
	5.0	a	3.8	0.1
	10.0	a	4.4	0.5
	25.0	a	4.8	0.4
	50.0	a	4.8	0.4
Anthracene *	0.0	a	4.6	0.5
	0.5	a	4.6	0.5
	1.0	a	4.4	0.9
	5.0	a	4.8	0.4
	10.0	a	4.2	1.3
	25.0	a	3.4	1.9
	50.0	a	3.8	0.4
Methanol	0.0	a	4.6	0.5
	0.1	a	4.4	0.9
	0.2	a	4.6	0.5
	0.5	a	4.4	0.9
	1.0	a	3.8	1.1
	2.5	a	4.2	1.1
	5.0	a	3.2	0.8

Table 4. Seed germination response of lizard's tail (*Saururus cernuus*) to a range of concentrations of various toxins. (*Original methanol carrier levels.)

LIZARD'S TAIL

		GERMINATION				
TOXIN	DOSE	TUKEY'S			MEAN	STD DEV
Nickel	0.0		b		1.4	1.1
	0.1	a	b		1.8	1.9
	0.5		b		1.2	1.3
	1.0	a	b		1.8	1.3
	5.0	a			4.0	1.2
	10.0	a			4.2	0.8
	50.0		b		0.4	0.5
Cadmium	0.0	a			1.4	1.1
	0.1	a			3.2	1.5
	0.5	a			3.0	1.0
	1.0	a			3.0	1.2
	5.0	a			1.8	1.5
	10.0	a			3.6	1.5
	50.0	a			1.0	1.4
Atrazine *	0.0	a	b		1.4	1.1
	0.1	a	b		1.4	0.9
	0.5	a	b		1.6	1.1
	1.0	a			3.0	0.0
	5.0		b		2.6	1.5
	10.0	a	b		1.4	1.7
	50.0	a	b		0.6	0.5
Perchloroethylene *	0.0	a	b		1.4	1.1
	0.1	a	b		1.8	1.3
	0.5	a	b		2.0	1.2
	1.0	a	b		2.2	0.4
	5.0		b		0.8	0.8
	10.0	a			3.4	1.5
	50.0	a	b		1.4	1.1
Anthracene *	0.0		b	c	1.4	1.1
	0.1	a	b	c	1.8	1.6
	0.5	a	b		2.6	1.1
	1.0	a	b		2.4	0.5
	5.0			c	0.0	0.0
	10.0	a			3.6	1.1
	50.0			c	0.0	0.0
Methanol	0.0		b		1.4	1.1
	0.5	a			3.8	1.1
	5.0		b		0.2	0.4
	10.0		b		1.6	1.5

Table 5. Seed germination response of Buttercrunch lettuce (*Lactuca sativa* var. Buttercrunch) to a range of concentrations of various toxins. (* Methanol carrier levels minimized.)

BUTTERCRUNCH LETTUCE

		GERMINATION		
TOXIN	DOSE	TUKEY'S	MEAN	STD DEV
Nickel	0.0	a	5.0	0.0
	0.5	a	5.0	0.0
	1.0	a	5.0	0.0
	5.0	a	5.0	0.0
	10.0	a	5.0	0.0
	25.0	a	5.0	0.0
	50.0	a	4.8	0.4
Cadmium	0.0	a	5.0	0.0
	0.5	a	5.0	0.0
	1.0	a	5.0	0.0
	5.0	a	5.0	0.0
	10.0	a	5.0	0.0
	25.0	a	5.0	0.0
	50.0	a	5.0	0.0
Atrazine *	0.0	a	5.0	0.0
	0.5	a	5.0	0.0
	1.0	a	5.0	0.0
	5.0	a	5.0	0.0
	10.0	a	5.0	0.0
	25.0	a	4.8	0.4
	50.0	a	5.0	0.0
Perchloroethylene *	0.0	a	5.0	0.0
	0.5	a	5.0	0.0
	1.0	a	5.0	0.0
	5.0	a	5.0	0.0
	10.0	a	5.0	0.0
	25.0	a	5.0	0.0
	50.0	a	5.0	0.0
Anthracene *	0.0	a	5.0	0.0
	0.5	a	5.0	0.0
	1.0	a	5.0	0.0
	5.0	a	5.0	0.0
	10.0	a	5.0	0.0
	25.0	a	5.0	0.0
	50.0	a	4.6	0.9
Methanol	0.0	a	5.0	0.0
	0.1	a	5.0	0.0
	0.2	a	5.0	0.0
	0.5	a	5.0	0.0
	1.0	a	5.0	0.0
	2.5	a	5.0	0.0
	5.0	a	4.4	0.5

Table 6. Seed germination response of cherrybark oak (*Quercus falcata*) to a range of concentrations of various toxins. (*With additional methanol control.)

CHERRYBARK OAK

TOXIN	DOSE	GERMINATION TUKEY'S		GERMINATION MEAN	GERMINATION STD DEV
Nickel	0.0		b	0.6	0.5
	0.1		b	0.8	0.8
	0.5		b	0.0	0.0
	1.0		b	0.4	0.5
	5.0		b	0.6	1.3
	10.0	a	b	1.2	0.4
	50.0	a		2.4	0.9
Cadmium	0.0	a		0.6	0.5
	0.1	a		1.4	1.1
	0.5	a		1.0	0.7
	1.0	a		0.8	0.8
	5.0	a		1.4	0.5
	10.0	a		0.4	0.5
	50.0	a		1.0	1.4
Atrazine	0.0	a		0.6	0.5
	0.1	a		0.8	0.8
	0.5	a		1.2	0.8
	1.0	a		1.0	1.0
	5.0	a		1.2	1.3
	10.0	a		2.0	1.0
	50.0	a		2.0	1.7
Perchloroethylene	0.0	a		0.6	0.5
	0.1	a		1.4	1.1
	0.5	a		1.4	1.1
	1.0	a		1.4	1.1
	5.0	a		1.8	0.8
	10.0	a		1.0	1.2
	50.0	a		1.8	1.1
Anthracene	0.0	a		0.6	0.5
	0.1	a		1.4	1.1
	0.5	a		1.8	1.3
	1.0	a		1.2	0.8
	5.0	a		1.2	1.1
	10.0	a		1.6	1.1
	50.0	a		0.0	0.0
Methanol *	0.0	a		0.6	0.5
	0.5	a		0.8	0.8
	1.0	a		0.4	0.9
	5.0	a		0.2	0.4
	10.0	a		0.0	0.0

Table 7. Seed germination response of buttonbush (*Cephalanthus occidentalis*) to a range of concentrations of various toxins. (*Original methanol carrier levels.)

BUTTONBUSH

TOXIN	DOSE	GERMINATION			
		TUKEY'S		MEAN	STD DEV
Nickel	0.0	a		2.4	1.5
	0.1	a		2.6	1.3
	0.5	a		2.8	1.5
	1.0	a		3.8	0.4
	5.0	a		4.4	0.5
	10.0	a		3.2	0.8
	50.0		b	0.0	0.0
Cadmium	0.0	a		2.4	1.5
	0.1	a		3.2	0.8
	0.5	a		3.4	0.9
	1.0	a		2.6	1.3
	5.0	a		2.6	0.5
	10.0	a		3.6	0.5
	50.0		b	0.0	0.0
Atrazine *	0.0	a	b	2.4	1.5
	0.1	a	b	2.8	0.8
	0.5	a	b	3.0	1.2
	1.0	a	b	2.4	1.1
	5.0	a	b	2.0	0.7
	10.0	a		3.4	0.9
	50.0		b	0.8	1.3
Perchloroethylene *	0.0	a		2.4	1.5
	0.1	a		2.0	1.0
	0.5	a		3.4	0.9
	1.0	a		2.8	1.1
	5.0	a		2.0	1.6
	10.0	a		2.8	0.8
	50.0	a		3.0	1.9
Anthracene *	0.0	a	b	2.4	1.5
	0.1	a	b	2.6	1.1
	0.5	a	b	2.8	1.1
	1.0	a		3.8	0.8
	5.0	a	b	2.8	1.3
	10.0	a	b	2.6	1.3
	50.0		b	0.6	0.5
Methanol	0.0	a	b	2.4	1.5
	0.5	a		3.2	0.8
	5.0	a	b	2.0	0.7
	10.0		b	1.0	1.0

Table 8. Seed germination response of buttonbush (*Cephalanthus occidentalis*) to a range of concentrations of various toxins, (*With additional methanol control.) (** Control data were derived from previous *Cephalanthus* experiment.)

BUTTONBUSH

		GERMINATION			
TOXIN	DOSE	TUKEY'S		MEAN	STD DEV
Atrazine	0.0**	a		2.4	1.5
	0.1	a		4.0	0.7
	0.5	a		3.6	0.5
	1.0	a		4.0	0.7
	5.0		b	1.8	1.3
	10.0	a		3.8	0.8
	50.0		b	1.8	1.3
Perchloroethylene	0.0**	a		2.4	1.5
	0.1	a		4.4	0.5
	0.5	a		3.8	1.1
	1.0	a		4.2	0.8
	5.0	a		3.4	0.5
	10.0	a		4.0	0.7
	50.0	a		3.2	1.3
Anthracene	0.0**	a	b	2.4	1.5
	0.1	a		4.2	1.3
	0.5	a		4.2	0.8
	1.0	a		4.4	0.5
	5.0	a		4.2	1.3
	10.0	a		4.2	0.8
	50.0		b	1.0	2.2
Methanol *	0.0**	a		2.4	1.5
	0.5	a		3.6	1.7
	1.0	a		3.0	1.0
	5.0	a		1.8	1.3
	10.0	a		1.2	1.6

Table 9. Root elongation response of Cherry Belle radish (*Rhaphanus sativus* var. Cherry Belle) to various levels of toxins. (control data for final root measurements are missing.)

CHERRY BELLE RADISH

TOXIN	DOSE	ROOT ELONGATION MEAN	ROOT ELONGATION STD DEV
Nickel	0.0	.	.
	0.5	5.5	3.9
	1.0	6.1	3.4
	5.0	6.8	2.5
	10.0	3.7	2.6
	25.0	2.4	1.4
	50.0	0.2	0.3
Cadmium	0.0	.	.
	0.5	6.9	2.3
	1.0	5.9	3.3
	5.0	4.3	2.9
	10.0	3.9	2.3
	25.0	2.4	1.4
	50.0	0.2	0.3
Atrazine	0.0	.	.
	0.5	5.6	3.6
	1.0	6.2	3.8
	5.0	6.2	3.2
	10.0	5.4	2.7
	25.0	5.1	3.7
	50.0	4.1	3.0
Perchloroethylene	0.0	.	.
	0.5	5.9	3.4
	1.0	6.5	3.7
	5.0	5.7	3.9
	10.0	6.5	3.8
	25.0	5.9	3.0
	50.0	5.5	3.4
Anthracene	0.0	.	.
	0.5	5.4	3.5
	1.0	6.5	4.0
	5.0	5.0	3.0
	10.0	4.2	3.6
	25.0	1.3	1.3
	50.0	0.2	
Methanol	0.0	.	.
	0.1	5.6	3.5
	0.2	5.7	3.2
	0.5	5.2	3.6
	1.0	4.2	3.5
	2.5	1.8	1.4
	5.0	1.4	0.1

Table 10. Root elongation response of cherrybark oak (*Quercus falcata*) to various levels of toxins.

CHERRYBARK OAK

TOXIN	DOSE	ROOT ELONGATION MEAN	ROOT ELONGATION STD DEV
Nickel	0.0	1.5	3.3
	0.5	2.7	5.7
	1.0	0.8	2.2
	5.0	0.4	1.4
	10.0	0.7	2.6
	25.0	2.1	3.4
	50.0	1.6	1.3
Cadmium	0.0	1.5	3.3
	0.5	3.1	4.3
	1.0	1.0	2.7
	5.0	1.7	3.1
	10.0	1.8	3.0
	25.0	0.7	2.7
	50.0	2.6	2.6
Atrazine	0.0	1.5	3.3
	0.5	0.6	1.5
	1.0	1.8	3.1
	5.0	1.9	3.0
	10.0	1.9	3.2
	25.0	4.3	5.0
	50.0	0.7	1.1
Perchloroethylene	0.0	1.5	3.3
	0.1	2.6	3.8
	0.5	2.3	3.4
	1.0	1.5	2.3
	5.0	2.2	3.6
	10.0	0.2	0.5
	50.0	0.6	1.3
Anthracene	0.0	1.5	3.3
	0.1	2.5	3.8
	0.5	4.0	4.8
	1.0	3.8	5.5
	5.0	2.0	3.1
	10.0	1.2	1.8
	50.0	0.0	0.0
Methanol	0.0	1.5	3.3
	0.5	0.9	2.4
	1.0	0.7	1.7
	5.0	0.0	0.0
	25.0	0.0	0.1

Table 11. Root elongation response of Buttercrunch lettuce (*Lactuca sativa* var. Buttercrunch) to various levels of toxins.

BUTTERCRUNCH LETTUCE

TOXIN	DOSE	ROOT ELONGATION MEAN	ROOT ELONGATION STD DEV
Nickel	0.0	6.7	2.3
	0.5	7.6	1.9
	1.0	6.8	2.6
	5.0	0.7	0.2
	10.0	0.4	0.2
	25.0	0.4	0.2
	50.0	0.1	.02
Cadmium	0.0	6.7	2.3
	0.5	7.4	1.8
	1.0	7.4	1.3
	5.0	6.0	1.2
	10.0	2.8	0.8
	25.0	0.3	0.3
	50.0	0.1	0.02
Atrazine	0.0	6.7	2.3
	0.5	6.2	1.4
	1.0	5.0	1.5
	5.0	5.7	1.3
	10.0	4.9	1.1
	25.0	3.5	1.1
	50.0	2.3	0.6
Perchloroethylene	0.0	6.7	2.3
	0.5	8.2	2.0
	1.0	7.7	1.6
	5.0	7.0	2.1
	10.0	8.4	1.4
	25.0	7.4	2.5
	50.0	7.2	2.2
Anthracene	0.0	6.7	2.3
	0.5	8.1	2.0
	1.0	8.9	2.2
	5.0	7.3	1.5
	10.0	4.5	1.7
	25.0	0.5	0.4
	50.0	0.1	0.2
Methanol	0.0	6.7	2.3
	0.1	7.8	1.6
	0.2	7.2	2.6
	0.5	7.5	2.5
	1.0	6.3	1.9
	2.5	0.7	0.5
	5.0	0.1	0.05

Table 12. Root elongation response of buttonbush (*Cephalanthus occidentalis*) to various levels of toxins. (Control data for final root measurements are missing.)

BUTTONBUSH

TOXIN	DOSE	ROOT ELONGATION	
		MEAN	STD DEV
Atrazine	0.0	.	.
	0.1	1.4	1.2
	0.5	0.7	0.6
	1.0	0.7	0.5
	5.0	0.5	0.5
	10.0	0.4	0.4
	50.0	0.1	0.2
Perchloroethylene	0.0	.	.
	0.1	1.6	1.2
	0.5	1.2	1.2
	1.0	1.1	1.0
	5.0	0.7	0.8
	10.0	0.8	0.9
	50.0	0.1	0.1
Anthracene	0.0	.	.
	0.1	1.3	1.3
	0.5	1.0	0.8
	1.0	1.1	1.0
	5.0	0.8	0.7
	10.0	0.5	0.5
	50.0	0.1	0.3
Methanol	0.0	.	.
	0.5	1.1	1.1
	1.0	0.7	0.8
	5.0	0.0	0.1
	25.0	0.0	0.0

Table 13. Root elongation response of white millet (*Panicum miliaceum*) to various levels of toxins.

WHITE MILLET

TOXIN	DOSE	ROOT ELONGATION MEAN	ROOT ELONGATION STD DEV
Nickel	0.0	3.7	3.2
	0.5	4.5	2.3
	1.0	4.0	3.1
	5.0	1.0	0.9
	10.0	0.8	0.6
	25.0	0.5	0.4
	50.0	0.0	0.0
Cadmium	0.0	3.7	3.2
	0.5	3.5	3.1
	1.0	3.6	3.2
	5.0	3.0	2.5
	10.0	2.0	1.9
	25.0	0.2	0.3
	50.0	0.0	0.0
Atrazine	0.0	3.7	3.2
	0.5	3.8	2.8
	1.0	3.7	3.6
	5.0	1.3	1.8
	10.0	2.1	2.6
	25.0	2.4	2.6
	50.0	0.9	0.9
Perchloroethylene	0.0	3.7	3.2
	0.5	3.8	2.8
	1.0	3.2	3.2
	5.0	3.0	3.2
	10.0	3.5	3.1
	25.0	3.1	3.2
	50.0	2.3	2.0
Anthracene	0.0	3.7	3.2
	0.5	2.8	2.9
	1.0	3.7	3.4
	5.0	1.7	2.1
	10.0	0.6	0.8
	25.0	0.3	0.4
	50.0	0.0	0.0
Methanol	0.0	3.7	3.2
	0.1	4.2	3.1
	0.2	3.5	3.5
	0.5	2.6	2.9
	1.0	2.5	2.4
	2.5	0.5	0.5
	5.0	0.0	0.1

Table 14 Stem and root elongation responses of cherrybark oak to nickel and cadmium dose rates

NI	2	3	ROOT		GREEN	BIOMASS		DRY		BIOMASS	
	INT	FINAL	SHAPE	FINAL STEM		FINAL ROOT		FINAL	STEM	FINAL	ROOT
TOX	SURV %	SURV %	s/c/vc	cm	s	cm	s	cm	s	cm	s
0	38	100		7.72	3.9289	4.09	1.0743				
5	38	100		4.51	3.5202	3.57	0.6753				
10	15	100		2.48	2.1398	2.80	0.8042				
20	8	100		3.12	1.4473	3.35	2.0723				
40	15	100		2.58	2.058	2.14	1.0038				

CD	2	3	ROOT		GREEN	BIOMASS		DRY		BIOMASS	
	INT	FINAL	SHAPE	FINAL	STEM	FINAL	ROOT	FINAL	STEM	FINAL	ROOT
TOX	SURV %	SURV%	s/c/vc	cm	s	cm	s	cm	s	cm	s
0	38	100		7.72	3.9289	4.09	1.0743				
5	15	92		4.36	3.4018	3.19	1.1041				
10	15	100		3.31	2.7978	3.38	0.5732				
20	15	92		3.14	2.3564	2.86	1.5956				
40	8	100		1.60	2.0351	1.92	1.1374				

QUFA DOSE ANOVA Nickel

FINAL STEM LENGTH (CM)

DOSE

0	5	10	20	40
12.70	4.50	5.80	3.40	4.20
4.90	4.10	0.10	2.90	1.40
11.10	4.30	2.90	2.30	2.80
10.70	3.80	7.00	4.60	0.40
11.80	3.70	1.40	2.10	6.90
1.70	5.40	2.00	2.10	0.30
10.90	0.00	1.90	2.80	3.70
3.70	10.00	0.90	1.80	2.80
7.40	0.70	0.40	3.40	0.50
5.80	2.80	2.60	5.30	2.10
11.90	12.40	0.50	0.30	2.50
2.90	2.60	4.70	4.50	5.40
4.80	3.60	2.00	5.00	0.50

Anova: Single-Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	100.3	7.7154	15.436
Column 2	13	57.9	4.4538	11.398
Column 3	13	32.2	2.4769	4.5786
Column 4	13	40.5	3.1154	2.0947
Column 5	13	33.5	2.5769	4.2353

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grour	248.49	4	62.122	8.2297	2E-05	2.5252
Within Groups	452.91	60	7.5485			
Total	701.4	64				

QUFA DOSE ANOVA Nickel

FINAL ROOT LENGTH (CM)

DOSE

0	5	10	20	40
3.40	3.90	3.10	10.00	1.80
3.90	3.30	4.70	2.50	1.90
4.40	3.50	2.10	1.90	2.30
3.60	3.50	2.00	2.80	0.30
3.90	3.70	2.80	2.60	2.70
4.00	4.00	3.40	2.30	1.90
3.90	2.90	2.40	3.40	3.40
7.30	5.10	1.50	2.60	3.00
3.70	2.30	2.80	3.20	0.60
3.10	3.70	2.60	3.90	2.00
3.10	3.90	2.80	2.50	1.30
4.10	3.40	2.60	3.40	3.40
4.80	3.30	3.60	2.40	3.20

Anova: Single-Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	53.2	4.0923	1.1541
Column 2	13	46.5	3.5769	0.4186
Column 3	13	36.4	2.8	0.6467
Column 4	13	43.5	3.3462	4.2944
Column 5	13	27.8	2.1385	1.0076

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grour	29.199	4	7.2998	4.8527	0.0019	2.5252
Within Groups	90.255	60	1.5043			
Total	119.45	64				

Table 14 (continued

QUFA DOSE ANOVA Cadmium

FINAL STEM LENGTH (CM)
DOSE

0	5	10	20	40
12.70	0.60	0.20	7.50	0.80
4.90	5.40	5.30	5.40	0.70
11.10	4.30	5.50	2.20	7.20
10.70	3.70	0.40	3.20	0.30
11.80	3.40	4.50	2.00	0.50
1.70	11.00	0.20	4.20	1.40
10.90	2.80	3.60	0.00	3.50
3.70	9.30	1.20	4.60	1.00
7.40	8.30	7.60	6.10	0.50
5.80	4.20	7.60	2.50	3.50
11.90	3.30	0.40	0.30	0.00
2.90	0.00	5.00	0.00	0.00
4.80	0.40	1.50	2.80	1.40

Anova: Single-Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	100.3	7.7154	15.436
Column 2	13	56.7	4.3615	11.573
Column 3	13	43	3.3077	7.8274
Column 4	13	40.8	3.1385	5.5526
Column 5	13	20.8	1.6	4.1417

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grour	271.87	4	67.968	7.6316	5E-05	2.5252
Within Groups	534.37	60	8.9061			
Total	806.24	64				

QUFA DOSE ANOVA Cadmium

FINAL ROOT LENGTH (CM)
DOSE

0	5	10	20	40
3.40	2.70	1.90	3.70	2.50
3.90	3.80	6.00	4.80	3.20
4.40	4.10	3.70	1.20	3.70
3.60	3.50	3.20	4.50	1.60
3.90	4.40	3.80	4.60	3.50
4.00	3.10	4.30	3.10	2.00
3.90	3.90	3.90	0.10	2.30
7.30	3.40	3.50	3.50	0.50
3.70	3.00	3.30	2.90	1.80
3.10	3.80	3.40	3.50	1.90
3.10	2.50	3.20	2.00	0.50
4.10	0.00	3.60	0.00	0.10
4.80	3.30	3.10	3.30	1.40

Anova: Single-Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	53.2	4.0923	1.1541
Column 2	13	41.5	3.1923	1.2191
Column 3	13	43.9	3.3769	0.3286
Column 4	13	37.2	2.8615	2.5459
Column 5	13	25	1.9231	1.2936

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grour	32.647	4	8.1618	6.2387	0.0003	2.5252
Within Groups	78.495	60	1.3083			
Total	111.14	64				

Table 15 Stem and root elongation responses of millet to nickel and cadmium dose rates

NI	2	3	ROOT		GREEN	BIOMASS		DRY		BIOMASS	
	INT	FINAL	SHAPE	INAL STEM		FINAL ROOT		FINAL	STEM	FINAL	ROOT
TOX	SURV %	SURV %	s/c/vc	cm	s	cm	s	cm	s	cm	s
0	100	92		7.88	3.4783	9.22	4.7494				
5	77	92		4.04	3.0626	3.47	1.8603				
10	77	85		5.08	3.4966	2.27	1.1771				
20	38	31		0.91	1.0766	0.49	0.5204				
40	8	8		0.88	1.3266	0.60	0.6164				

CD	2	3	ROOT		GREEN	BIOMASS		DRY		BIOMASS	
	INT	FINAL	SHAPE	FINAL	STEM	FINAL	ROOT	FINAL	STEM	FINAL	ROOT
TOX	SURV %	SURV %	s/c/vc	cm	s	cm	s	cm	s	cm	s
0	100	92		7.88	3.4783	9.22	4.7494				
5	92	85		5.22	2.5719	5.90	2.5965				
10	77	85		4.25	2.3497	3.79	1.9276				
20	85	54		1.63	1.8794	1.41	1.7173				
40	8	15		0.25	0.5502	0.06	0.171				

PAMI DOSE ANOVA Nickel

FINAL STEM LENGTH (CM)

DOSE

0	5	10	20	40
13.10	6.90	11.10	2.90	0.40
6.50	9.90	1.10	0.40	0.20
3.20	0.60	5.20	0.20	3.50
8.80	9.60	8.90	0.50	0.80
9.80	2.60	0.40	0.00	0.80
10.40	0.00	8.10	0.00	0.30
0.70	2.60	1.20	0.40	0.20
7.30	2.80	0.30	1.60	0.00
6.60	3.70	4.90	0.30	0.70
4.90	2.10	5.70	0.30	4.10
9.20	4.60	4.50	2.10	0.20
10.60	4.10	7.20	0.20	0.00
11.30	3.00	7.50	2.90	0.30

Anova: Single-Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	102.4	7.8769	12.099
Column 2	13	52.5	4.0385	9.3792
Column 3	13	66.1	5.0846	12.226
Column 4	13	11.8	0.9077	1.1591
Column 5	13	11.5	0.8846	1.7597

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grour	457.4	4	114.35	15.612	8E-09	
Within Groups	439.48	60	7.3246			
Total	896.88	64				

PAMI DOSE ANOVA Nickel

FINAL ROOT LENGTH (CM)

DOSE

0	5	10	20	40
				0.60
18.00	3.40	3.60	0.80	0.30
6.90	5.50	1.20	0.20	2.30
3.70	1.50	2.20	0.00	0.80
9.80	6.20	4.00	0.00	0.60
12.50	3.10	1.70	0.30	0.00
7.20	0.00	2.40	0.10	0.60
0.00	1.00	0.90	0.00	0.00
12.40	4.90	0.30	1.30	0.40
7.20	3.30	1.80	0.40	1.30
6.90	3.50	2.40	0.20	0.40
8.30	5.70	2.00	1.60	0.20
13.00	2.80	4.30	0.60	0.30
14.00	2.80	2.70	0.90	

Anova: Single-Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	119.9	9.2231	22.557
Column 2	13	43.7	3.3615	3.4609
Column 3	13	29.5	2.2692	1.3856
Column 4	13	6.4	0.4923	0.2708
Column 5	13	7.8	0.6	0.38

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grour	666.39	4	166.6	29.692	1E-13	2.5252
Within Groups	336.65	60	5.6108			
Total	1003	64				

Table 15 (continued)
PAMI DOSE ANOVA Cadmium

FINAL STEM LENGTH (CM)
DOSE

0	5	10	20	40
				0.00
13.10	3.10	0.00	1.50	0.00
6.50	8.20	6.00	1.20	0.00
3.20	8.20	3.60	1.60	0.30
8.80	4.90	4.20	1.60	0.00
9.80	5.60	5.90	5.60	1.20
10.40	4.80	4.50	1.90	0.00
0.70	6.50	4.60	0.20	0.00
7.30	6.30	1.60	0.30	0.00
6.60	0.20	0.30	1.20	0.00
4.90	6.80	7.00	0.00	1.70
9.20	7.60	7.40	0.00	0.00
10.60	4.90	4.60	0.50	0.00
11.30	0.70	5.50	5.60	

Anova: Single-Factor

Summary

Groups	Count	Sum	Average	Variance
Column 1	13	102.4	7.8769	12.099
Column 2	13	67.8	5.2154	6.6147
Column 3	13	55.2	4.2462	5.521
Column 4	13	21.2	1.6308	3.5323
Column 5	13	3.2	0.2462	0.3027

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Grour	469.95	4	117.49	20.928	8E-11	2.5252
Within Groups	336.83	60	5.6139			
Total	806.78	64				

PAMI DOSE ANOVA Cadmium

FINAL ROOT LENGTH (CM)
DOSE

0	5	10	20	40
				0.00
18.00	6.30	0.60	0.50	0.00
6.90	8.40	5.50	0.50	0.00
3.70	6.00	5.70	0.60	0.00
9.80	5.10	4.60	3.30	0.00
12.50	6.40	4.80	5.30	0.20
7.20	8.20	5.30	0.70	0.00
0.00	5.70	3.30	1.20	0.00
12.40	8.10	0.70	0.70	0.00
7.20	0.10	0.50	0.00	0.00
6.90	8.00	4.20	1.10	0.60
8.30	6.90	5.20	0.00	0.00
13.00	6.50	4.10	0.20	0.00
14.00	1.00	4.80	4.20	

Anova: Single-Factor

Summary

Groups	Count	Sum	Average	Variance
Column 1	13	119.9	9.2231	22.557
Column 2	13	76.7	5.9	6.7417
Column 3	13	49.3	3.7923	3.7158
Column 4	13	18.3	1.4077	2.9491
Column 5	13	0.8	0.0615	0.0292

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Grour	690.76	4	172.69	23.99	7E-12	2.5252
Within Groups	431.91	60	7.1985			
Total	1122.7	64				

Table 16 Stem and root elongation responses of lettuce to nickel and cadium dose rates

NI	2	3	ROOT		GREEN	BIOMASS		DRY		BIOMASS	
	INT	FINAL	SHAPE	FINAL STEM		FINAL ROOT		FINAL	STEM	FINAL	ROOT
TOX	SURV %	SURV%	s/c/vc	cm	s	cm	s	cm	s	cm	s
0	31	31		0.28	0.5019	1.09	2.6043				
5	15	38		0.53	0.7443	0.16	0.2329				
10	23	15		0.48	0.6918	0.45	0.6765				
20	31	46		0.99	0.8301	0.34	0.2293				
40	23	15		0.51	0.8261	0.18	0.3113				

CD	2	3	ROOT		GREEN	BIOMASS		DRY		BIOMASS	
	INT	FINAL	SHAPE	FINAL	STEM	FINAL	ROOT	FINAL	STEM	FINAL	ROOT
TOX	SURV %	SURV%	s/c/vc	cm	s	cm	s	cm	s	cm	s
0	31	31		0.28	0.5019	1.09	2.6043				
5	8	23		0.22	0.3539	0.18	0.5786				
10	23	8		0.22	0.3976	0.09	0.1706				
20	8	8		0.42	0.6821	0.19	0.3639				
40	8	15		0.50	0.4983	0.27	0.2869				

LASA DOSE ANOVA Nickel

FINAL STEM LENGTH (CM)

DOSE

0	5	10	20	40
0.00	0.00	1.50	0.00	1.30
0.90	0.00	0.00	1.60	0.00
0.00	1.10	0.00	1.60	1.20
0.00	1.90	1.50	0.00	0.00
0.00	0.00	0.00	0.60	0.00
0.00	0.00	0.50	0.00	0.00
0.00	·0.00	0.00	1.50	0.00
0.70	0.00	0.00	1.00	0.00
1.60	1.70	0.00	1.70	0.00
0.00	0.00	0.50	1.30	0.00
0.40	0.80	0.00	1.00	2.10
0.00	1.40	1.90	2.60	2.00
0.00	0.00	0.30	0.00	0.00

Anova: Single-Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	3.6	0.2769	0.2519
Column 2	13	6.9	0.5308	0.554
Column 3	13	6.2	0.4769	0.4786
Column 4	13	12.9	0.9923	0.6891
Column 5	13	6.6	0.5077	0.6824

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grour	3.6071	4	0.9018	1.6976	0.1624	2.5252
Within Groups	31.872	60	0.5312			
Total	35.479	64				

LASA DOSE ANOVA Nickel

FINAL ROOT LENGTH (CM)

DOSE

0	5	10	20	40
0.00	0.00	0.30	0.00	0.40
9.20	2.00	0.00	0.60	0.00
0.00	0.50	0.00	0.50	0.50
0.00	0.50	0.50	0.50	0.00
0.00	0.00	0.00	0.20	0.00
0.00	0.00	0.30	0.00	0.00
0.00	0.00	0.00	0.40	0.00
2.80	0.00	0.00	0.60	0.00
2.10	0.60	1.80	0.50	0.00
0.00	0.00	0.40	0.50	0.00
0.10	0.30	0.00	0.40	0.40
0.00	0.20	0.50	0.20	1.00
0.00	0.00	2.00	0.00	0.00

Anova: Single-Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	14.2	1.0923	6.7824
Column 2	13	4.1	0.3154	0.3081
Column 3	13	5.8	0.4462	0.4577
Column 4	13	4.4	0.3385	0.0526
Column 5	13	2.3	0.1769	0.0969

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grour	6.6932	4	1.6733	1.0869	0.3712	2.5252
Within Groups	92.372	60	1.5395			
Total	99.066	64				

Table 16 (continued)

LASA DOSE ANOVA Cadmium

FINAL STEM LENGTH (CM)
DOSE

0	5	10	20	40
0.00	0.00	0.00	0.00	0.00
0.90	0.00	0.00	1.40	0.00
0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.90	0.00	1.10
0.00	0.90	0.40	0.00	0.30
0.00	0.70	0.30	0.90	0.80
0.00	0.00	0.00	0.00	1.20
0.70	0.60	0.00	1.50	1.30
1.60	0.00	0.00	0.00	0.80
0.00	0.00	0.00	0.00	0.00
0.40	0.00	0.00	1.70	0.60
0.00	0.70	0.00	0.00	0.00
0.00	0.00	1.20	0.00	0.40

Anova: Single-Factor

Summary

Groups	Count	Sum	Average	Variance
Column 1	13	3.6	0.2769	0.2519
Column 2	13	2.9	0.2231	0.1253
Column 3	13	2.8	0.2154	0.1581
Column 4	13	5.5	0.4231	0.4653
Column 5	13	6.5	0.5	0.2483

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Grour	0.844	4	0.211	0.8448	0.5024	2.5252
Within Groups	14.986	60	0.2498			
Total	15.83	64				

LASA DOSE ANOVA Cadmium

FINAL ROOT LENGTH (CM)
DOSE

0	5	10	20	40
0.00	0.00	0.00	0.00	0.00
9.20	0.00	0.00	0.30	0.00
0.00	0.00	0.00	0.00	0.70
0.00	0.00	0.20	0.00	0.20
0.00	0.00	0.40	0.00	0.40
0.00	0.10	0.10	0.30	0.30
0.00	0.00	0.00	0.00	0.20
2.80	2.10	0.00	0.40	0.50
2.10	0.00	0.00	0.00	0.20
0.00	0.00	0.00	0.00	0.00
0.10	0.00	0.00	0.20	0.90
0.00	0.20	0.00	0.00	0.00
0.00	0.00	0.50	1.30	0.10

Anova: Single-Factor

Summary

Groups	Count	Sum	Average	Variance
Column 1	13	14.2	1.0923	6.7824
Column 2	13	2.4	0.1846	0.3347
Column 3	13	1.2	0.0923	0.0291
Column 4	13	2.5	0.1923	0.1324
Column 5	13	3.5	0.2692	0.0823

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Grour	8.7732	4	2.1933	1.4898	0.2166	2.5252
Within Groups	88.332	60	1.4722			
Total	97.106	64				

Table 17. Stem and root elongation responses of green ash to nickel and cadmium dose rates

NI	2	3	ROOT	GREEN		BIOMASS		DRY		BIOMASS	TIWET, P.O. Box 709
	INT	FINAL	SHAPE	FINAL STEM		FINAL ROOT		FINAL		FINAL	
TOX	SURV	SURV %	s/c/vc	cm	s	ROOT cm	s	STEM cm	s	ROOT cm	s (803)646-2200
0	77	31		1.31	0.7932	1.22	1.644104				
5	62	30		1.33	0.6824	1.26	1.636836				
10	92	30		1.63	0.8826	0.85	0.545612				
20	69	31		1.66	0.565	0.85	0.545612				
40	85	23		1.41	0.5408	0.82	0.559533				

CD	2	3	ROOT	GREEN		BIOMASS		DRY		BIOMASS	
	INT	FINAL	SHAPE	FINAL STEM		FINAL		FINAL		FINAL	
TOX	SURV	SURV %	s/c/vc	cm	s	ROOT		STEM		ROOT	s
0	77	31		1.31	0.7932	1.22	1.644104				
5	69	38		1.31	0.6344	1.12	1.195933				
10	77	46		1.44	0.7066	1.08	0.991502				
20	23	54		1.18	0.5257	0.95	0.595281				
40	69	23		1.17	0.5851	0.72	0.435596				

FRPE DOSE ANOVA Nickel

FINAL STEM LENGTH (CM)

DOSE

0	5	10	20	40
1.40	0.00	0.50	1.90	1.30
2.50	1.10	2.40	1.80	0.30
0.00	1.20	0.00	1.30	0.90
0.60	1.60	0.80	1.80	0.80
1.60	1.30	2.30	2.00	0.90
1.80	1.80	1.40	0.50	1.70
0.80	0.20	2.10	2.20	1.90
1.40	0.00	1.30	1.90	2.10
1.20	1.40	1.50	0.70	1.70
2.50	1.90	3.30	1.20	1.80
1.60	2.40	2.30	2.10	1.70
0.00	1.20	1.50	2.30	1.30
1.60	1.80	1.80	1.90	1.90

Anova: Single-Factor

Summary

Groups	Count	Sum	Average	Variance
Column 1	13	17	1.30769231	0.629103
Column 2	13	15.9	1.22307692	0.561923
Column 3	13	21.2	1.63076923	0.778974
Column 4	13	21.6	1.66153846	0.319231
Column 5	13	18.3	1.40769231	0.292436

ANOVA

TIWET, P.O. Box 709

Source of Variation

	SS	df	MS	F	P-value (803)646-2200	F crit
Between Gr	1.961538	4	0.49038462	0.949744	0.44173991	2.525212
Within Grou	30.98	60	0.51633333			
Total	32.94154	64				

FRPE DOSE ANOVA Nickel

FINAL ROOT LENGTH (CM)

DOSE

0	5	10	20	40
0.70	1.30	0.30	0.00	0.70
6.40	1.00	0.40	0.30	1.20
0.20	0.20	1.50	0.70	0.00
0.80	0.40	0.00	1.00	0.10
1.50	2.10	0.70	0.60	0.30
2.00	0.80	0.90	0.90	0.40
0.00	0.00	0.70	1.80	0.40
1.00	0.60	0.30	0.70	0.80
0.40	0.20	0.70	0.30	0.60
1.00	0.40	0.90	0.20	1.70
0.60	0.70	0.70	0.90	0.40
0.50	0.40	0.50	0.20	1.10
0.70	0.10	0.50	0.40	0.50

Anova: Single-Factor

Summary

Groups	Count	Sum	Average	Variance
Column 1	13	15.8	1.21538462	2.703077
Column 2	13	8.2	0.63076923	0.332308
Column 3	13	8.1	0.62307692	0.135256
Column 4	13	8	0.61538462	0.224744
Column 5	13	8.2	0.63076923	0.223974

ANOVA

Source of Variation

	SS	df	MS	F	P-value	F crit
Between Gr	3.627077	4	0.90676923	1.252666	0.29862135	
Within Grou	43.43231	60	0.72387179			
Total	47.05938	64				

2.525212

FRPE DOSE ANOVA Cadmium

FINAL STEM LENGTH (CM)

DOSE

0	5	10	20	40
1.40	0.50	1.10	0.80	1.60
2.50	1.10	1.50	0.70	2.20
0.00	1.20	1.50	1.90	1.70
0.60	1.80	2.50	1.30	1.10
1.60	2.00	1.10	1.90	0.00
1.80	1.80	0.70	0.60	1.00
0.80	2.30	0.70	0.90	1.00
1.40	1.80	1.20	1.70	1.20
1.20	1.20	1.20	0.80	1.10
2.50	0.30	2.70	1.70	1.80
1.60	0.90	0.60	0.40	0.40
0.00	0.50	2.50	1.60	1.30
1.60	1.60	1.40	1.10	0.80

Anova: Single-Factor

Summary

TIWET, P.O. Box 709
(803)646-2200

Groups	Count	Sum	Average	Variance
Column 1	13	17	1.30769231	0.629103
Column 2	13	17	1.30769231	0.402436
Column 3	13	18.7	1.43846154	0.499231
Column 4	13	15.4	1.18461538	0.27641
Column 5	13	15.2	1.16923077	0.342308

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Gr	0.624	4	0.156	0.362877	0.83407361	2.525212
Within Grou	25.79385	60	0.42989744			
Total	26.41785	64				

FRPE DOSE ANOVA Cadmium

FINAL ROOT LENGTH (CM)

DOSE

0	5	10	20	40
0.70	0.20	0.70	1.10	0.80
6.40	0.60	0.50	1.50	0.60
0.20	1.10	0.50	0.30	0.80
0.80	1.90	2.70	1.90	1.40
1.50	4.40	,1.50	0.60	0.20
2.00	0.60	0.30	0.40	0.30
0.00	2.30	0.10	0.80	0.90
1.00	0.00	0.80	1.90	1.00
0.40	0.50	1.40	0.40	0.20
1.00	0.00	3.50	0.60	0.90
0.60	0.80	0.50	0.50	0.50
0.50	1.00	1.00	1.70	1.50
0.70	1.20	0.60	0.70	0.20

Anova: Single-Factor

Summary

Groups	Count	Sum	Average	Variance
Column 1	13	15.8	1.21538462	2.703077
Column 2	13	14.6	1.12307692	1.430256
Column 3	13	14.1	1.08461538	0.983077
Column 4	13	12.4	0.95384615	0.354359
Column 5	13	9.3	0.71538462	0.189744

ANOVA

TIWET, P.O. Box 709
(803)646-2200

Source of Variation	SS	df	MS	F	P-value	F crit
Between Gr	1.951692	4	0.48792308	0.430988	0.78568365	2.525212
Within Grou	67.92615	60	1.13210256			
Total	69.87785	64				

Figure 1.

Impact of cadmium on germination of Liquidambar styraciflua

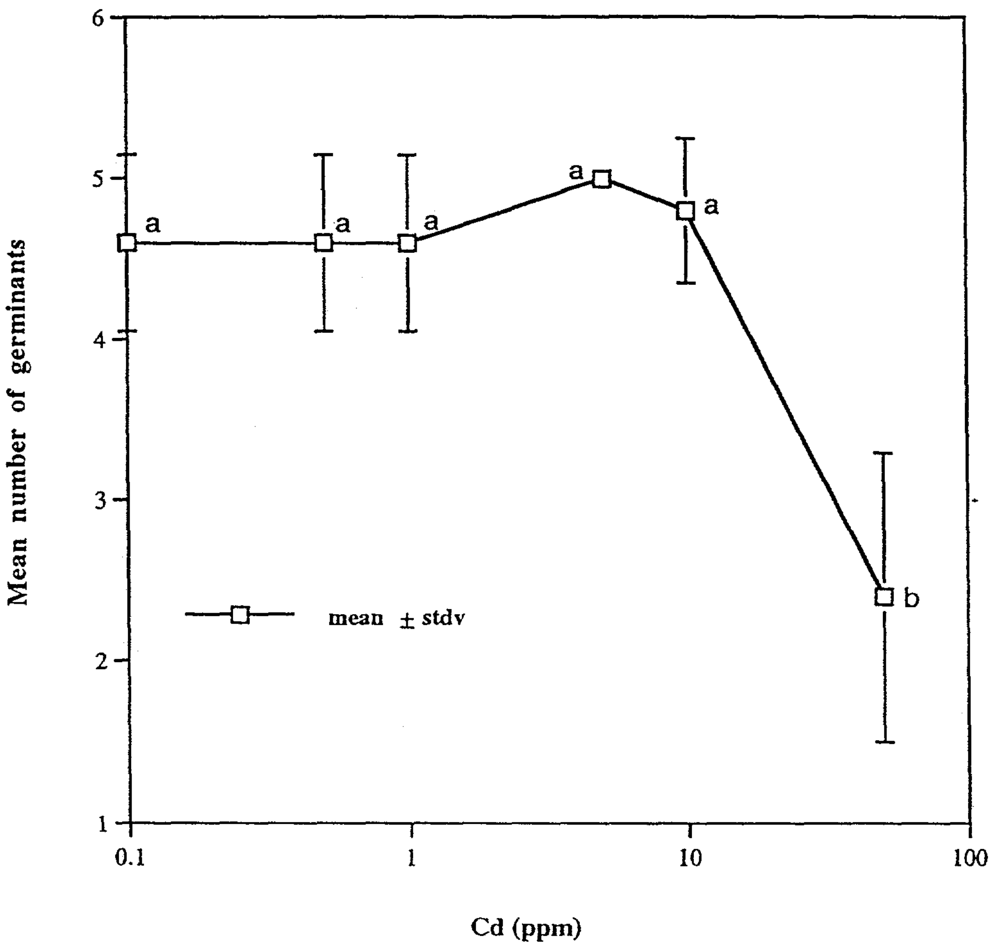


Figure 2.

Impact of nickel on germination of Liquidambar styraciflua

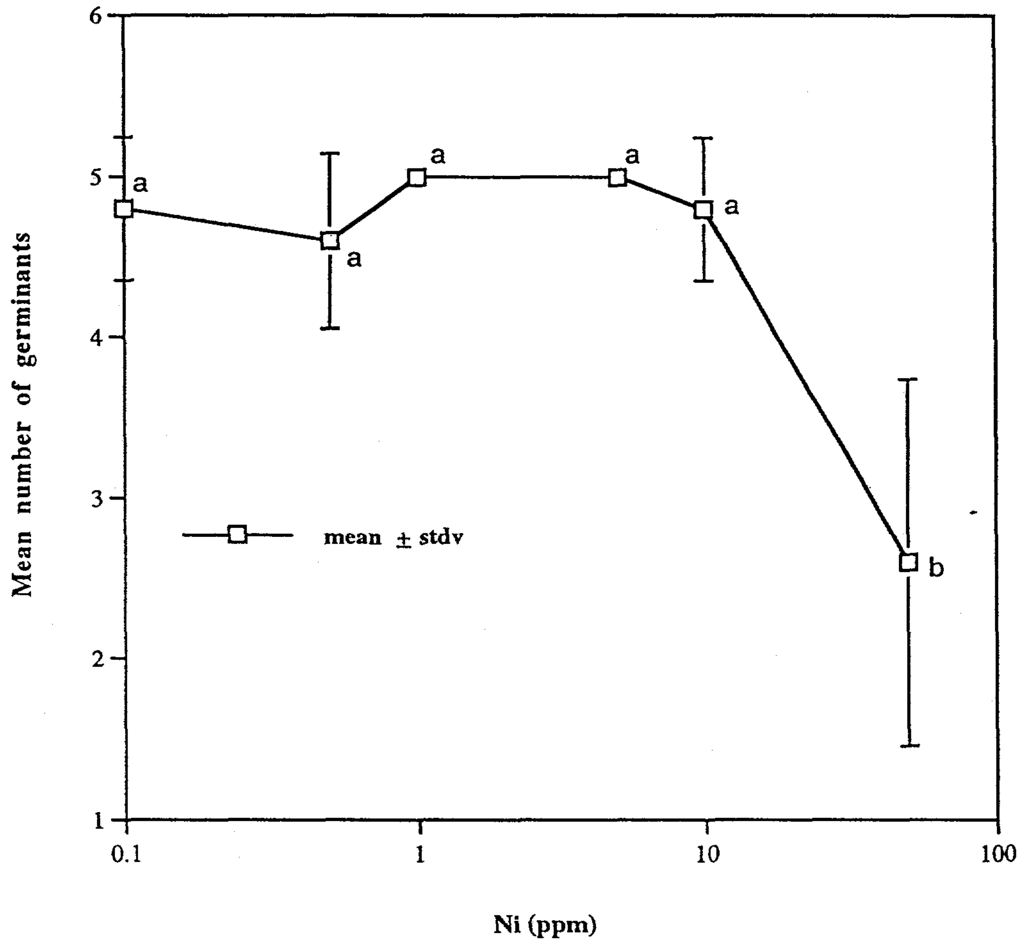


Figure 3.

Impact of anthracene on germination of Liquidambar styraciflua

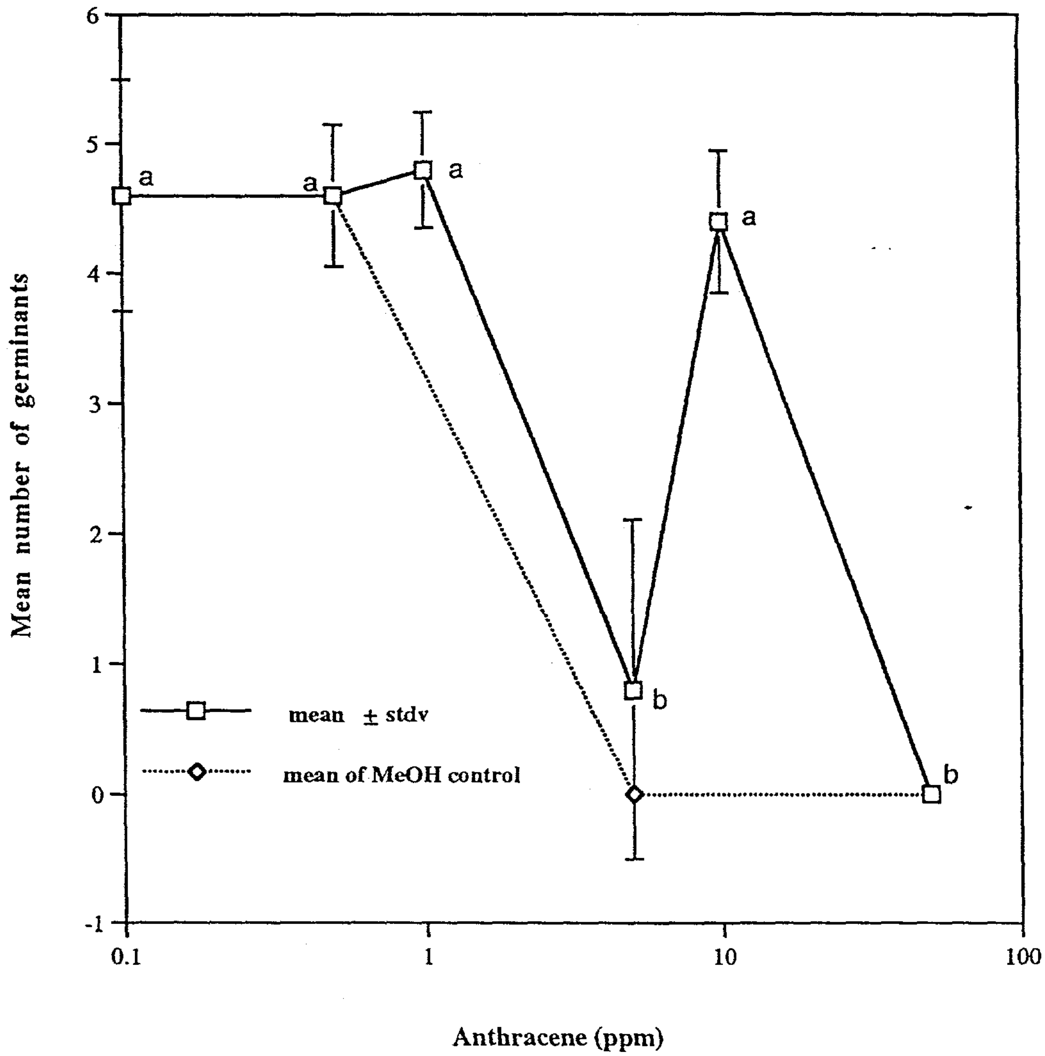
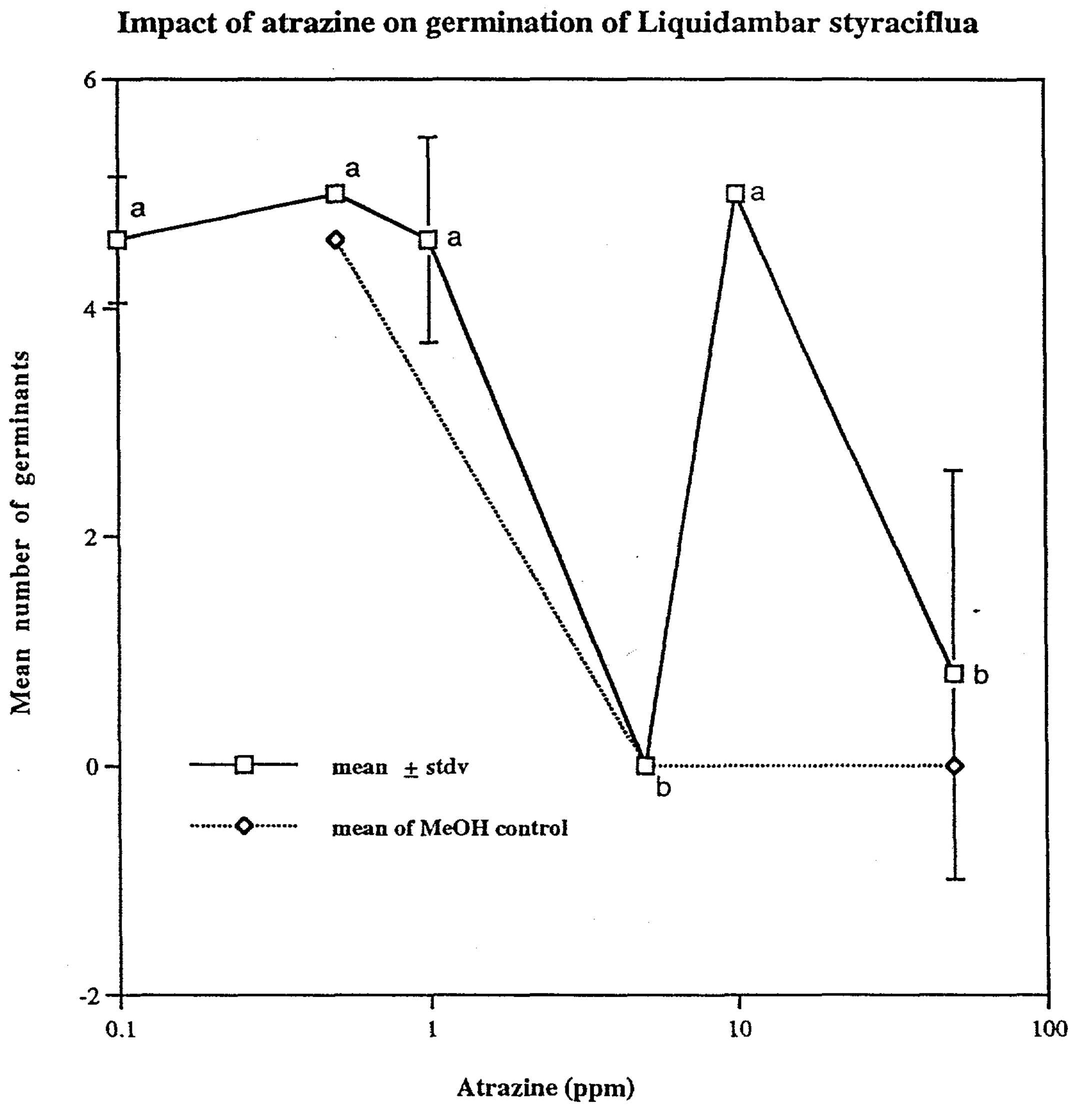


Figure 4.



Impact of atrazine on germination of Liquidambar styraciflua
Mean number of germinants
Atrazine (ppm)
6
4
2
0
-2
0.1
1
10
100
a
a
a
a
b
b
mean ± stdv
mean of MeOH control

Figure 5.

Impact of pce on germination of Liquidambar styraciflua

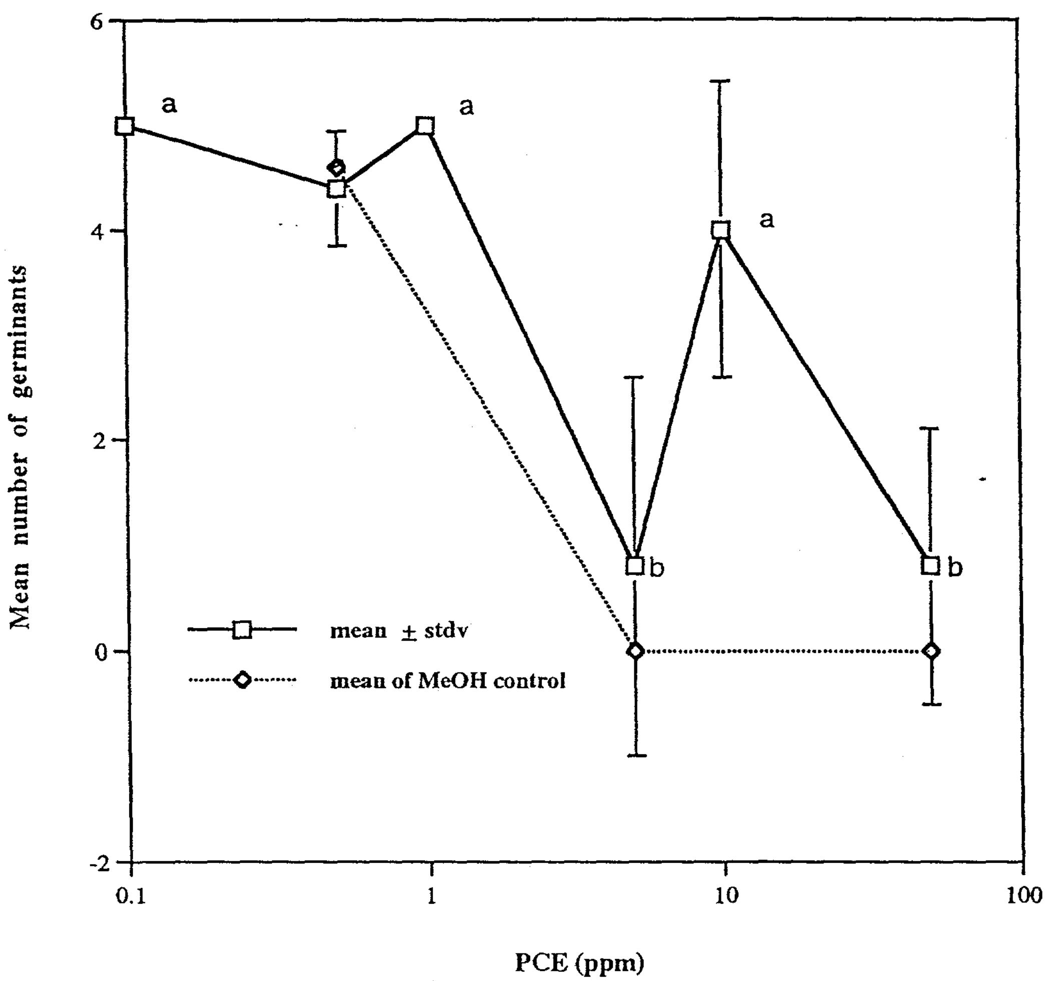


Figure 6.

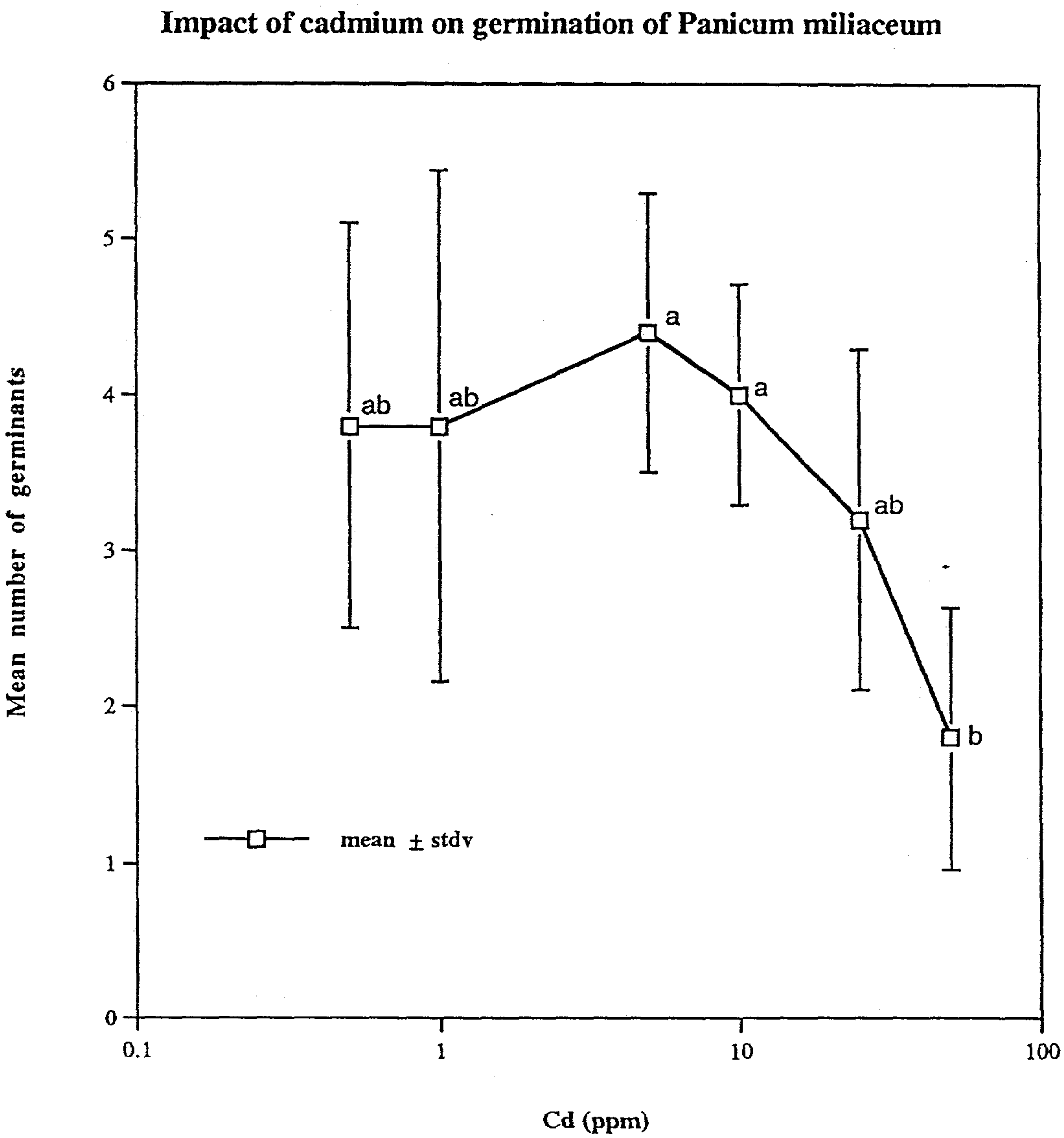

Impact of cadmium on germination of Panicum miliaceum
Mean number of germinants
Cd (ppm)
0
1
2
3
4
5
6
0.1
1
10
100
ab
ab
a
a
ab
b
mean ± stdv

Figure 7.

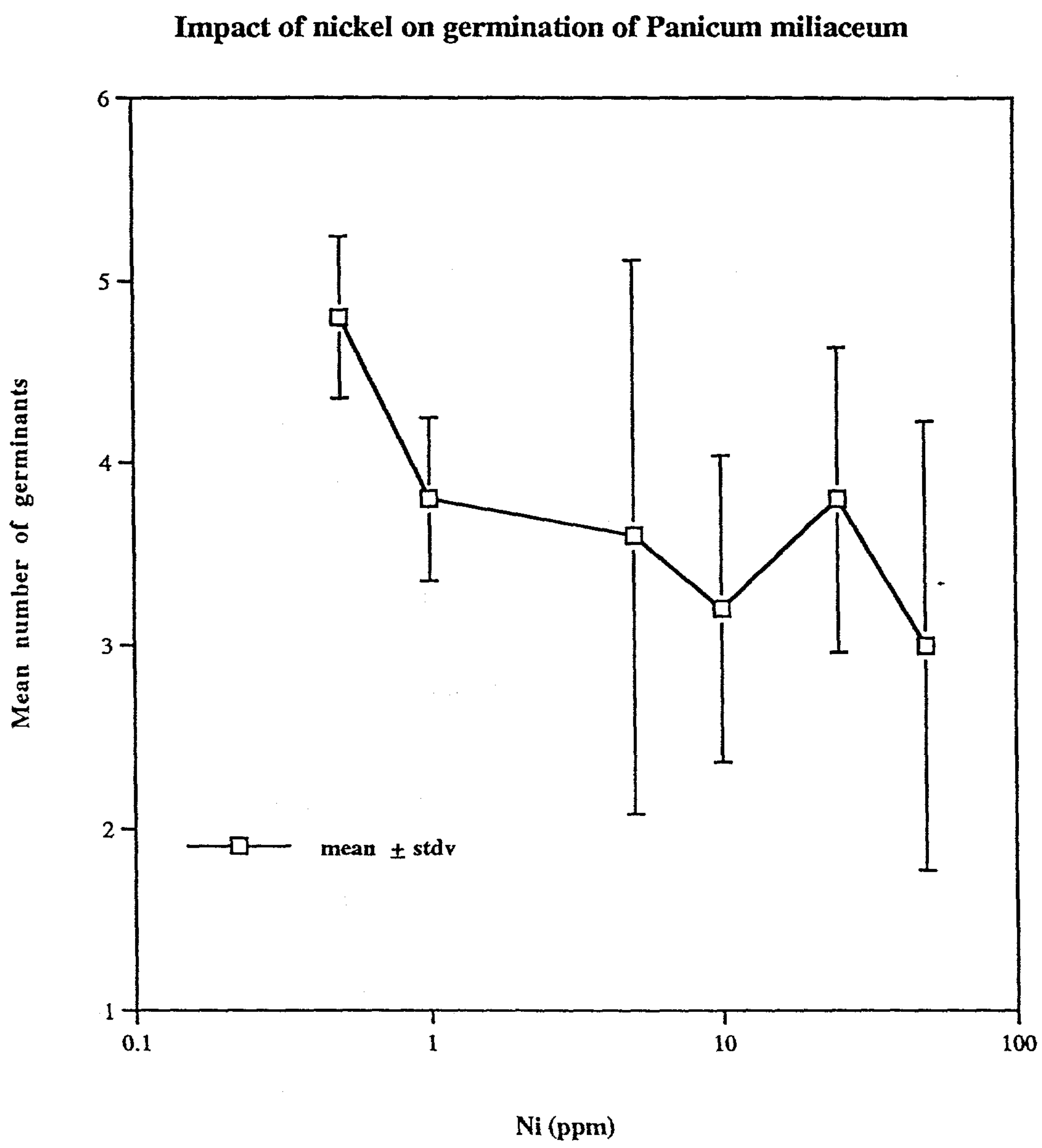

Impact of nickel on germination of Panicum miliaceum
6
5
4
3
2
1
Mean number of germinants
mean ± stdv
0.1
1
10
100
Ni (ppm)

Figure 8.

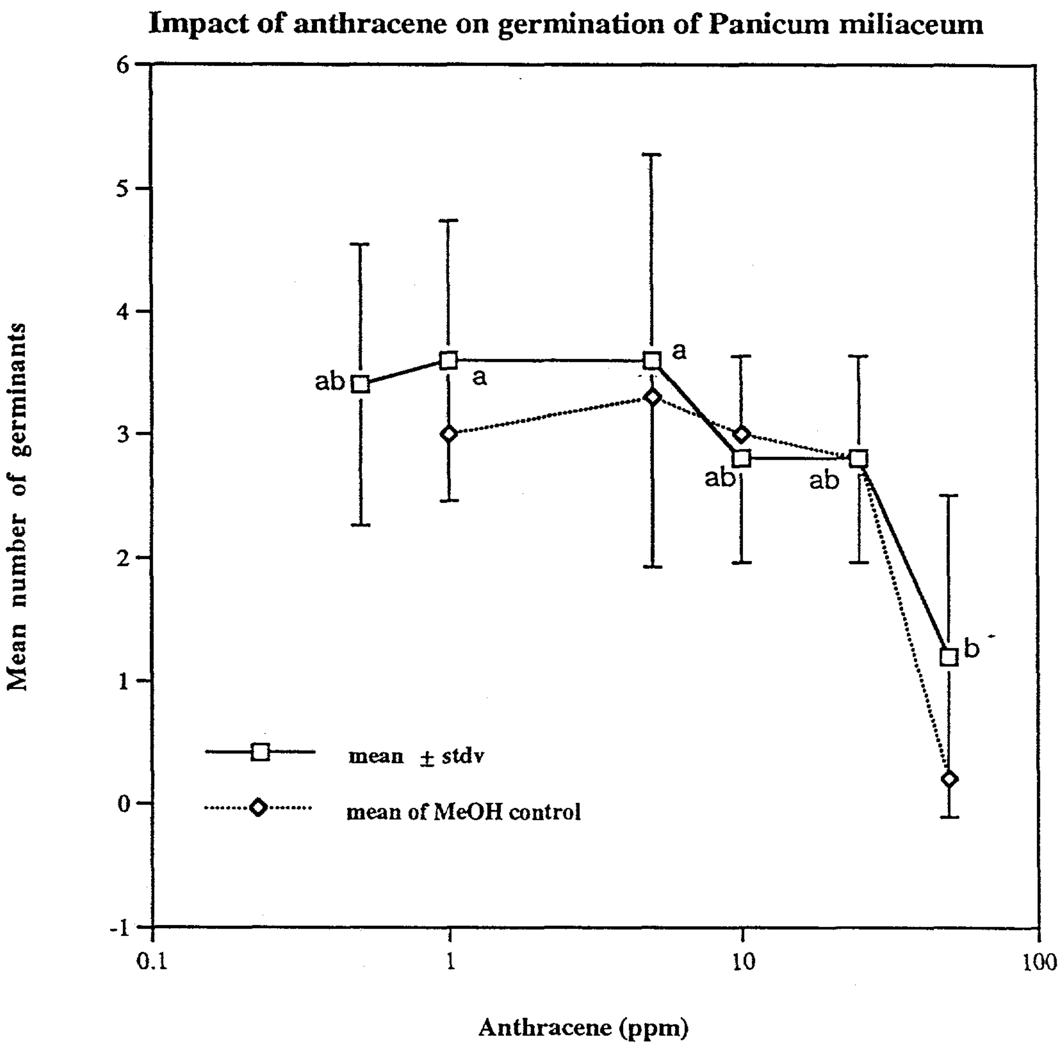
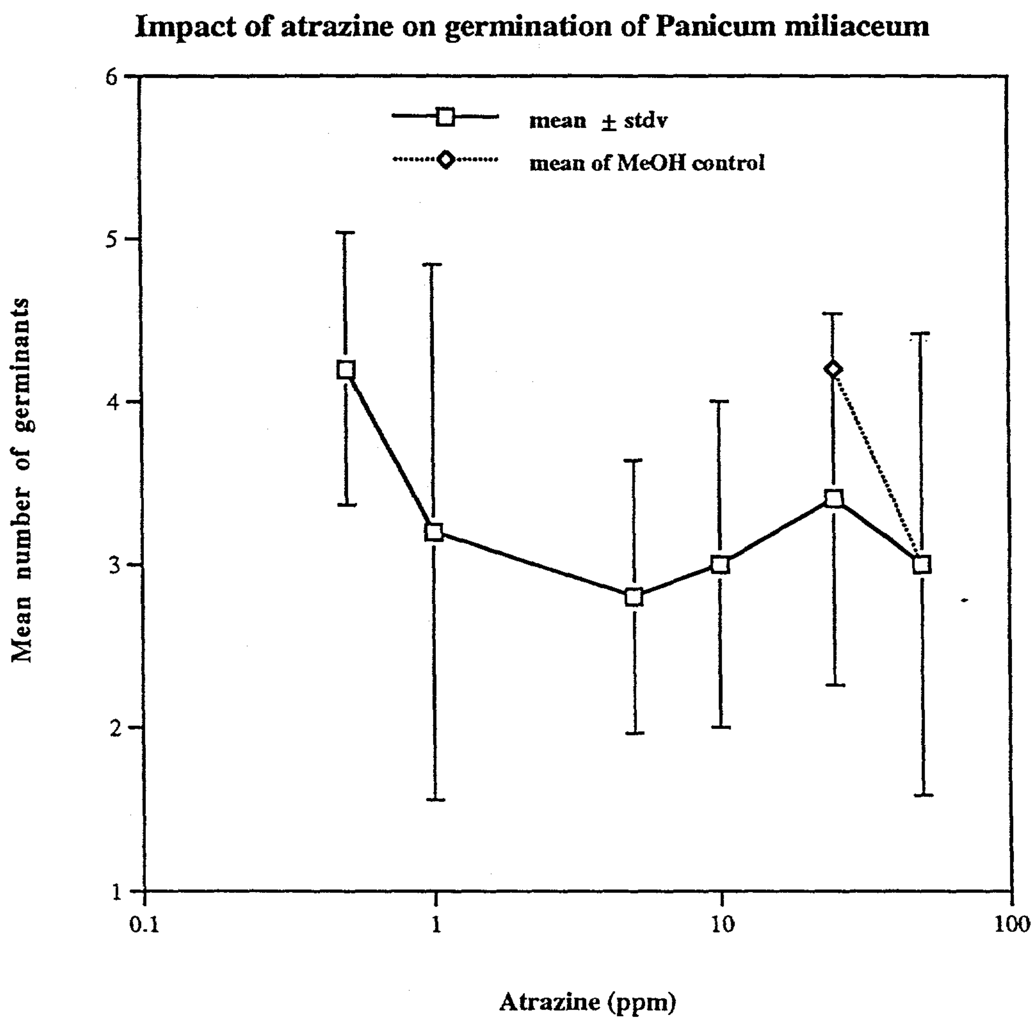
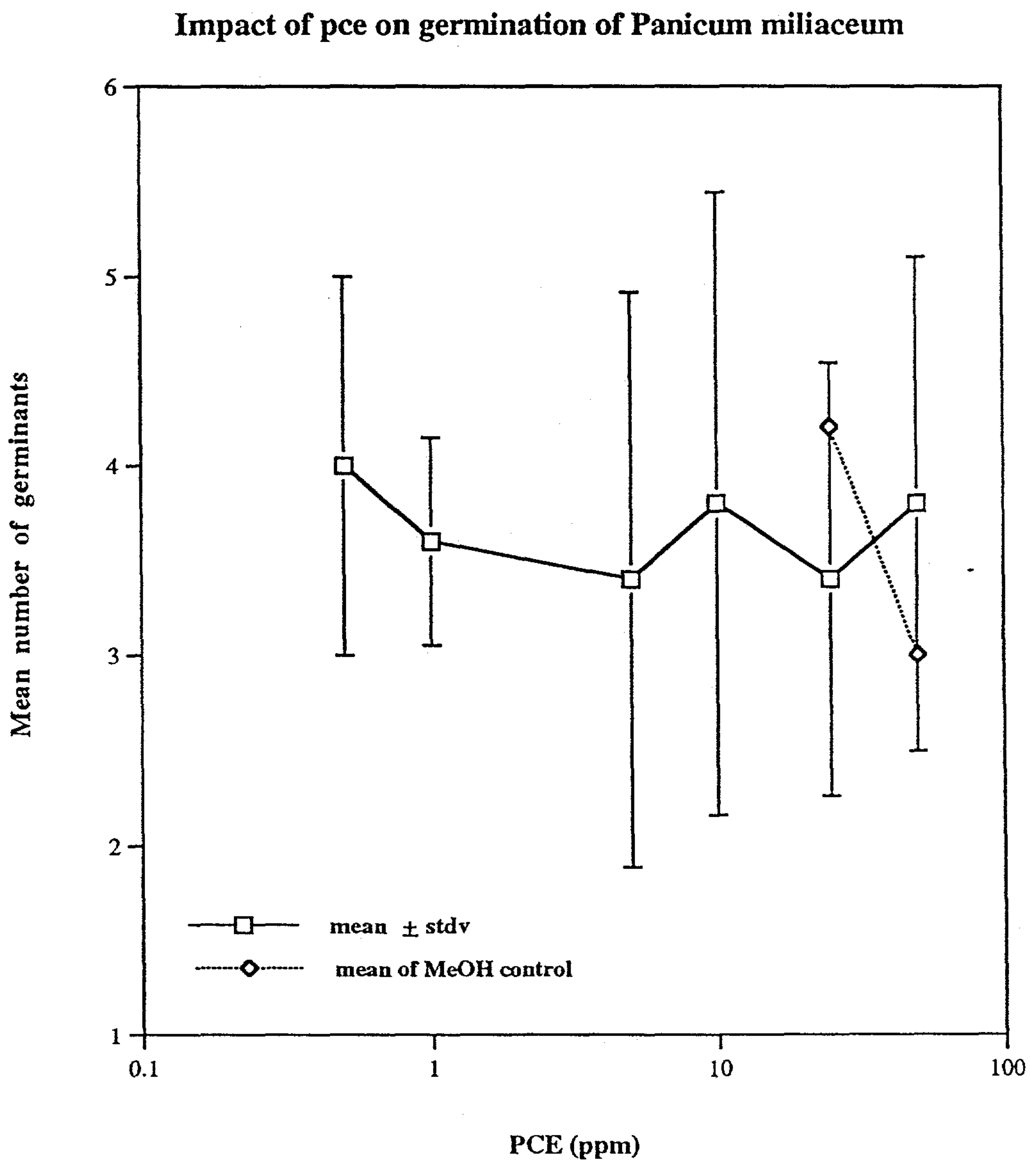

Impact of anthracene on germination of Panicum miliaceum
Mean number of germinants
Anthracene (ppm)
6
5
4
3
2
1
0
-1
0.1
1
10
100
ab
a
a
ab
ab
b
mean ± stdv
mean of MeOH control

Figure 9.



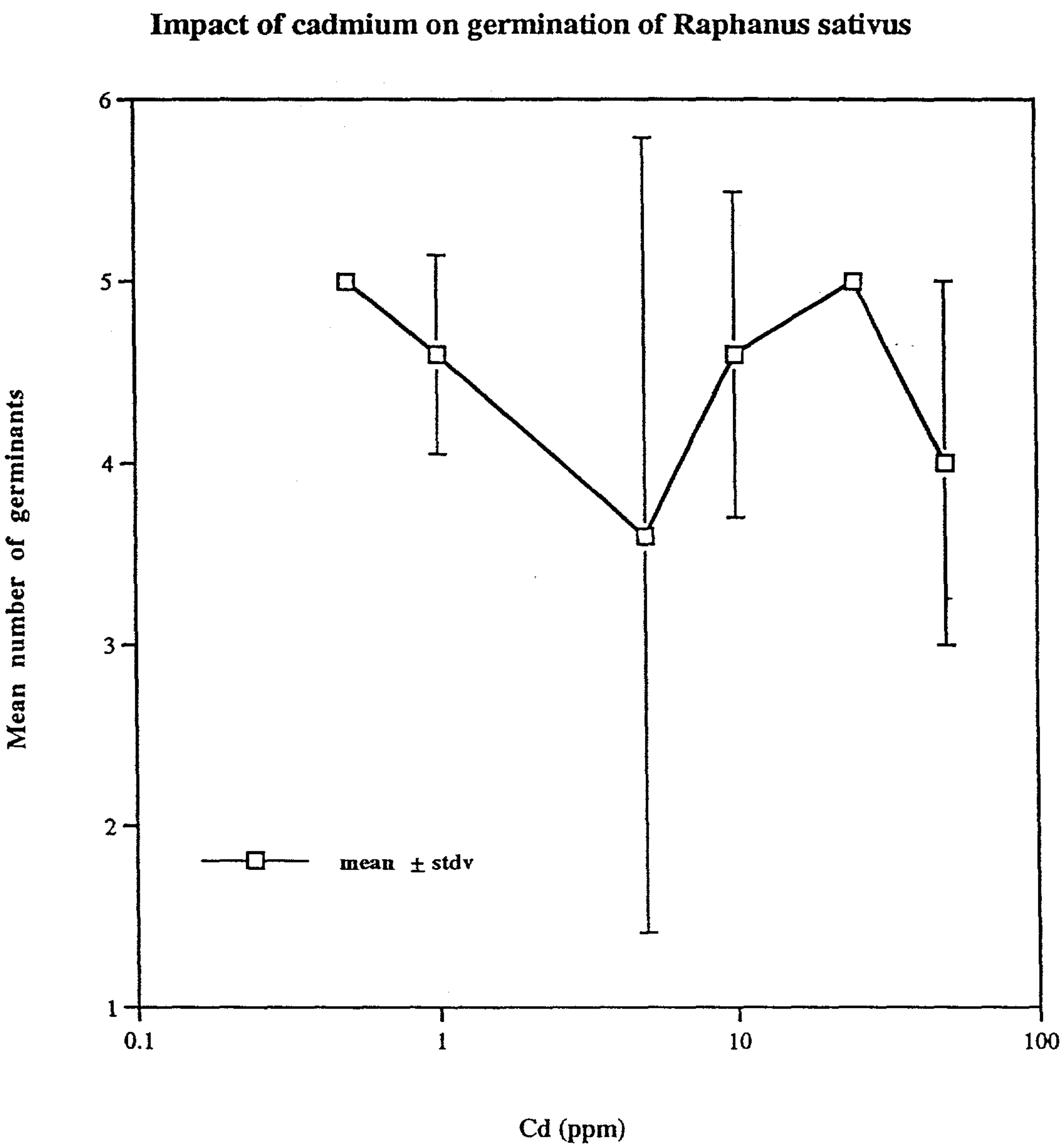
Impact of atrazine on germination of Panicum miliaceum
mean ± stdv
mean of MeOH control
Mean number of germinants
Atrazine (ppm)
6
5
4
3
2
1
0.1
1
10
100

Figure 10.



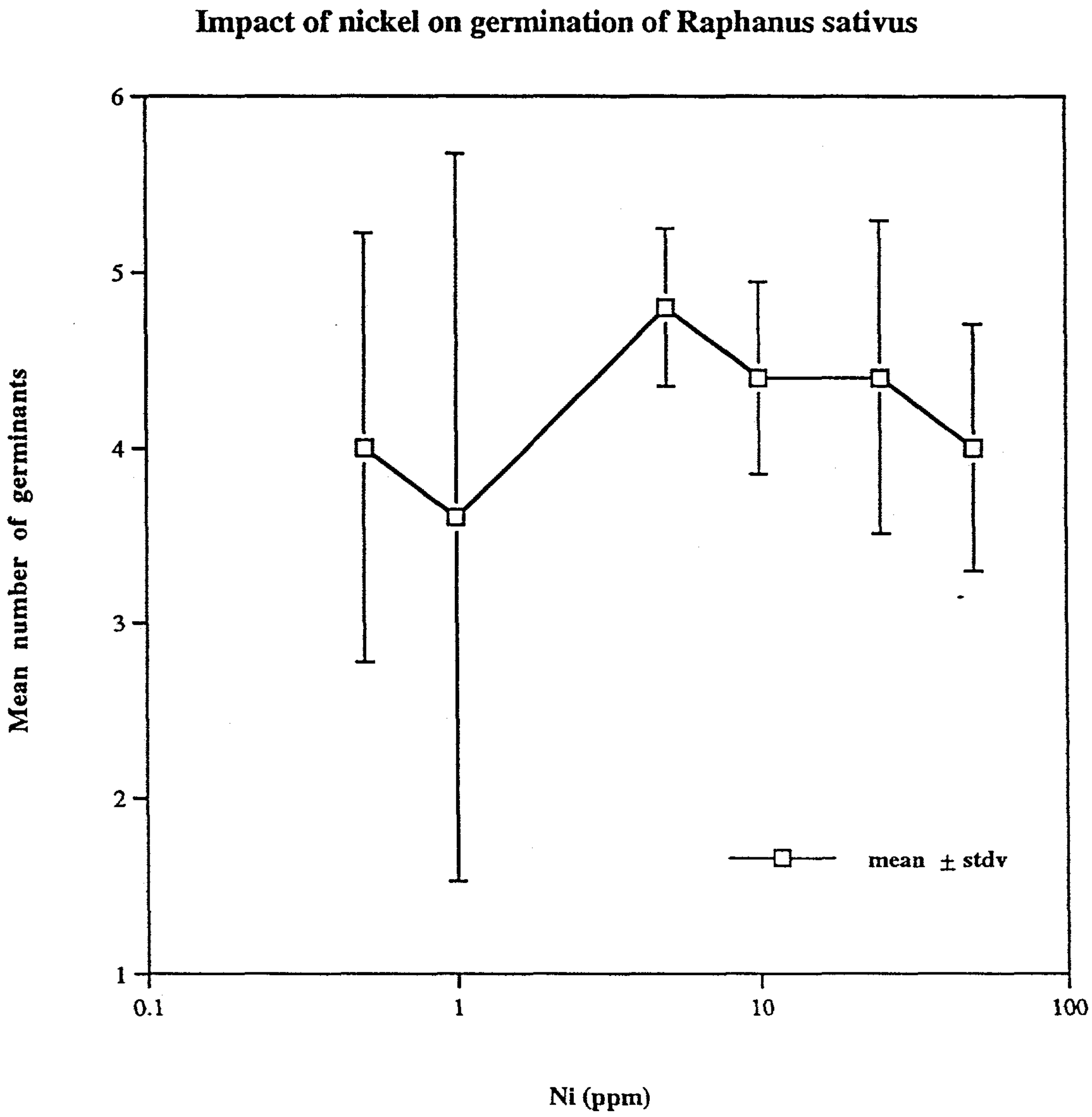
Impact of pce on germination of Panicum miliaceum
Mean number of germinants
PCE (ppm)
mean ± stdv
mean of MeOH control
1
2
3
4
5
6
0.1
1
10
100

Figure 11.



Impact of cadmium on germination of Raphanus sativus
Mean number of germinants
6
5
4
3
2
1
0.1
1
10
100
Cd (ppm)
mean ± stdv

Figure 12.



Impact of nickel on germination of Raphanus sativus
Mean number of germinants
6
5
4
3
2
1
0.1
1
10
100
Ni (ppm)
mean ± stdv

Figure 13.

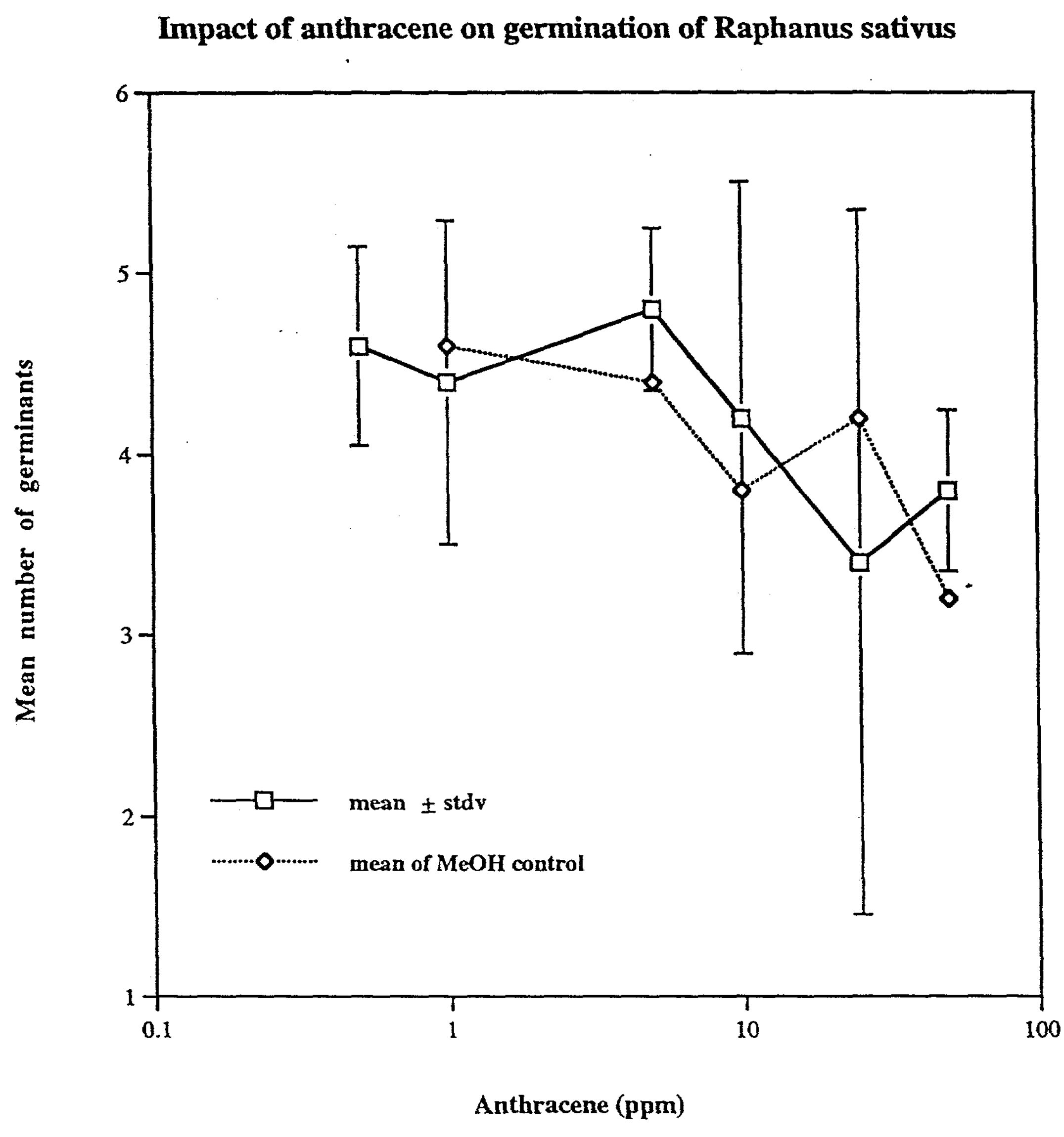
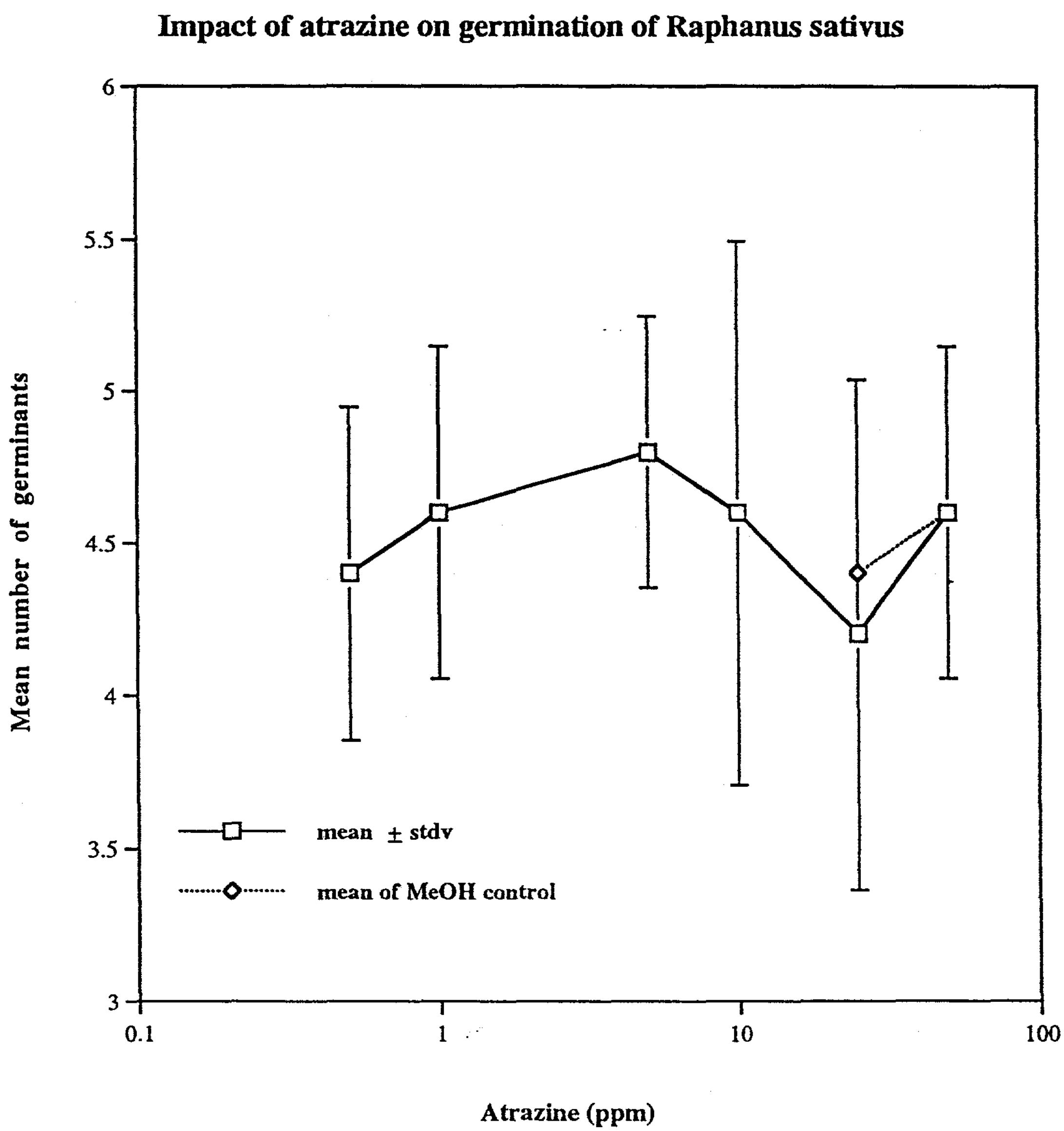

Impact of anthracene on germination of Raphanus sativus
Mean number of germinants
Anthracene (ppm)
mean ± stdv
mean of MeOH control
1
2
3
4
5
6
0.1
1
10
100

Figure 14.



Impact of atrazine on germination of Raphanus sativus
6
5.5
5
4.5
4
3.5
3
0.1
1
10
100
Mean number of germinants
Atrazine (ppm)
mean ± stdv
mean of MeOH control

Figure 15.

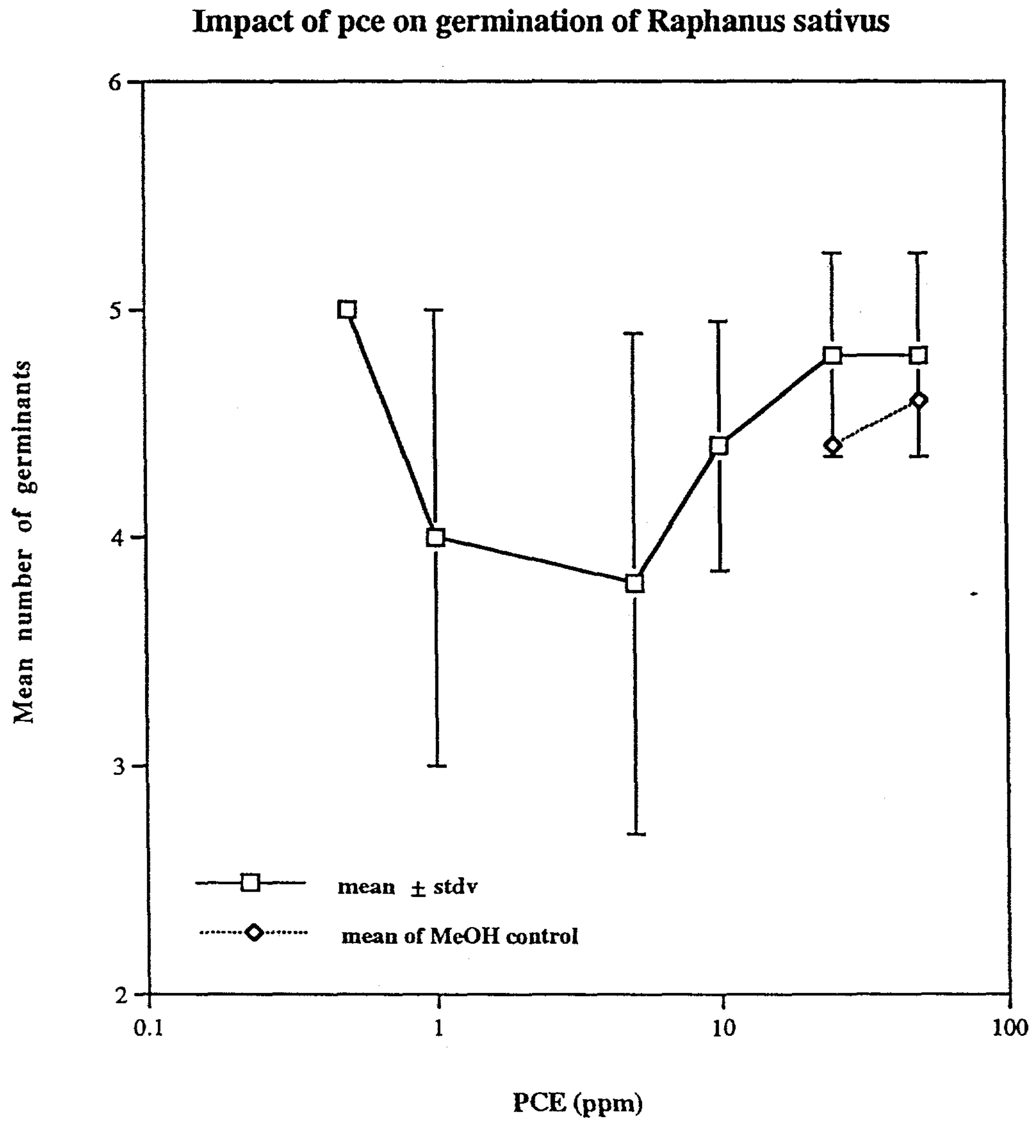

Impact of pce on germination of Raphanus sativus
Mean number of germinants
6
5
4
3
2
0.1
1
10
100
PCE (ppm)
mean ± stdv
mean of MeOH control

Figure 16.

Impact of cadmium on germination of Saururus cernuus

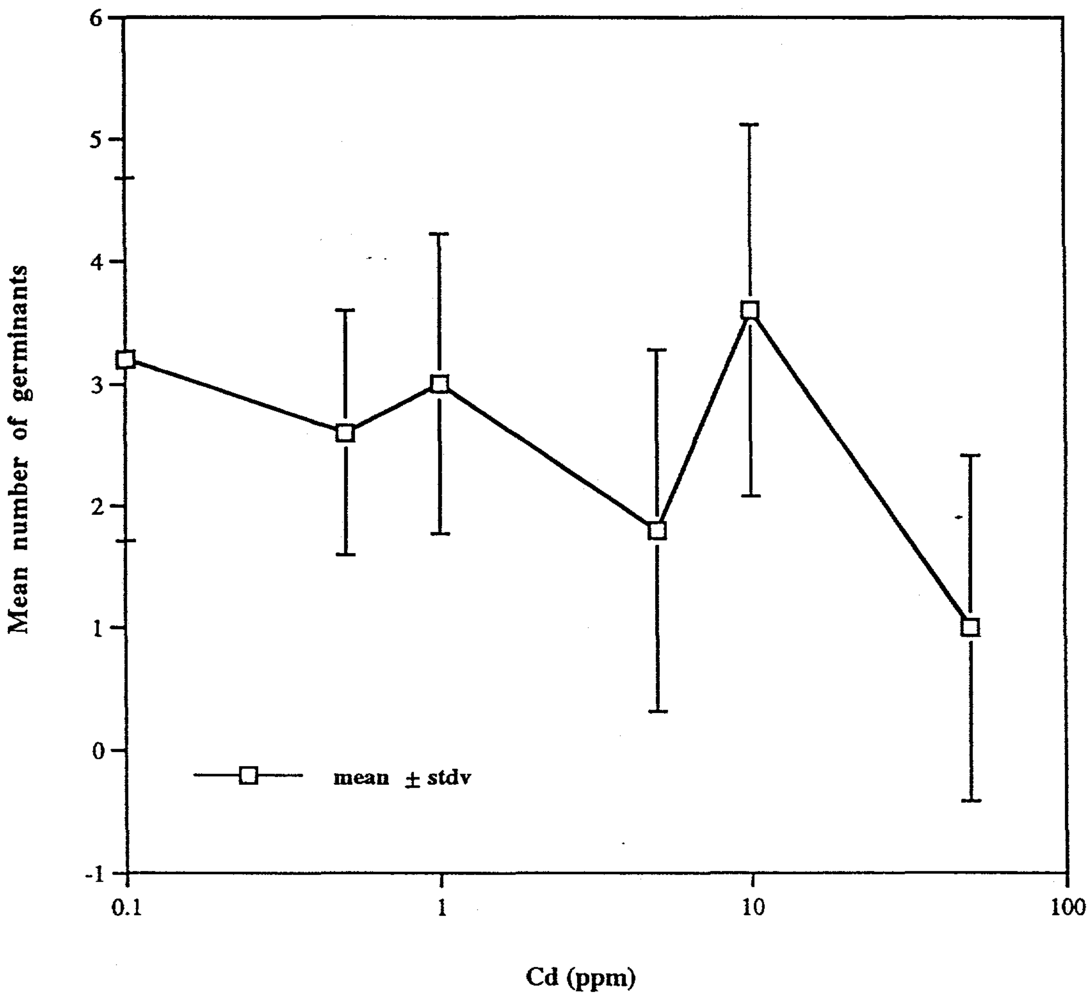


Figure 17.

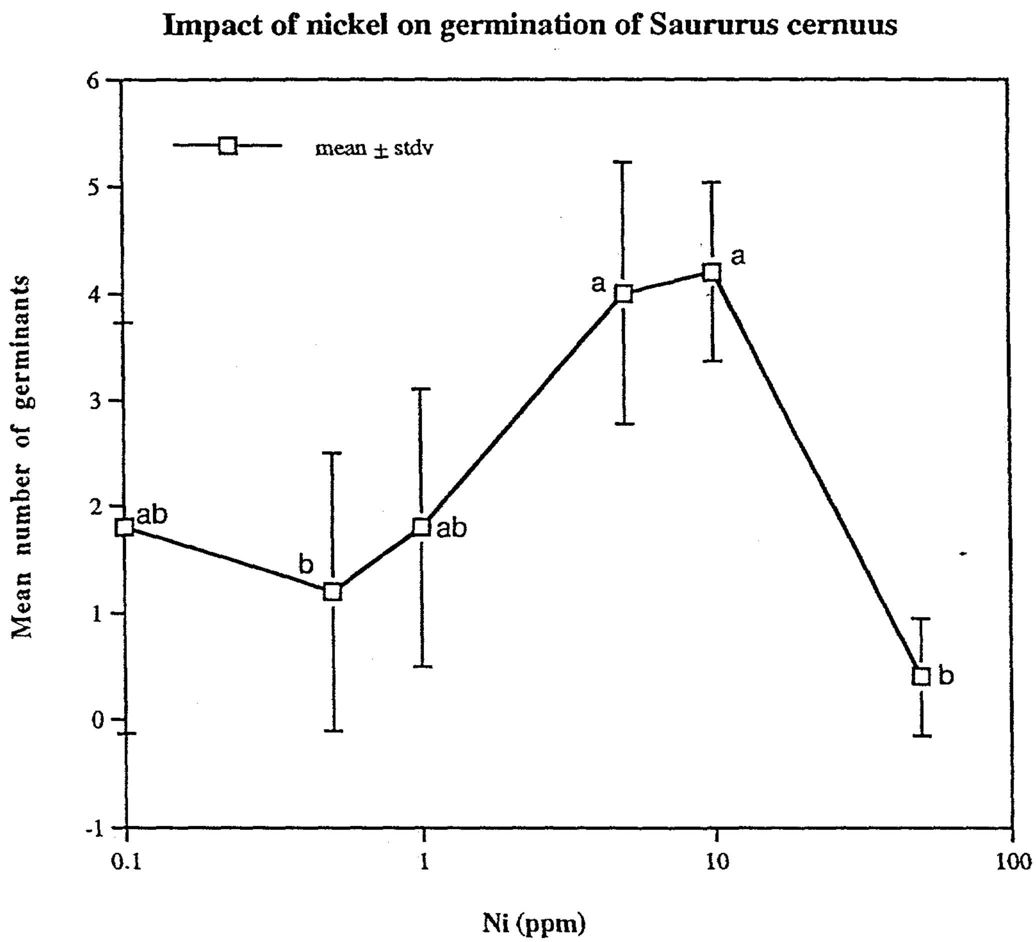

Impact of nickel on germination of Saururus cernuus
mean ± stdv
Mean number of germinants
Ni (ppm)
0.1
1
10
100
-1
0
1
2
3
4
5
6
ab
b
ab
a
a
b

Figure 18.

Impact of anthracene on germination of Saururus cernuus

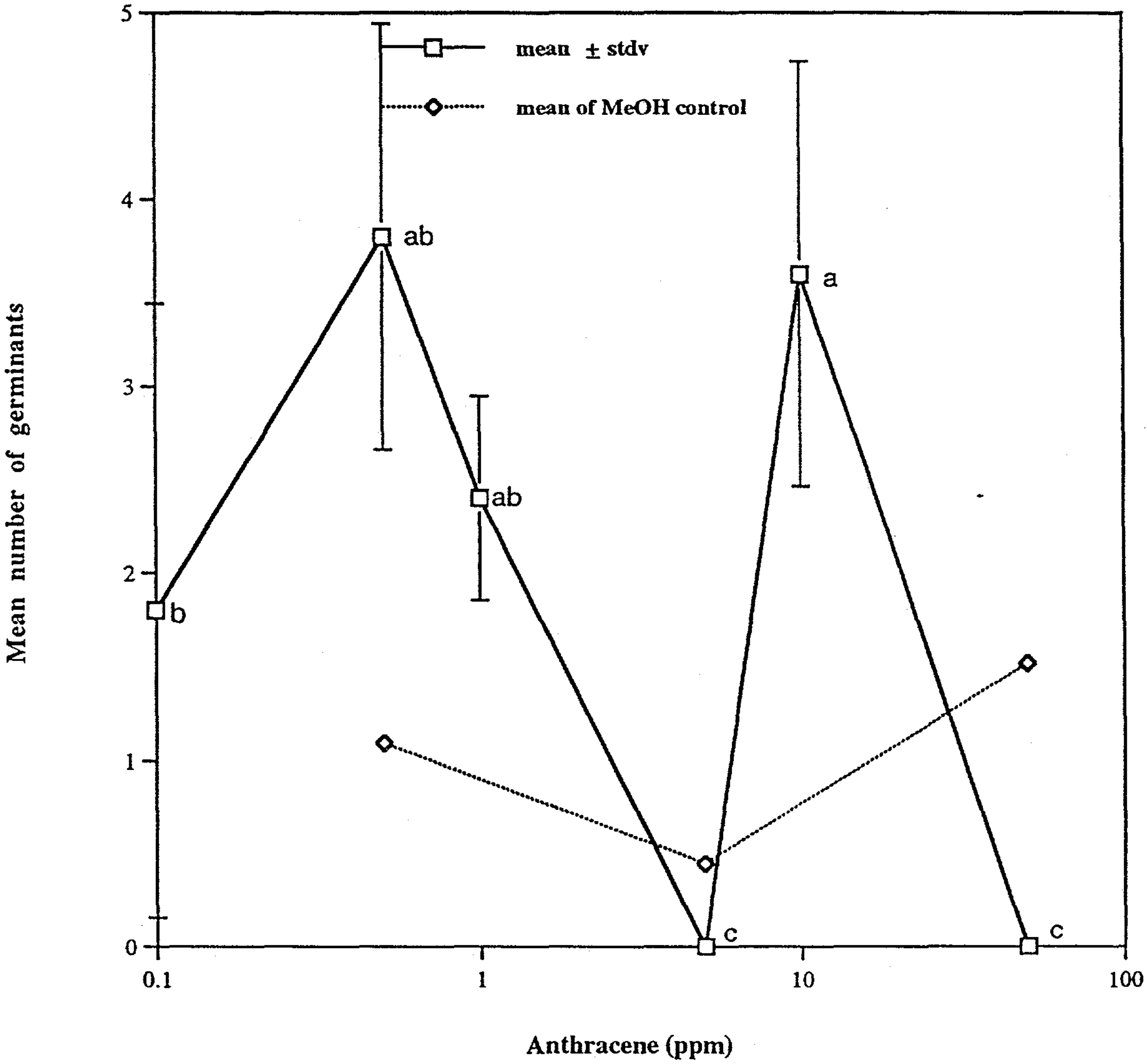


Figure 19.

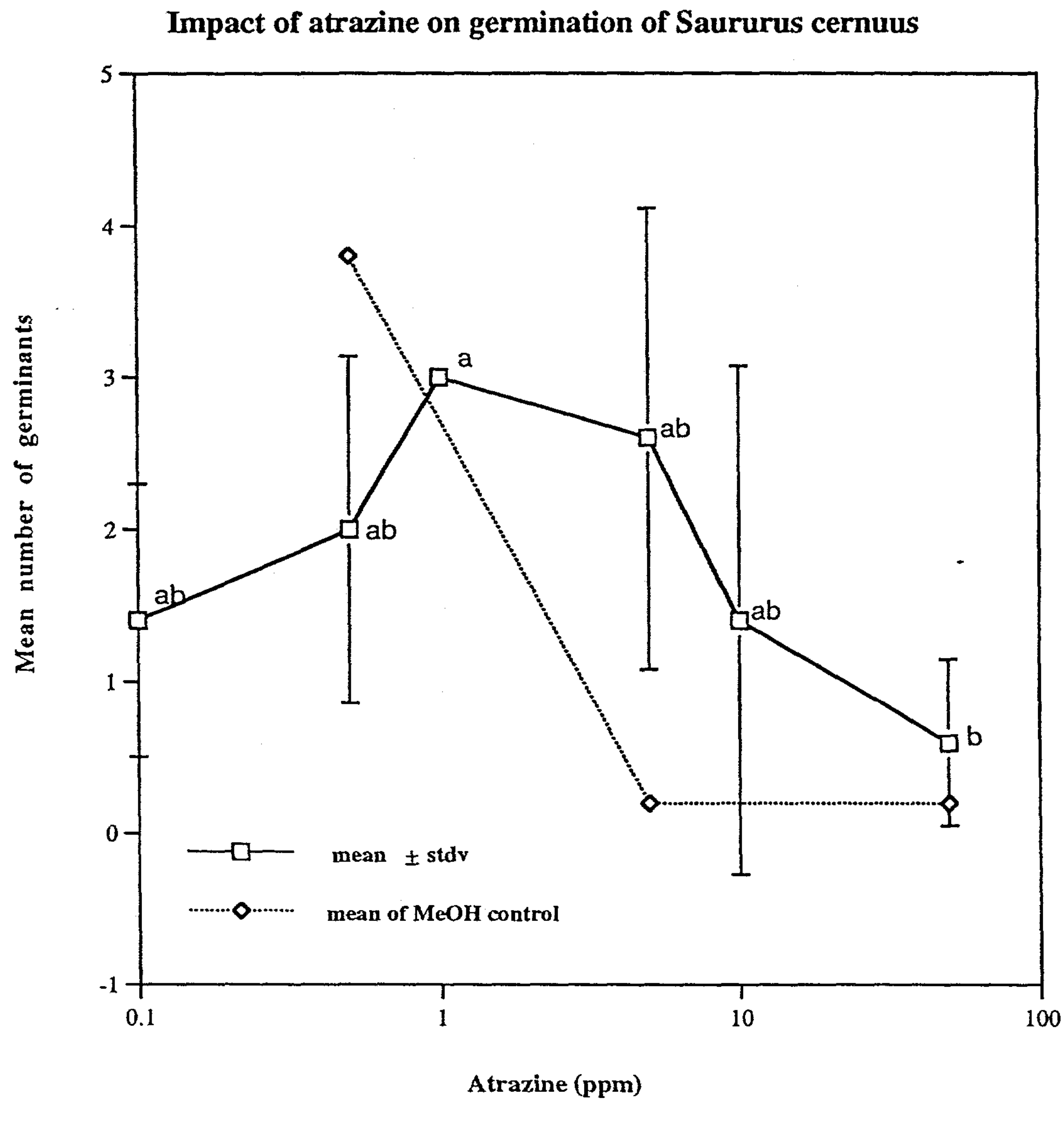
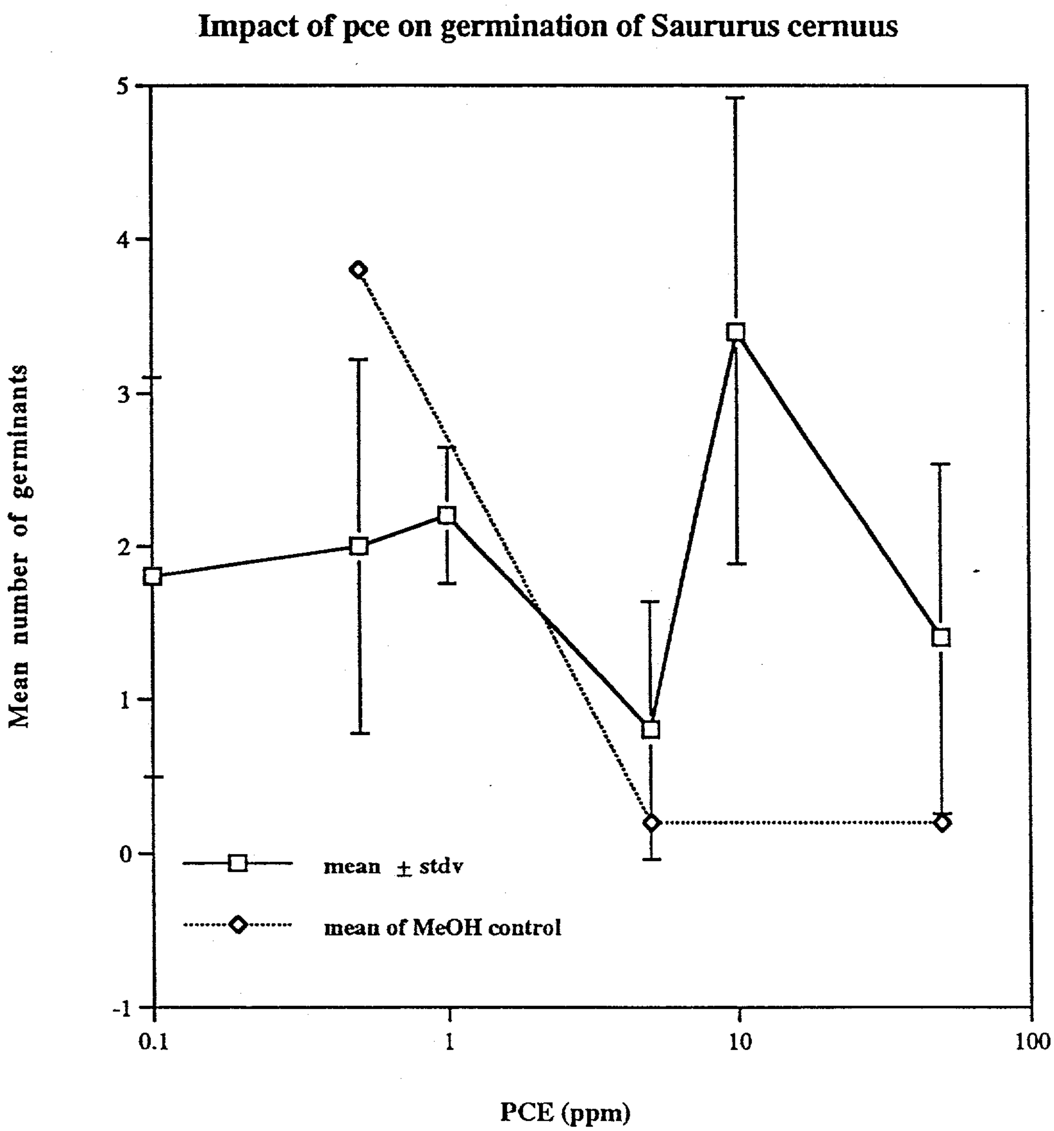

Impact of atrazine on germination of Saururus cernuus
Mean number of germinants
Atrazine (ppm)
5
4
3
2
1
0
-1
0.1
1
10
100
a
ab
ab
ab
ab
b
mean ± stdv
mean of MeOH control

Figure 20.



Impact of pce on germination of Saururus cernuus
Mean number of germinants
PCE (ppm)
mean ± stdv
mean of MeOH control
5
4
3
2
1
0
-1
0.1
1
10
100

Figure 21.

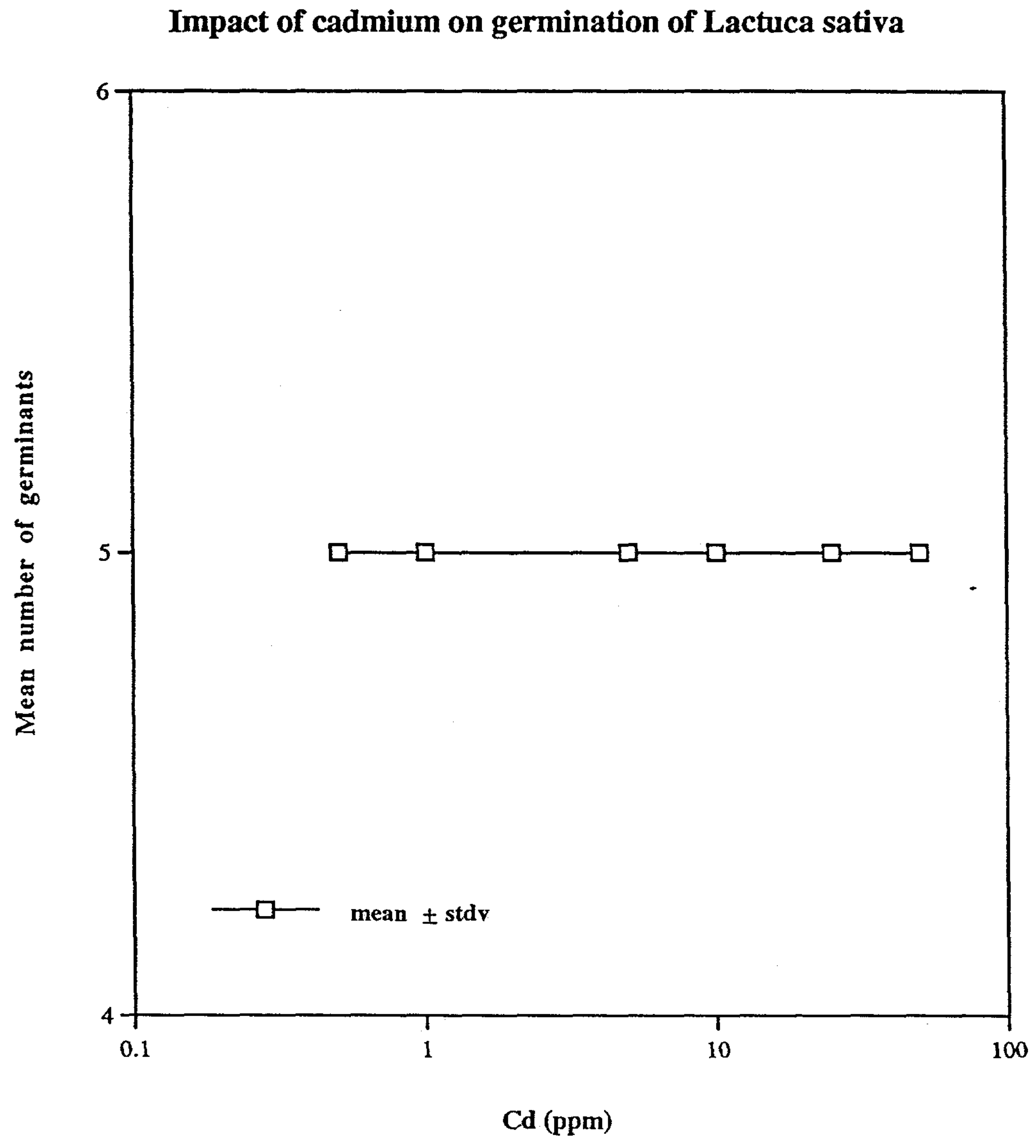
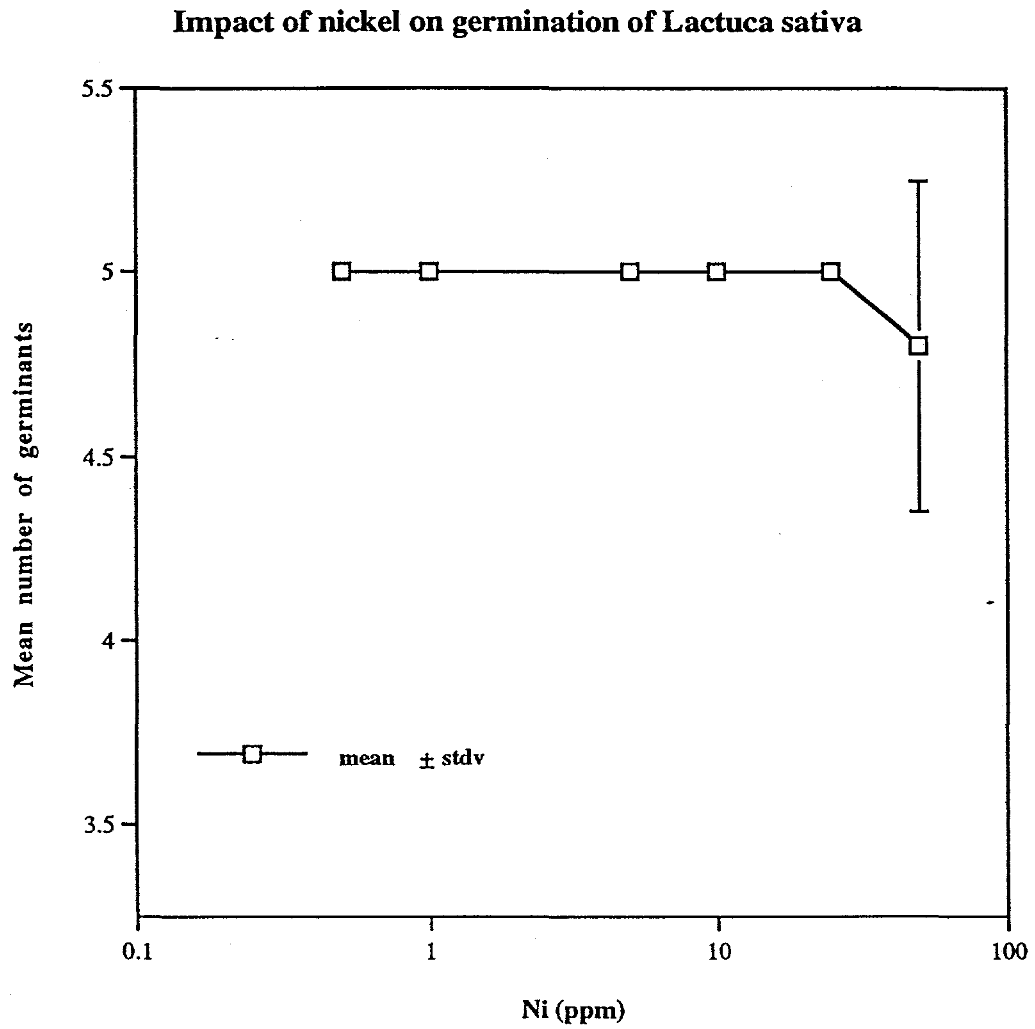

Impact of cadmium on germination of Lactuca sativa
Mean number of germinants
6
5
4
0.1
1
10
100
Cd (ppm)
mean ± stdv

Figure 22.



Impact of nickel on germination of Lactuca sativa
5.5
5
4.5
4
3.5
Mean number of germinants
mean ± stdv
0.1
1
10
100
Ni (ppm)

Figure 23.

Impact of anthracene on germination of Lactuca sativa

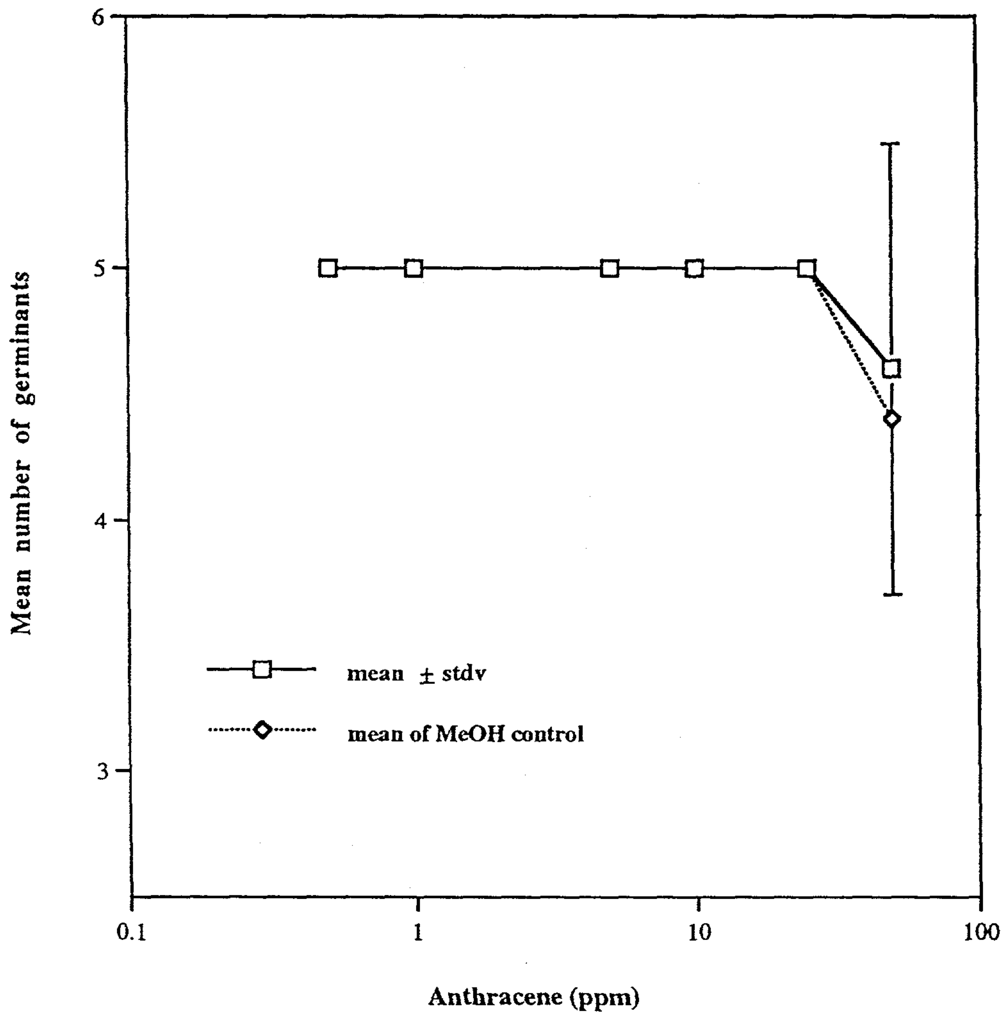


Figure 24.

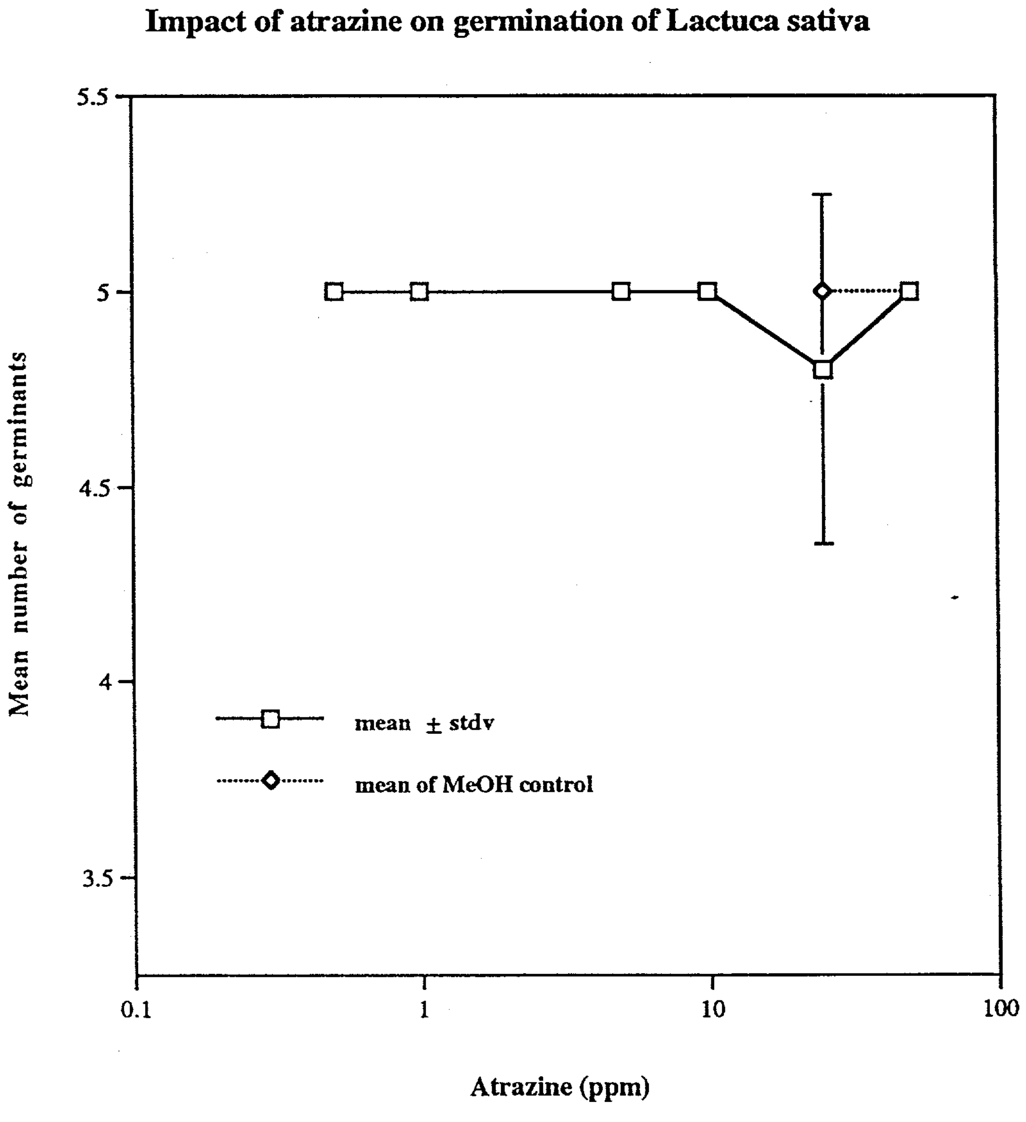
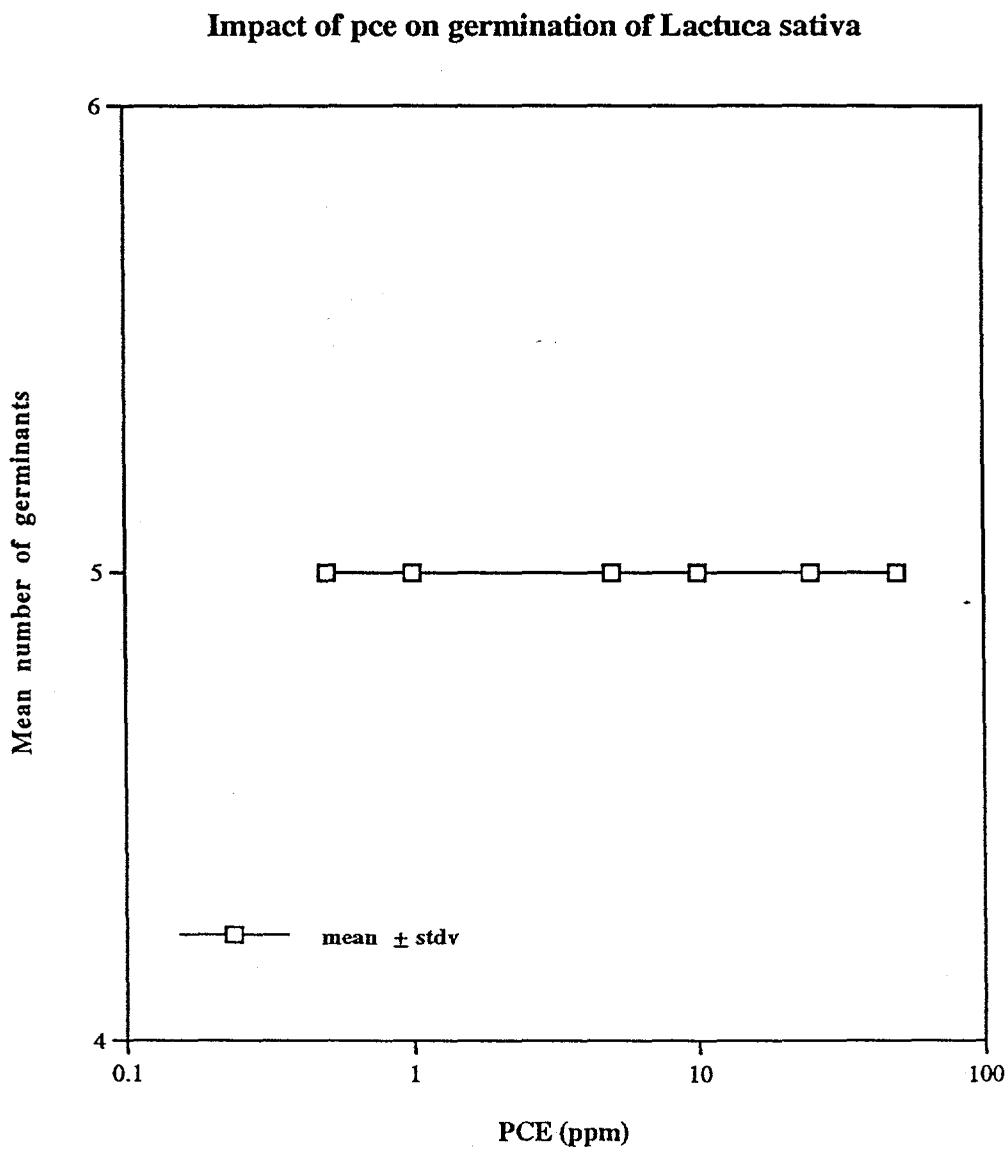

Impact of atrazine on germination of Lactuca sativa
5.5
5
4.5
4
3.5
Mean number of germinants
mean ± stdv
mean of MeOH control
0.1
1
10
100
Atrazine (ppm)

Figure 25.



Impact of pce on germination of Lactuca sativa
6
5
4
Mean number of germinants
0.1
1
10
100
PCE (ppm)
mean ± stdv

Figure 26.

Impact of cadmium on germination of Quercus falcata

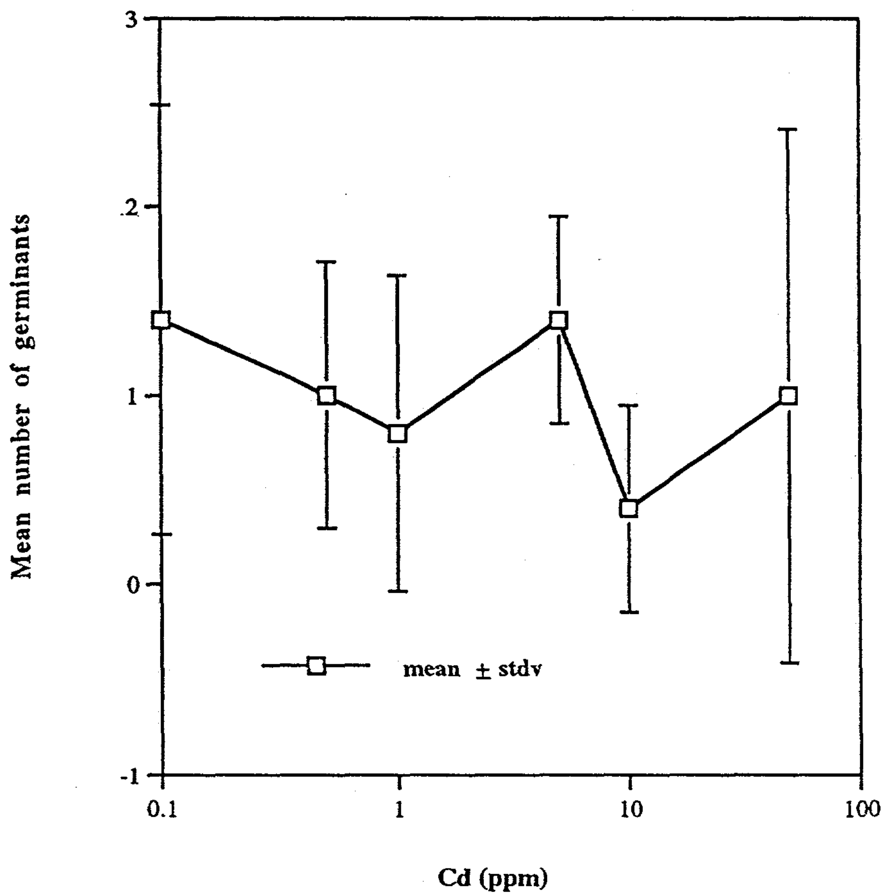
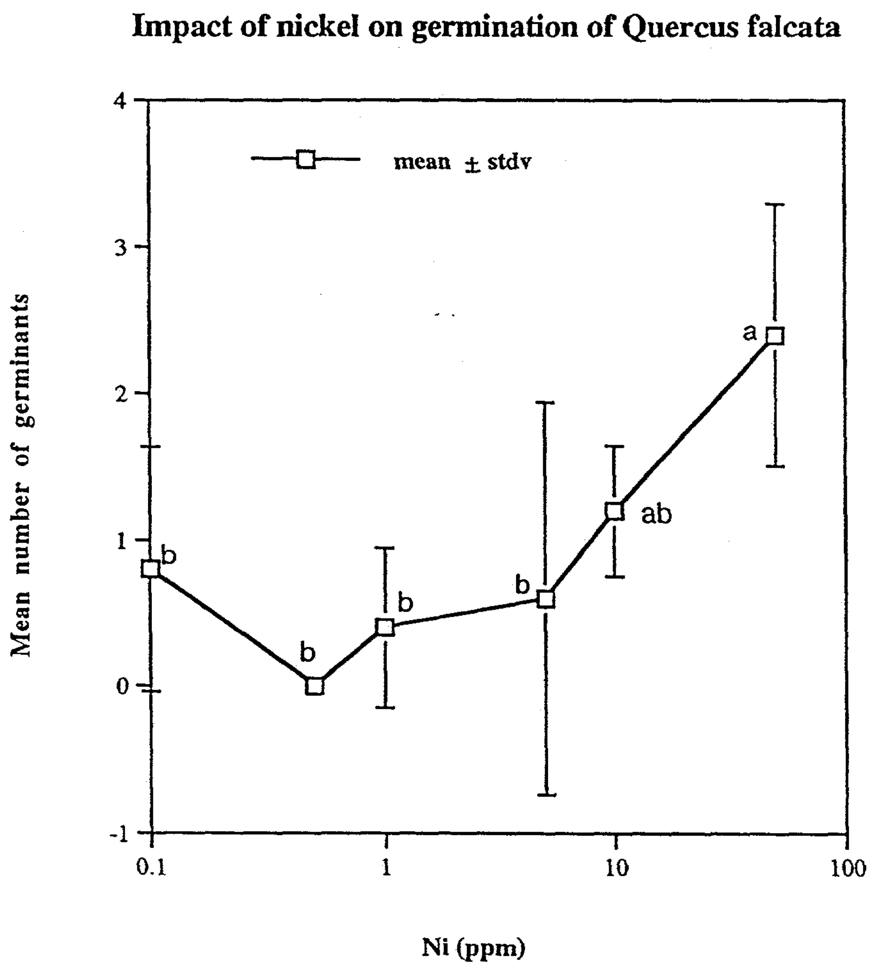


Figure 27.



Impact of nickel on germination of Quercus falcata
mean ± stdv
Mean number of germinants
Ni (ppm)
4
3
2
1
0
-1
0.1
1
10
100
a
ab
b
b
b
b
b

Figure 28.

Impact of anthracene germination of Quercus falcata

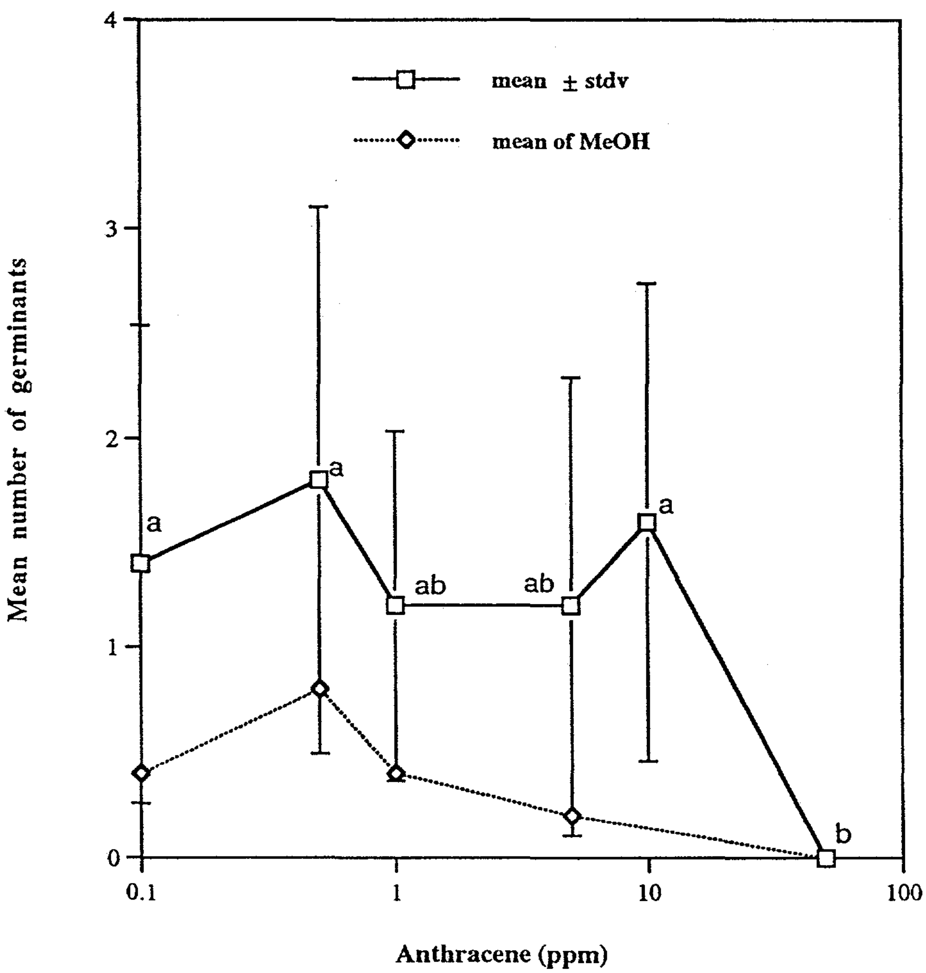


Figure 29.

Impact of atrazine on germination of Quercus falcata

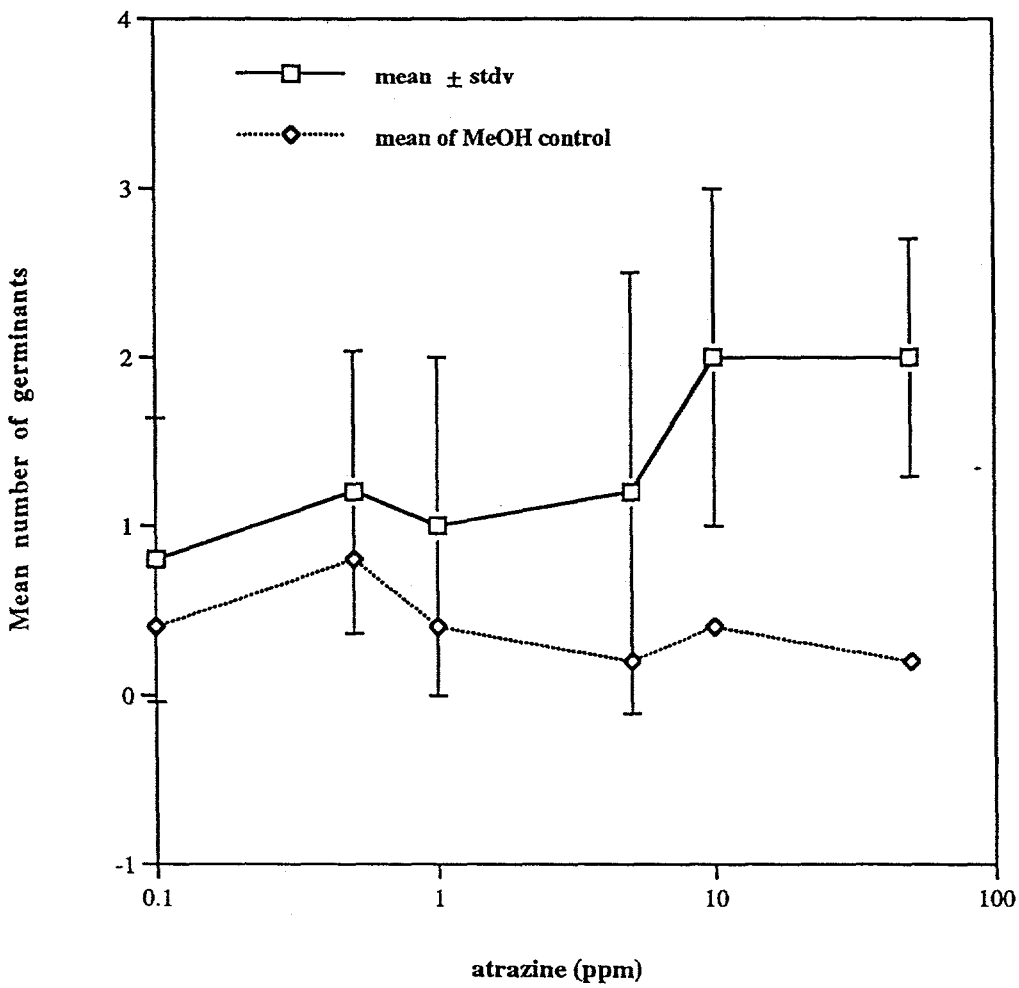
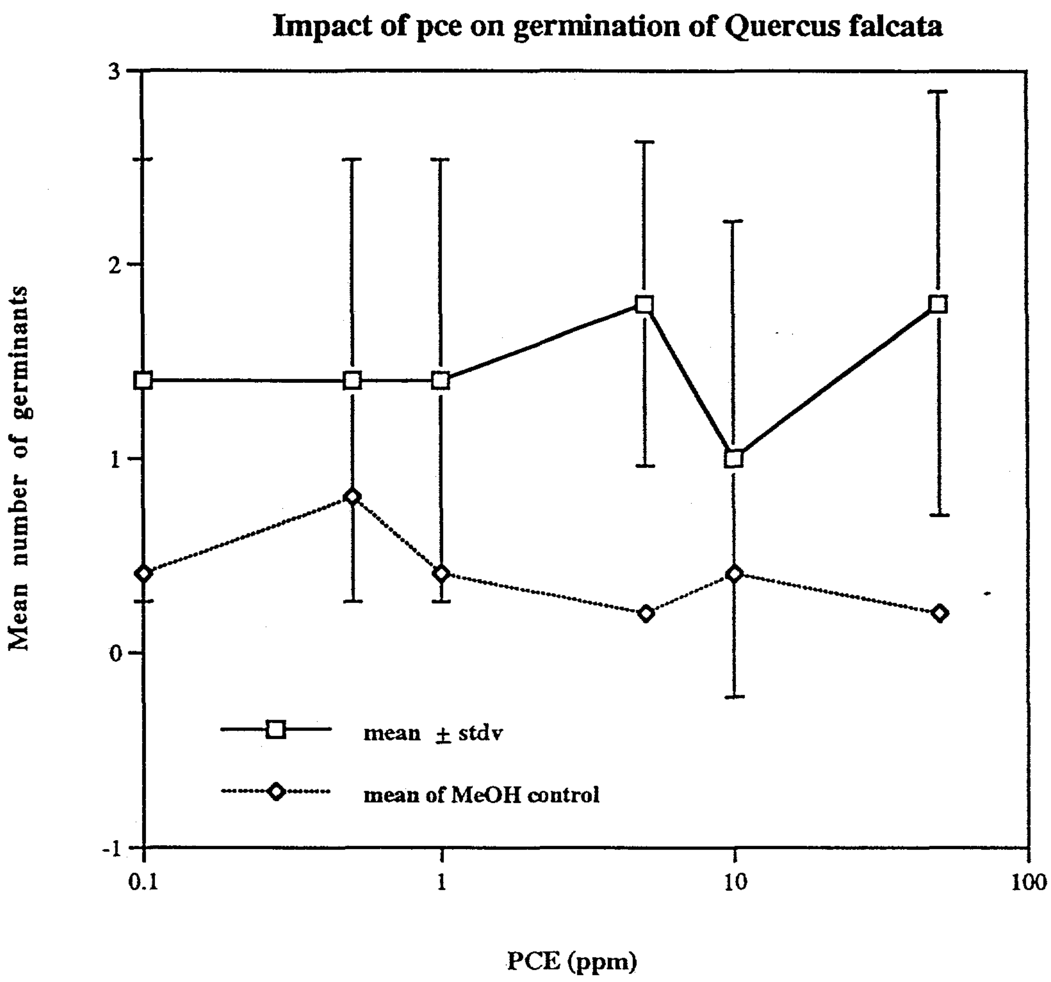
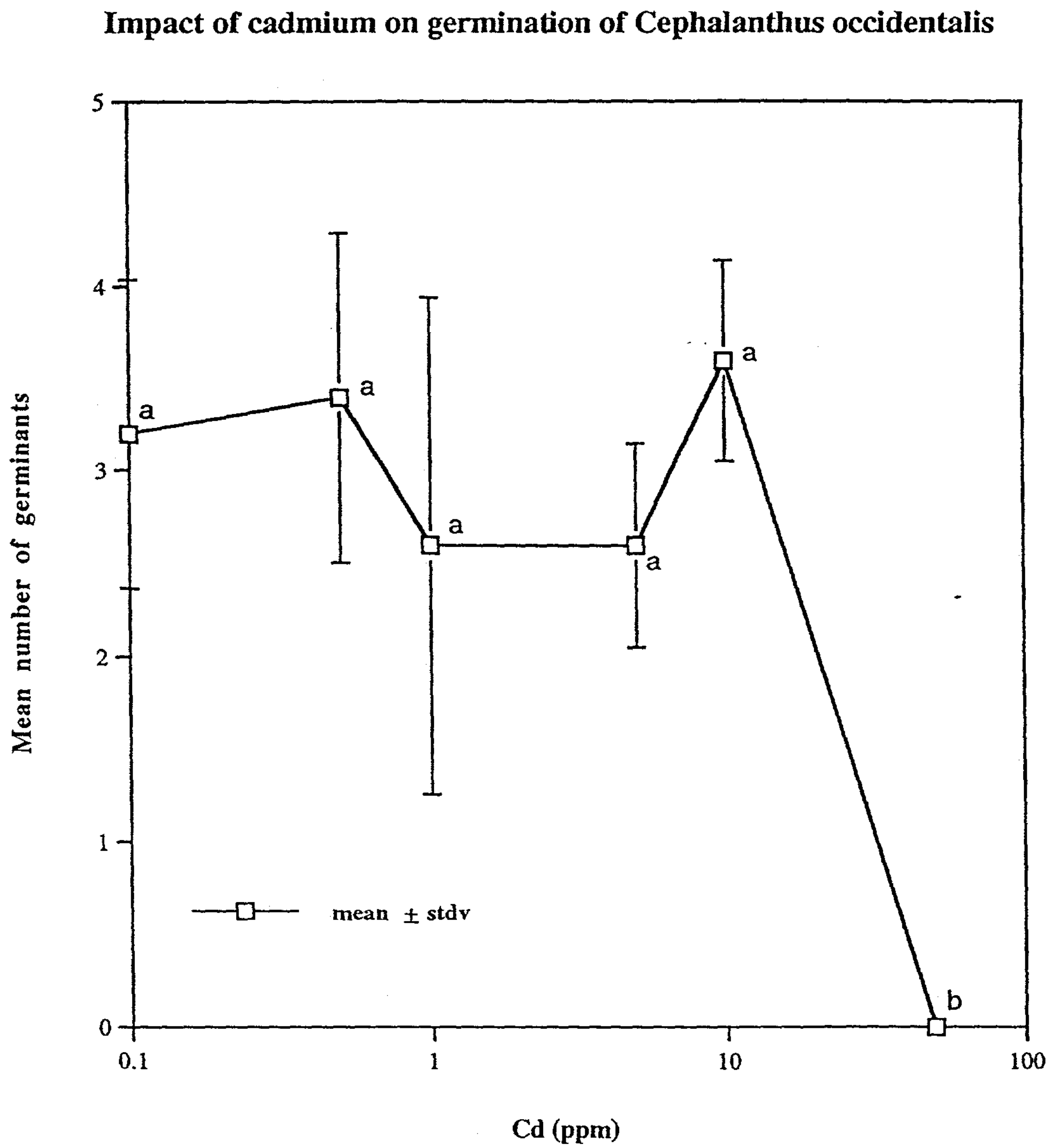


Figure 30.



Impact of pce on germination of Quercus falcata
3
2
1
0
-1
0.1
1
10
100
Mean number of germinants
PCE (ppm)
mean ± stdv
mean of MeOH control

Figure 31.



Impact of cadmium on germination of Cephalanthus occidentalis
Mean number of germinants
Cd (ppm)
mean ± stdv
a
a
a
a
a
b
0
1
2
3
4
5
0.1
1
10
100

Figure 32.

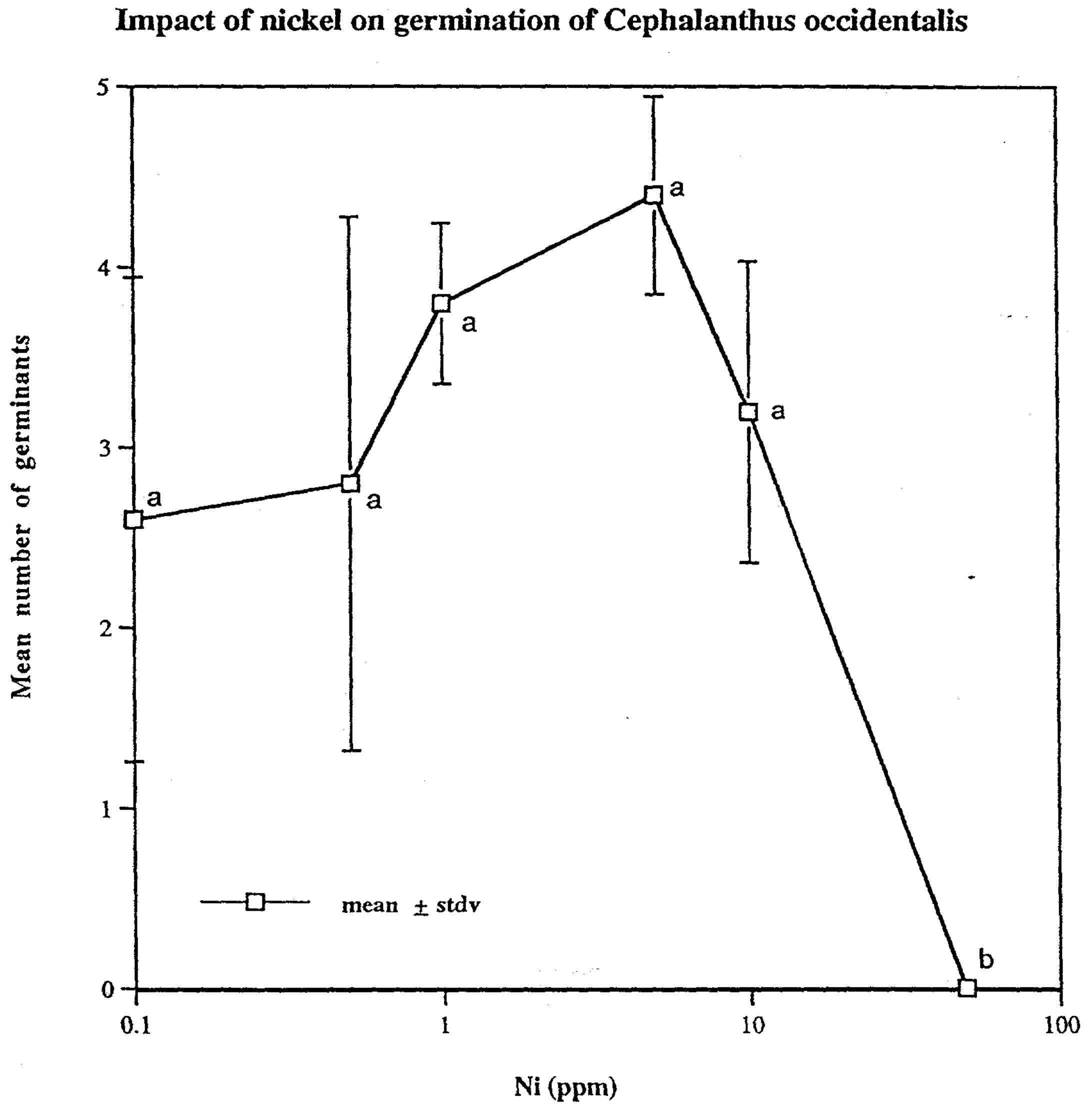
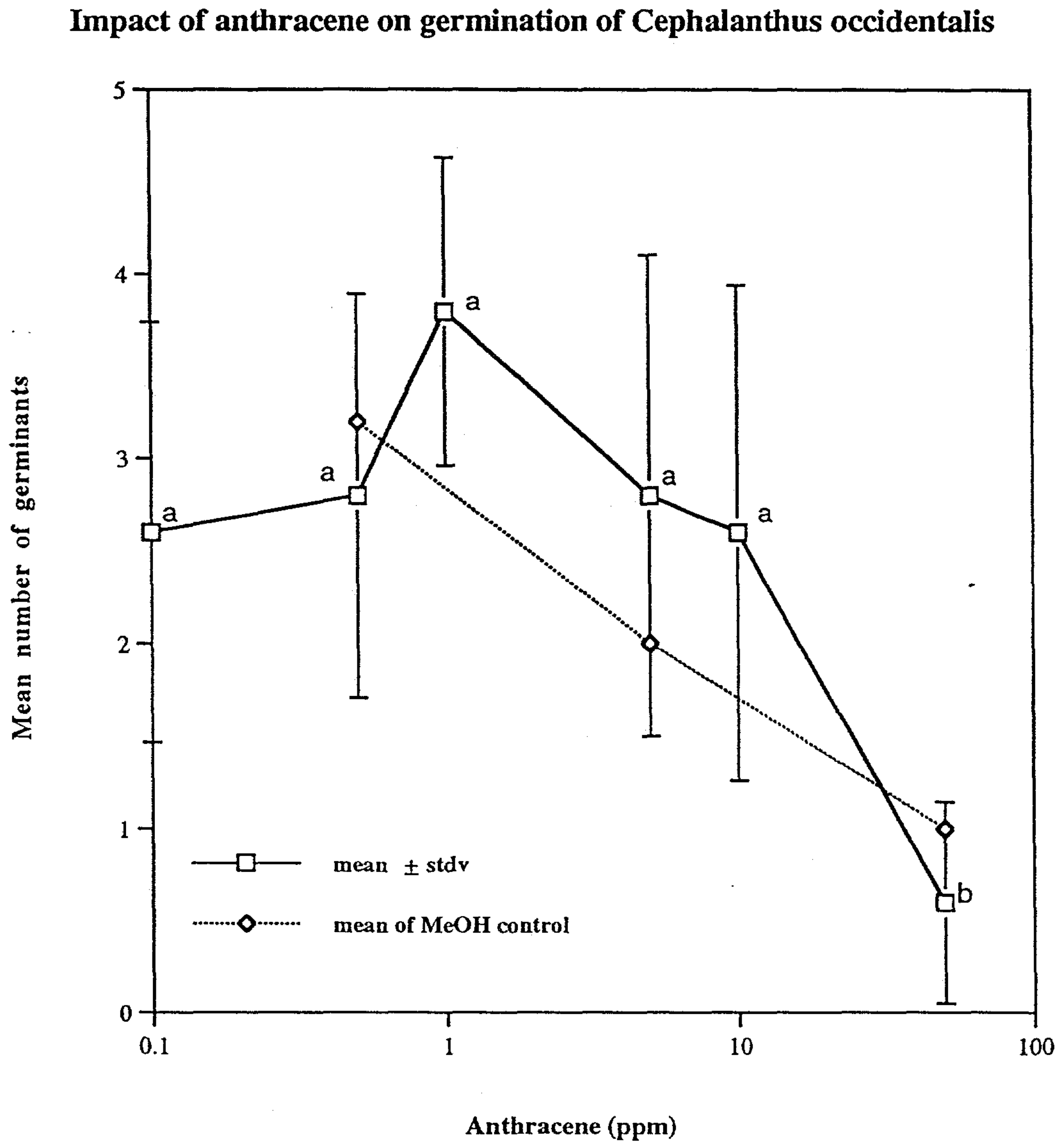

Impact of nickel on germination of Cephalanthus occidentalis
Mean number of germinants
Ni (ppm)
0
1
2
3
4
5
0.1
1
10
100
a
a
a
a
a
b
mean ± stdv

Figure 33.



Impact of anthracene on germination of Cephalanthus occidentalis
Mean number of germinants
Anthracene (ppm)
0
1
2
3
4
5
0.1
1
10
100
a
a
a
a
a
b
mean ± stdv
mean of MeOH control

Figure 34.

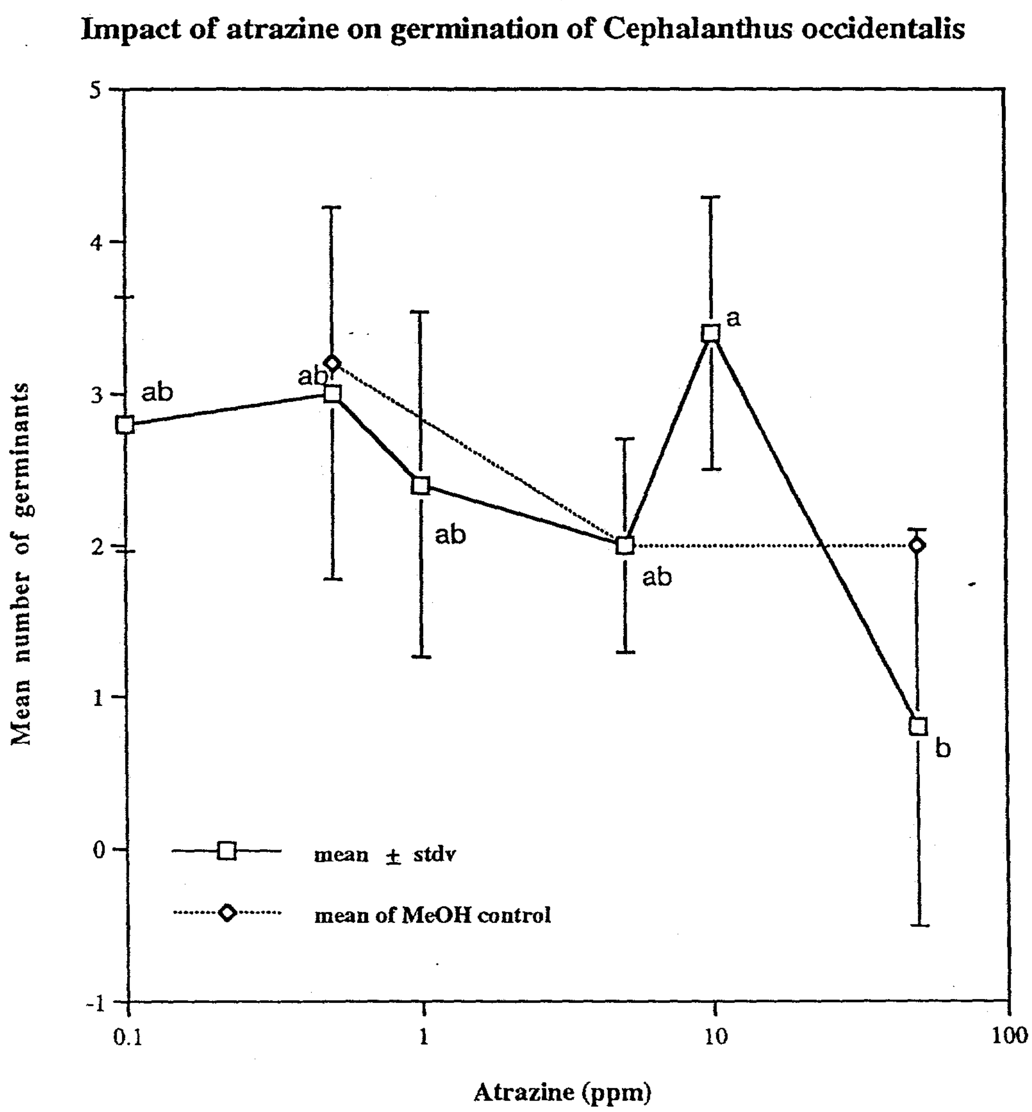
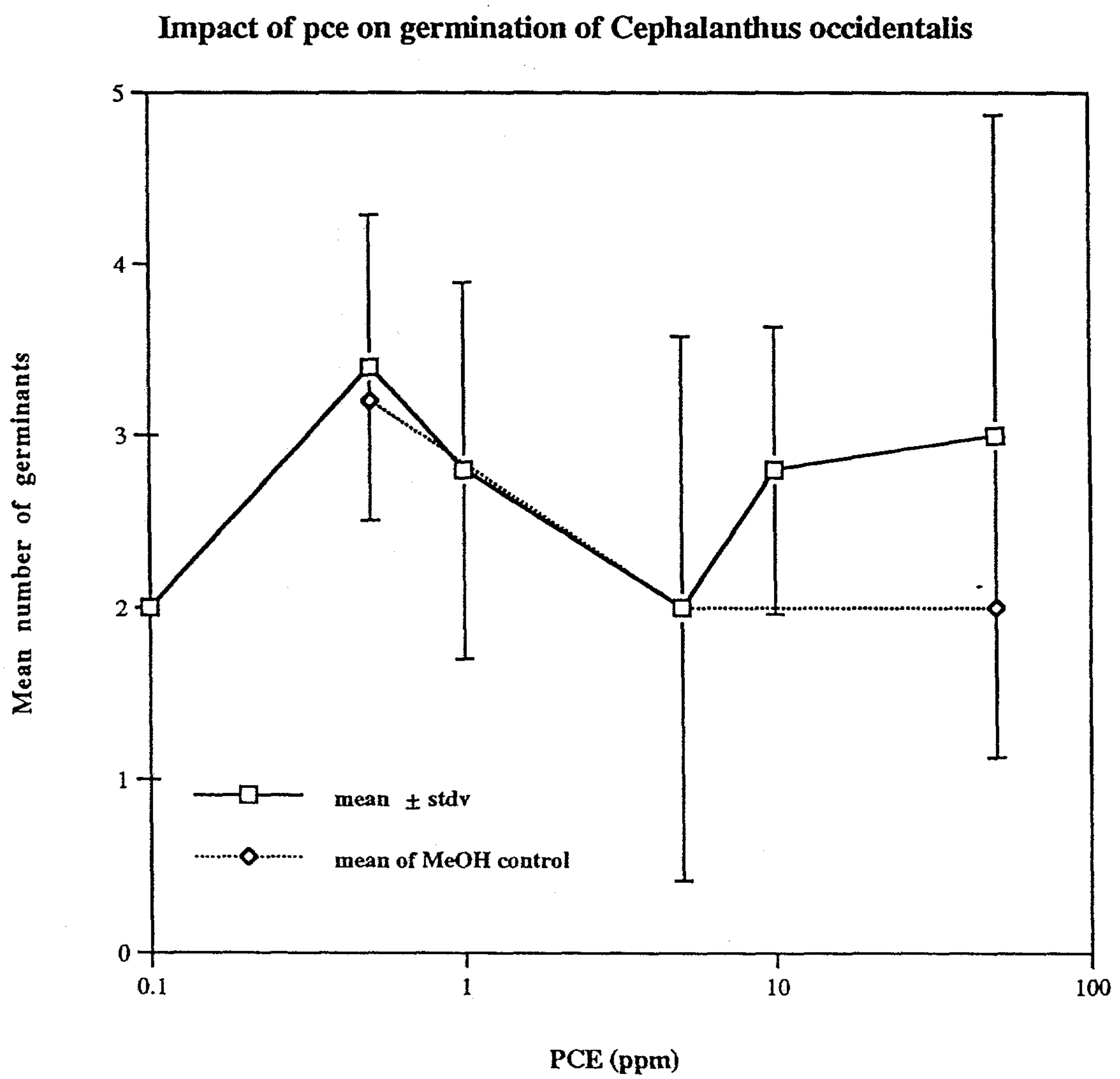

Impact of atrazine on germination of Cephalanthus occidentalis
Mean number of germinants
Atrazine (ppm)
5
4
3
2
1
0
-1
0.1
1
10
100
ab
ab
ab
ab
a
b
mean ± stdv
mean of MeOH control

Figure 35.



Impact of pce on germination of Cephalanthus occidentalis
Mean number of germinants
0
1
2
3
4
5
0.1
1
10
100
PCE (ppm)
mean ± stdv
mean of MeOH control

Figure 36.

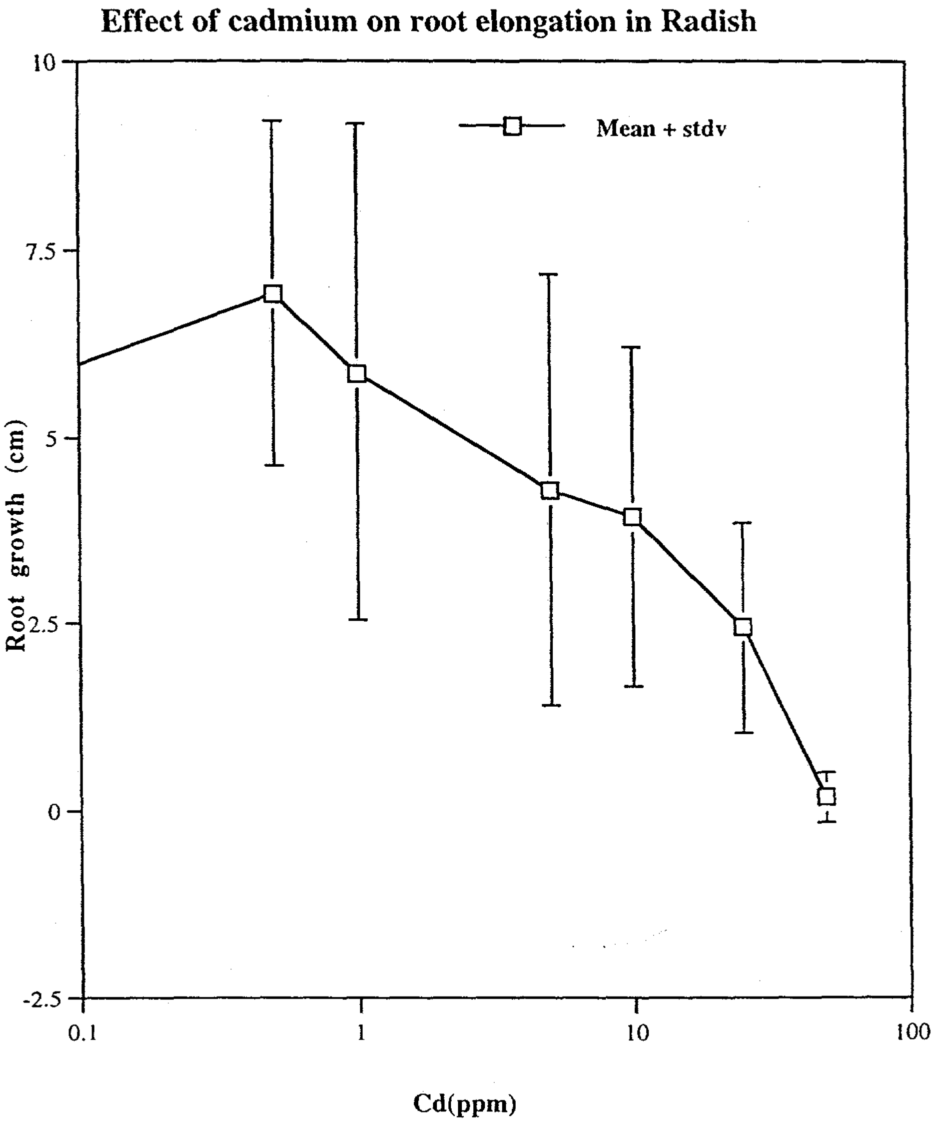
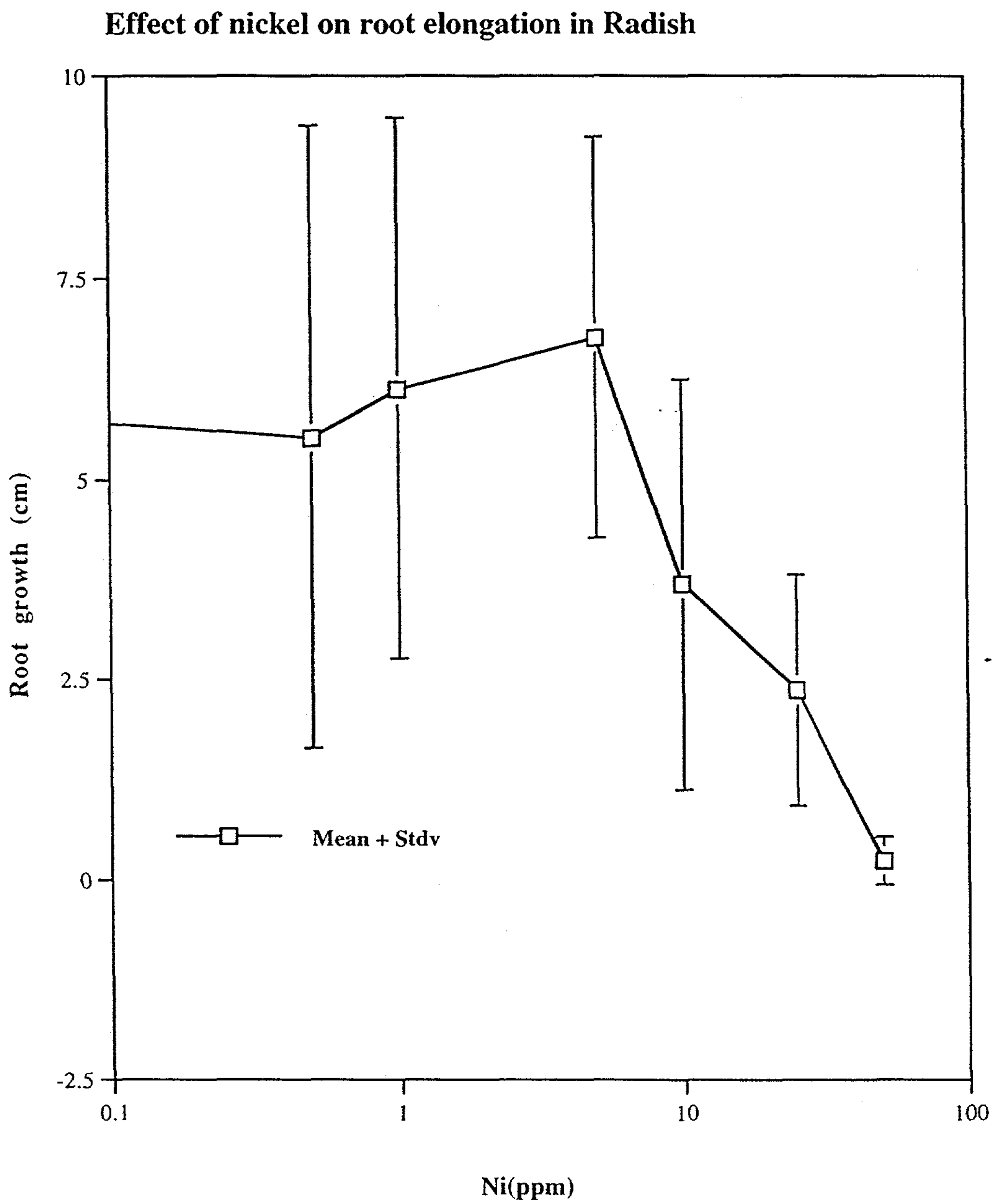
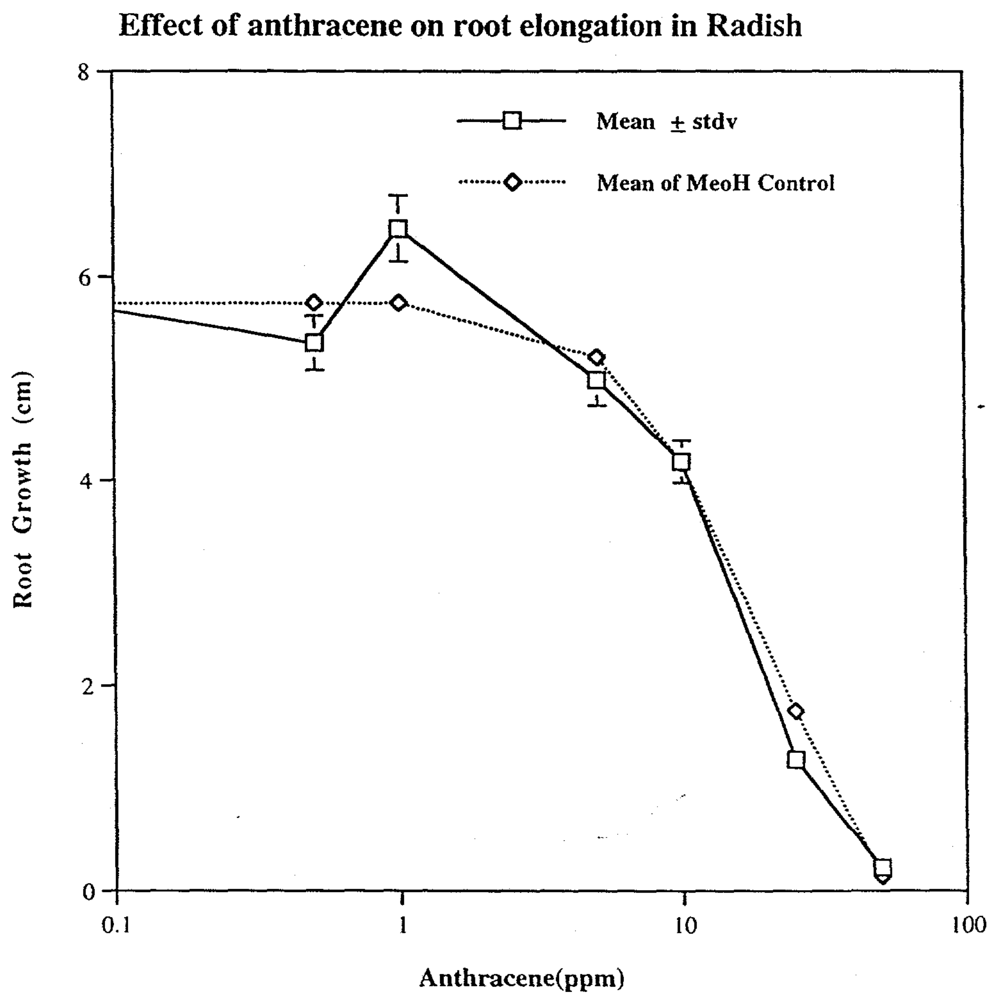

Effect of cadmium on root elongation in Radish
Mean + stdv
Root growth (cm)
10
7.5
5
2.5
0
-2.5
0.1
1
10
100
Cd(ppm)

Figure 37.



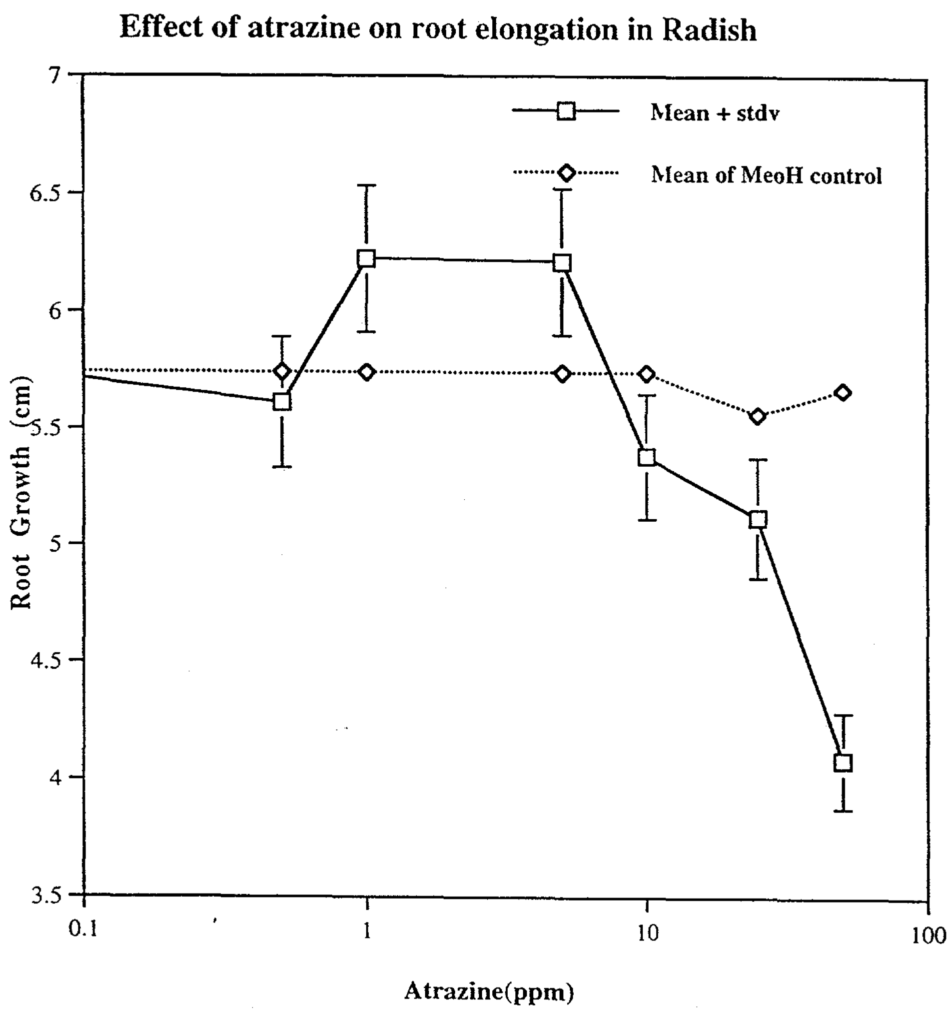
Effect of nickel on root elongation in Radish
10
7.5
5
2.5
0
-2.5
Root growth (cm)
Mean + Stdv
0.1
1
10
100
Ni(ppm)

Figure 38.



Effect of anthracene on root elongation in Radish
Mean ± stdv
Mean of MeoH Control
Root Growth (cm)
Anthracene(ppm)
0
2
4
6
8
0.1
1
10
100

Figure 39.



Effect of atrazine on root elongation in Radish
Mean + stdv
Mean of MeoH control
Root Growth (cm)
7
6.5
6
5.5
5
4.5
4
3.5
0.1
1
10
100
Atrazine(ppm)

Figure 40.

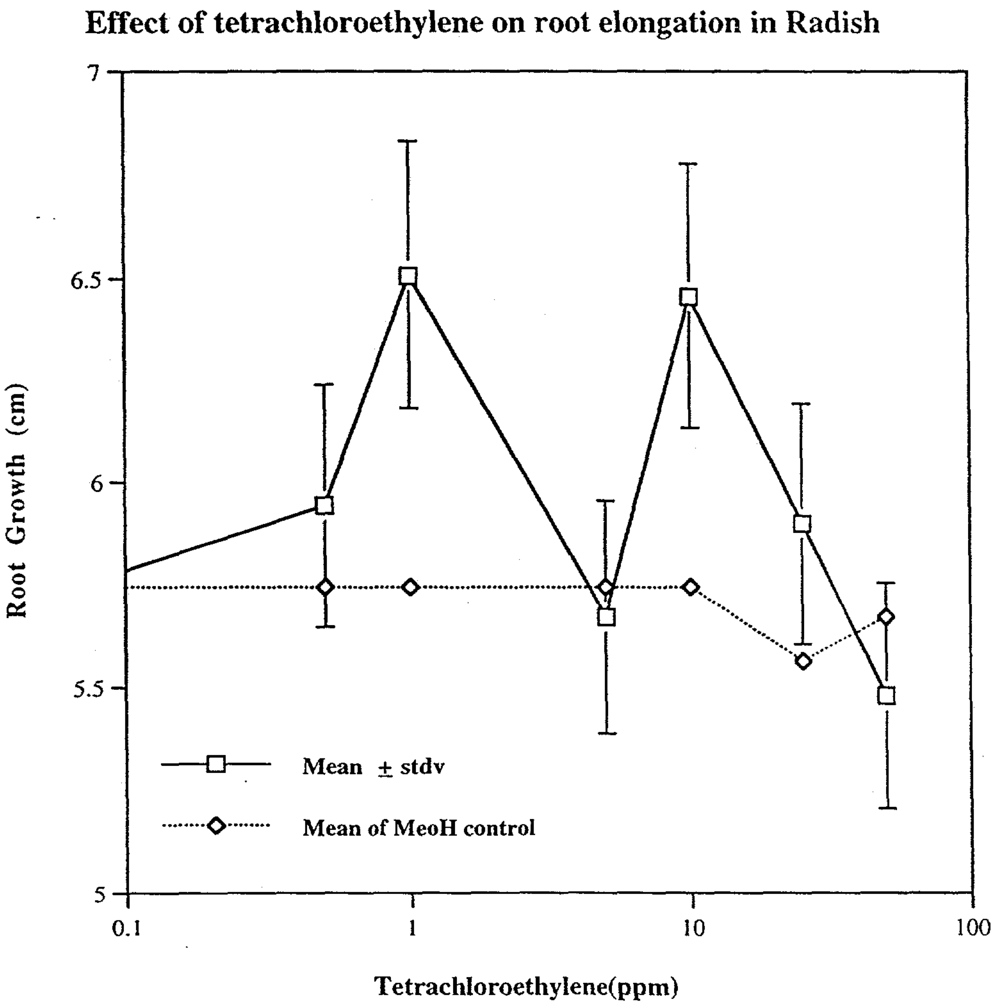

Effect of tetrachloroethylene on root elongation in Radish
7
6.5
6
5.5
5
Root Growth (cm)
0.1
1
10
100
Tetrachloroethylene(ppm)
Mean ± stdv
Mean of MeoH control

Figure 41.

Effect of cadmium on root elongation in Quercus falcata.

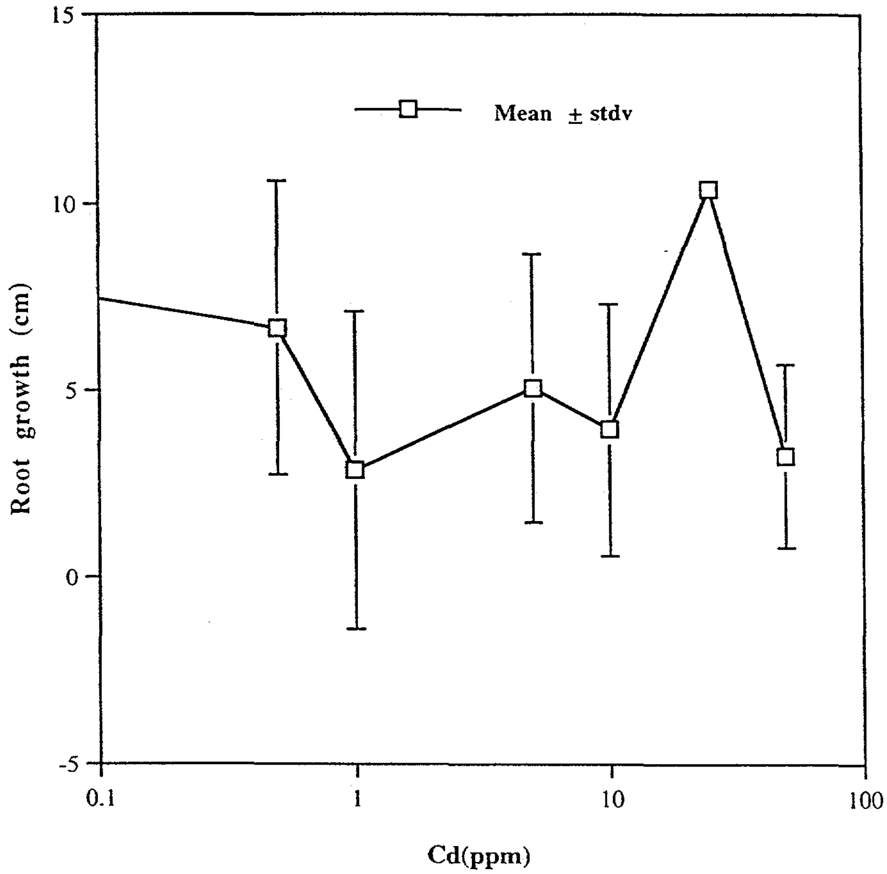


Figure 42.

Effect of nickel on root elongation in Quercus falcata.

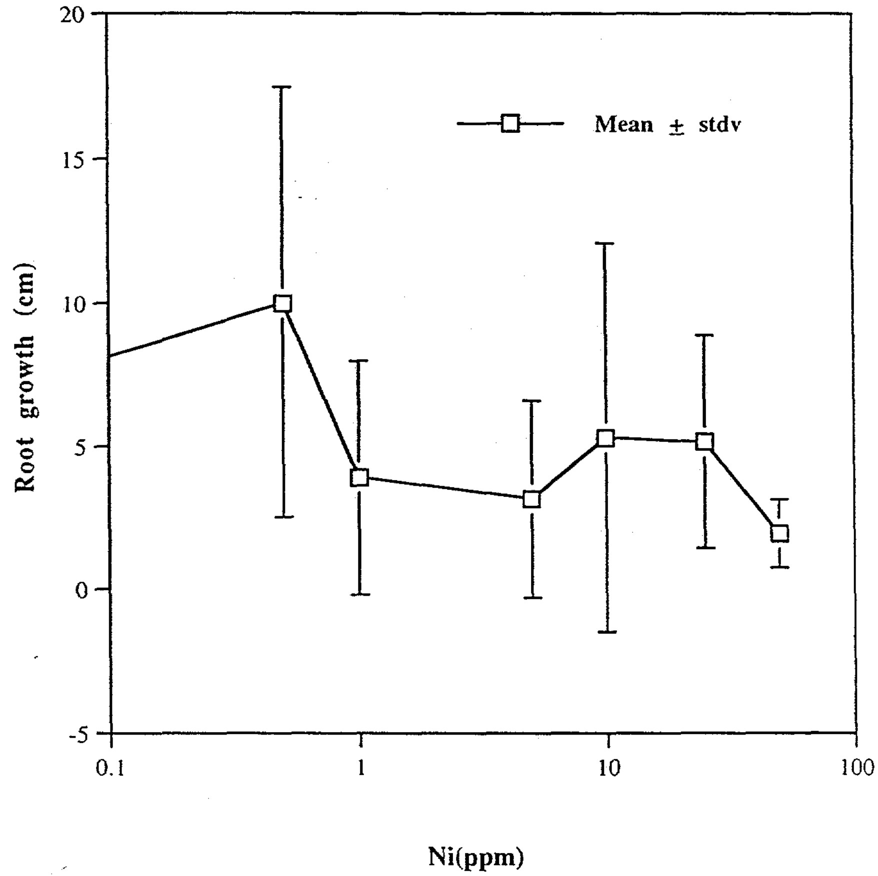


Figure 43.

Effect of anthracene on root elongation in Quercus falcata.

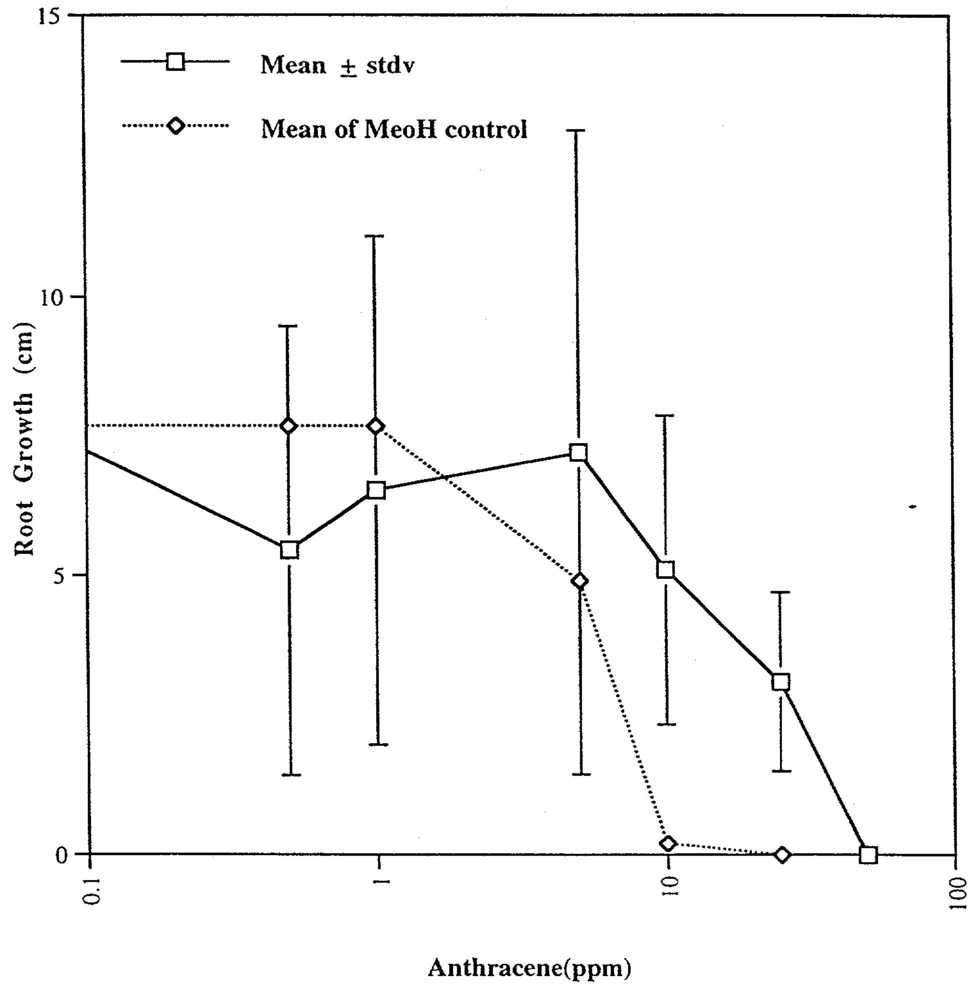


Figure 44.

Éffect of atrazine on root elongation in Quercus falcata.

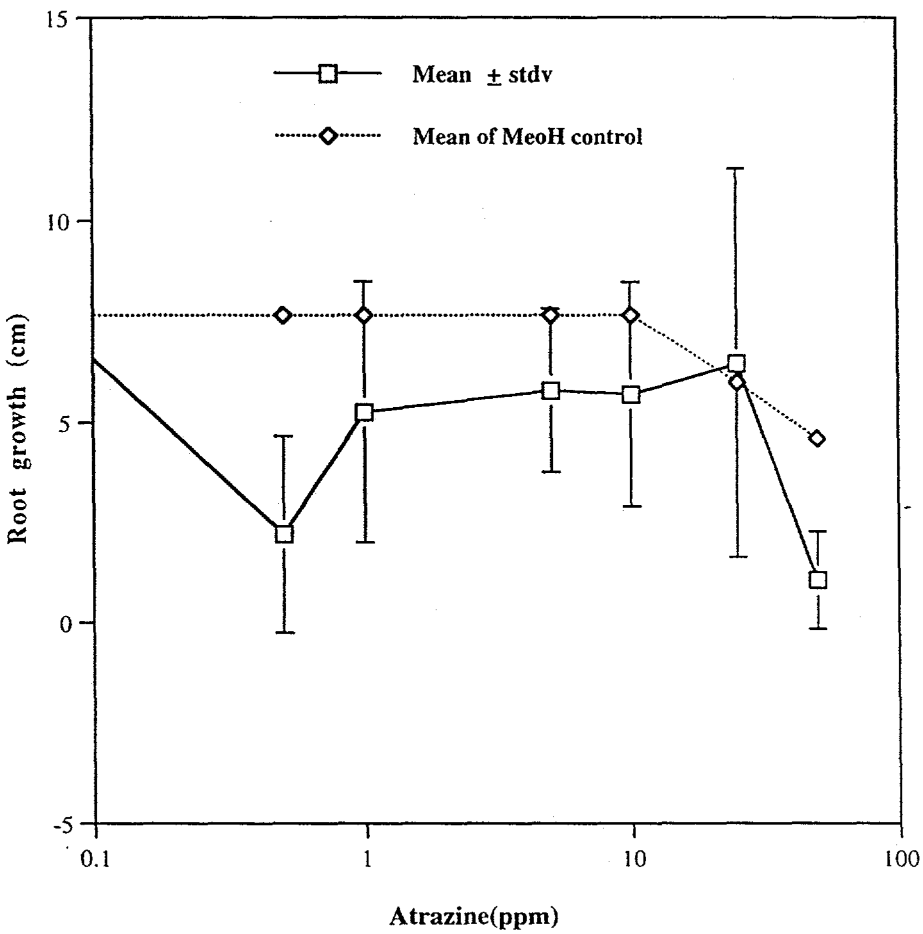


Figure 45.

Effect of tetrachloroethylene on root elongation in Quercus falcata.

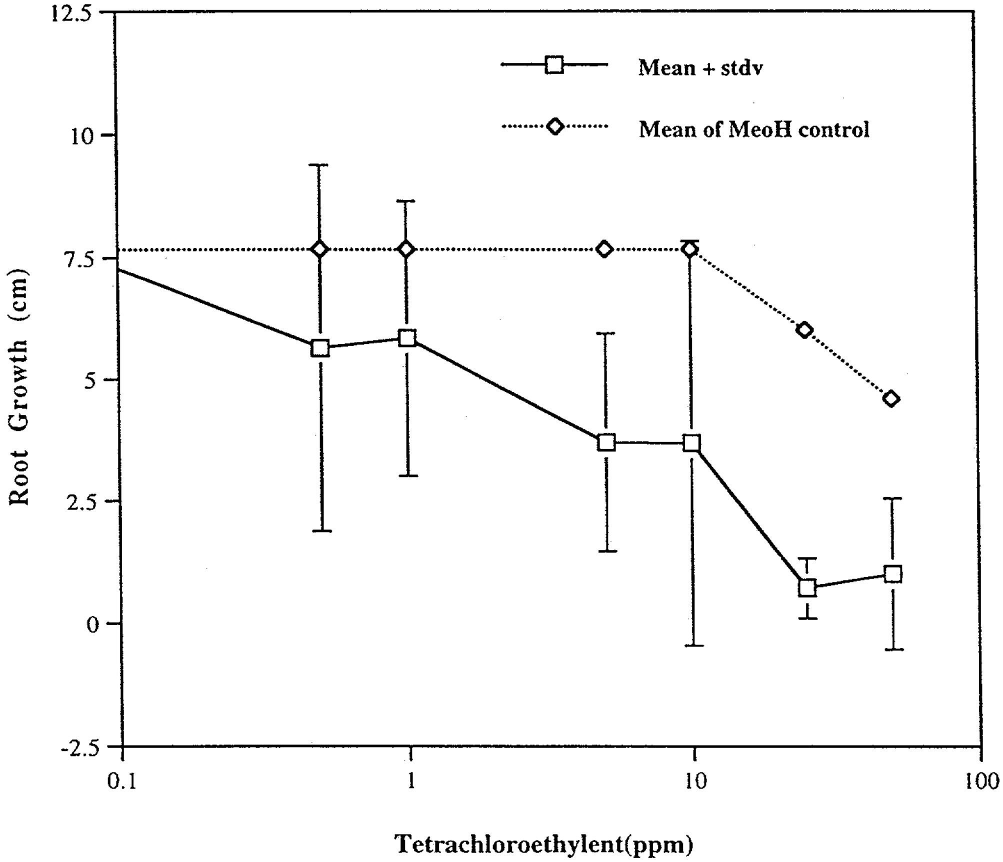


Figure 46.

Impact of Cd on root elongation in Lactuca sativa

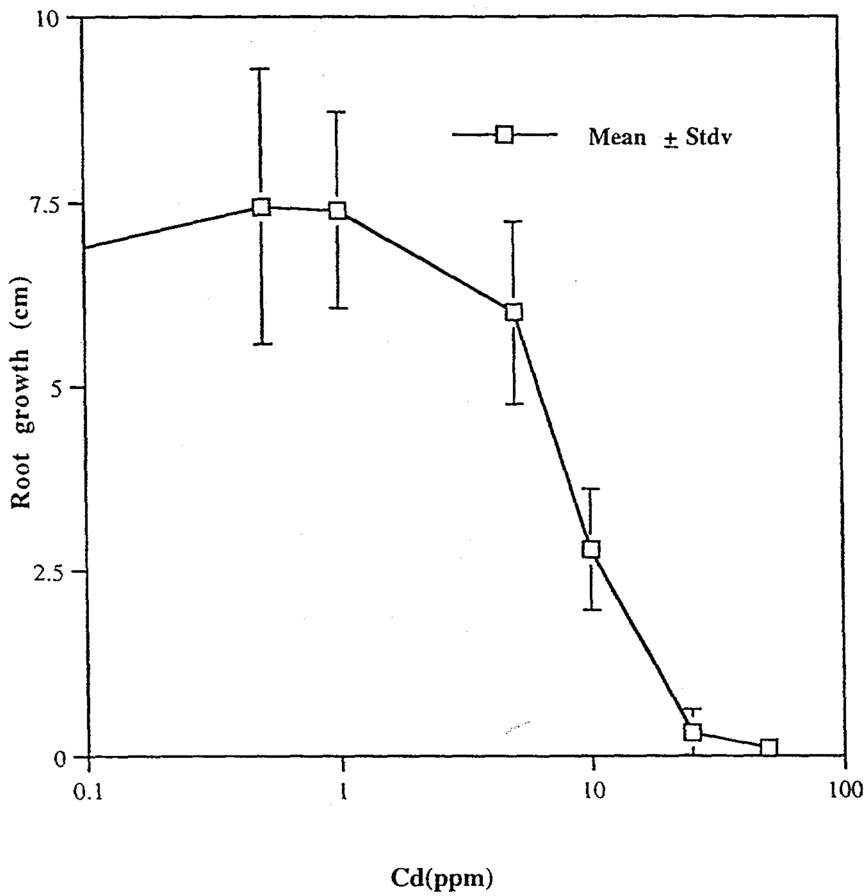
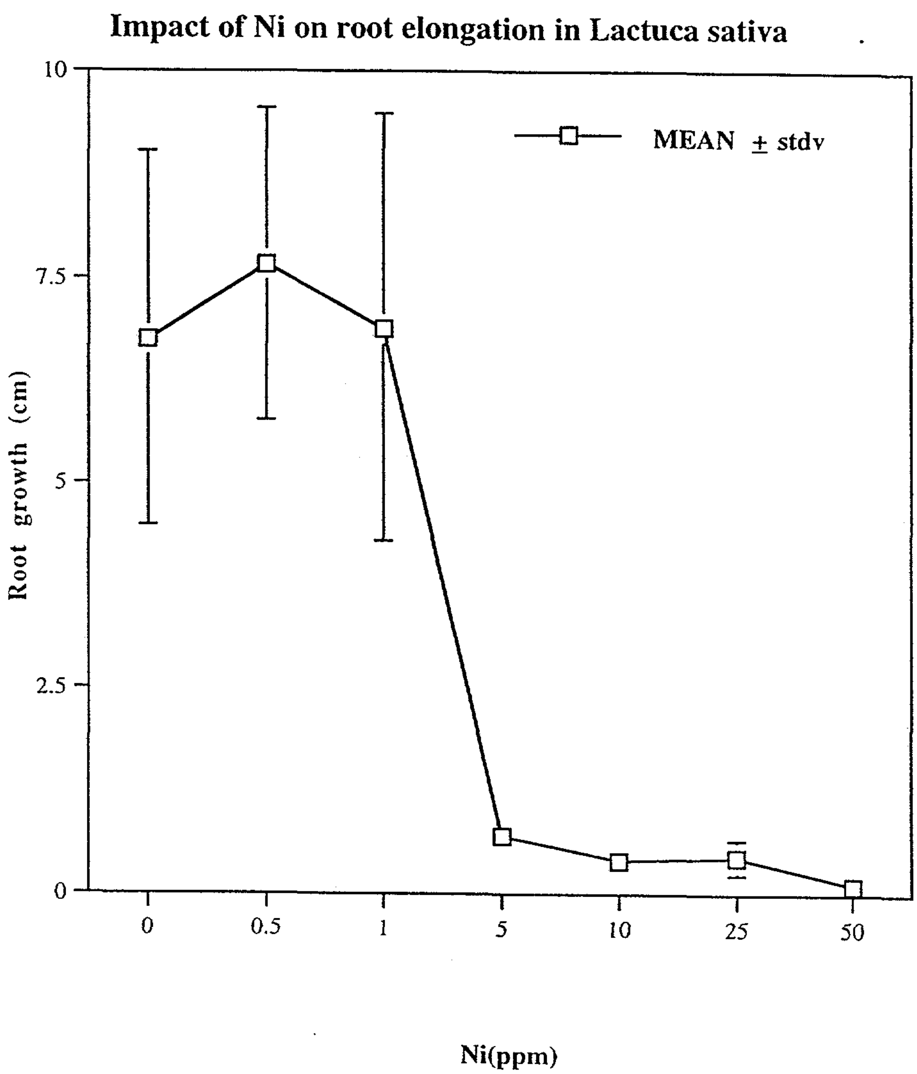


Figure 47.



Impact of Ni on root elongation in Lactuca sativa
MEAN ± stdv
Root growth (cm)
10
7.5
5
2.5
0
0
0.5
1
5
10
25
50
Ni(ppm)

Figure 48.

Effect of anthracene on the root elongation of Lactuca sativa

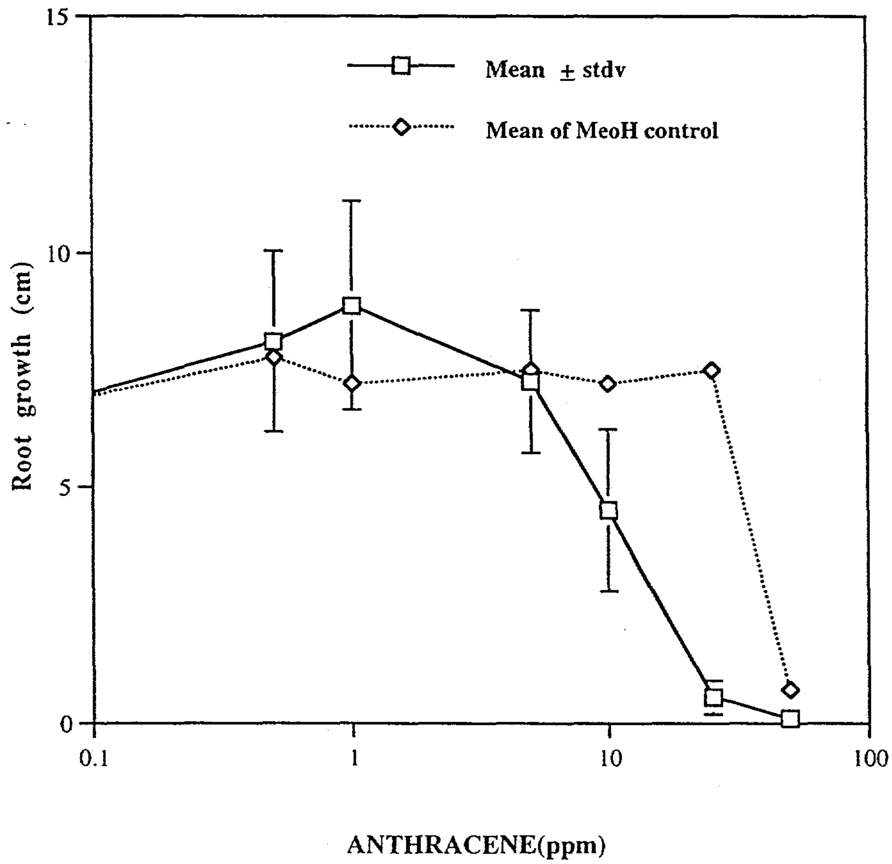


Figure 49.

Effect of atrazine on root elongation in Lactuca sativa

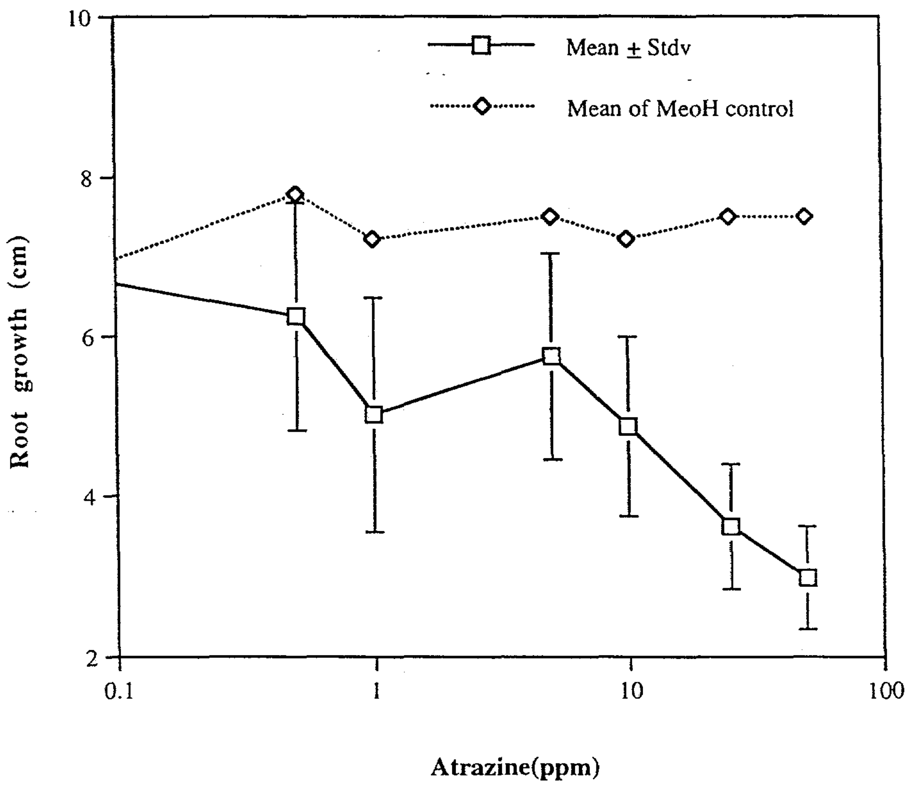
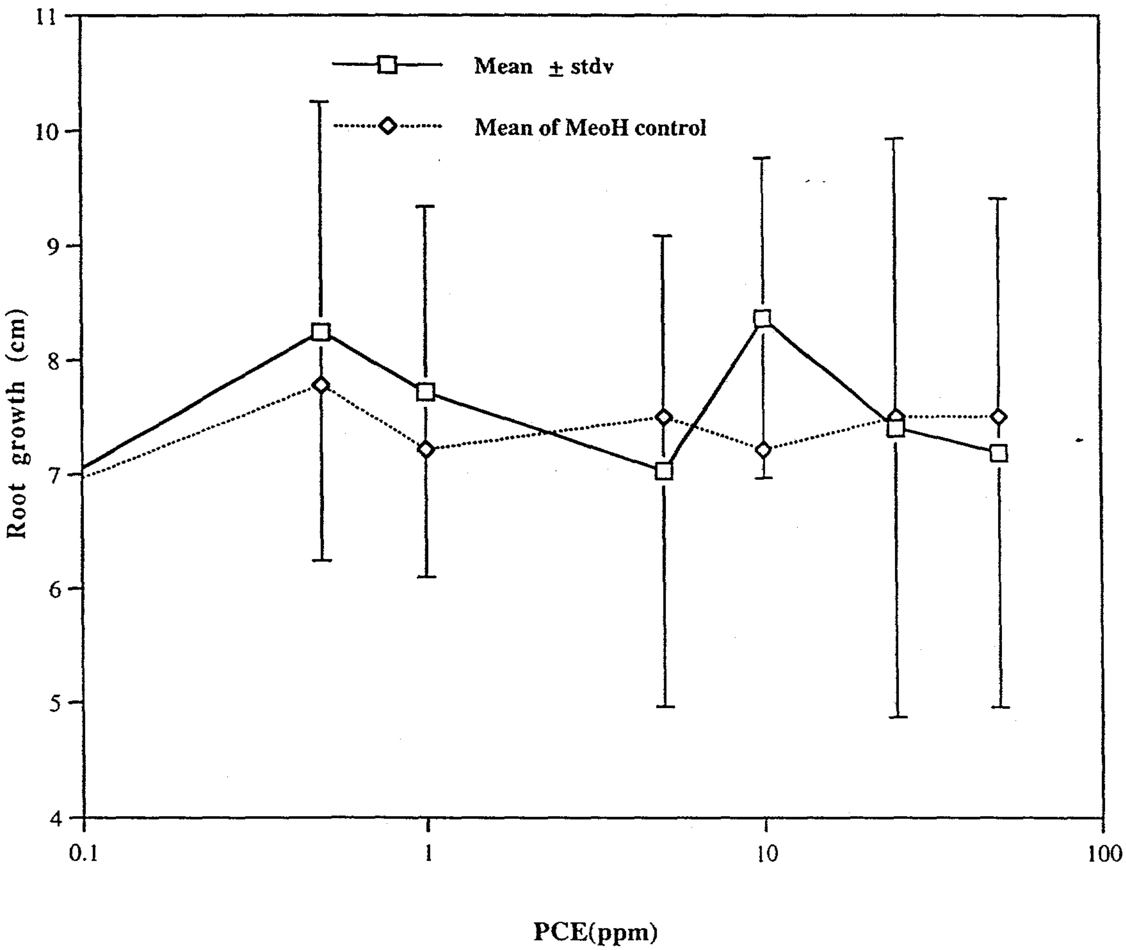


Figure 50.

Effect of Tetrachloroethylene on root elongation in Lactuca sativa



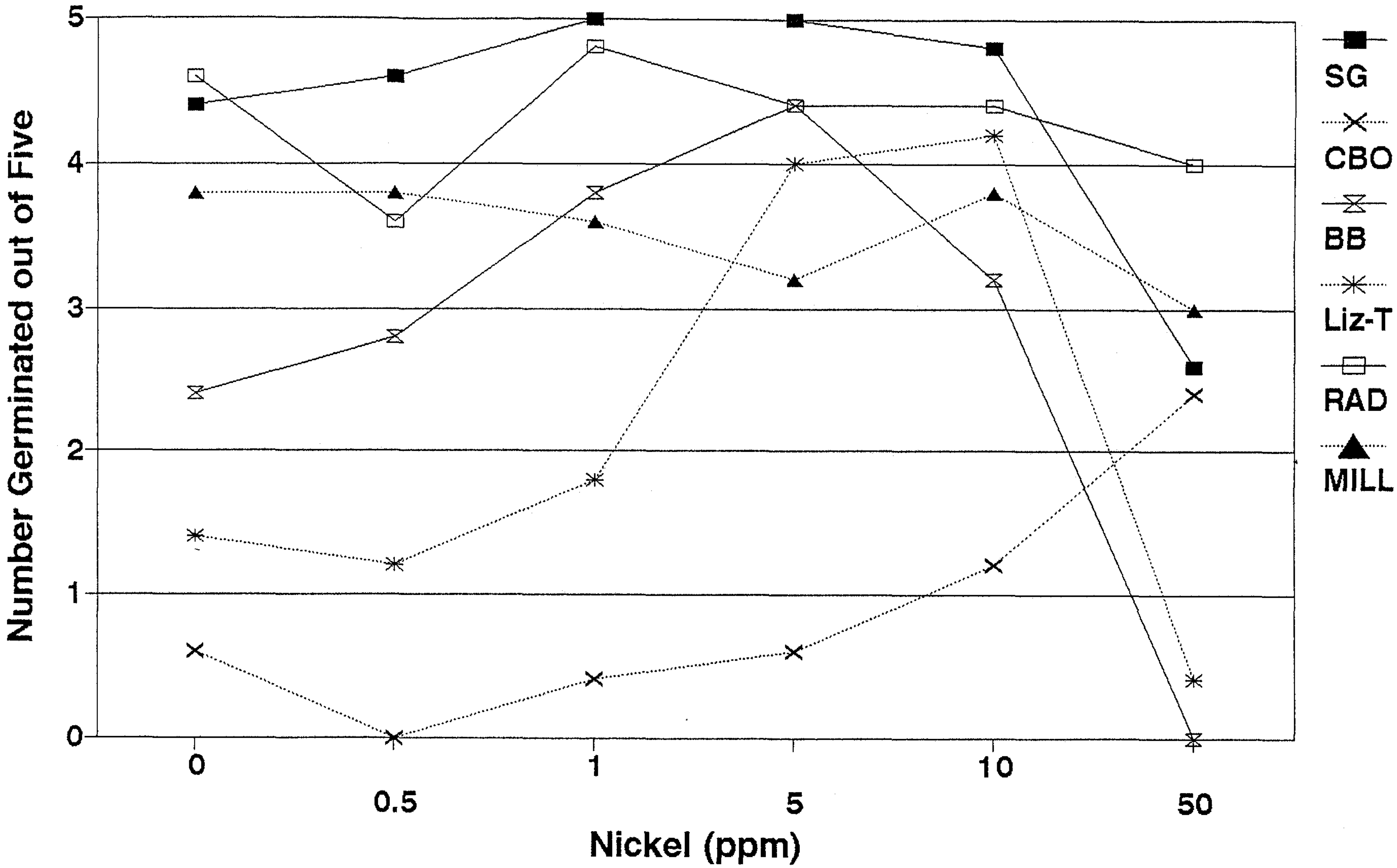


Figure 51. Number of seed out of five that germinated by dose rate for six species. SG = sweetgum, CBO = cherrybark oak, BB = buttonbush, Liz-T = lizard's tail, RAD = radish, MILL = millet

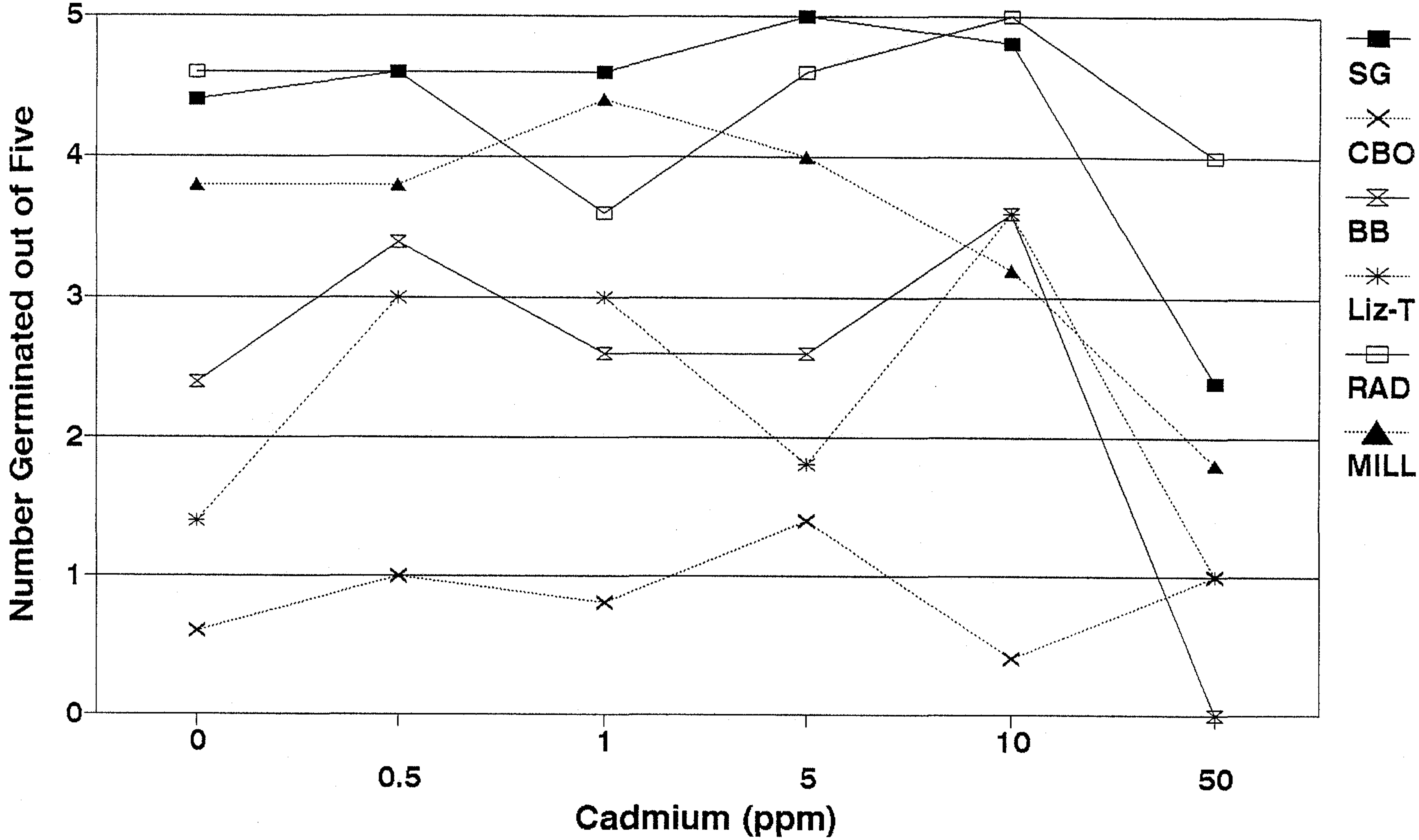


Figure 52. Number of seed that germinated out of five by dose rate for six species. SG = sweetgum, CBO = cherrybark oak, BB = buttonbush, Liz=T = lizard's tail, MILL = millet.

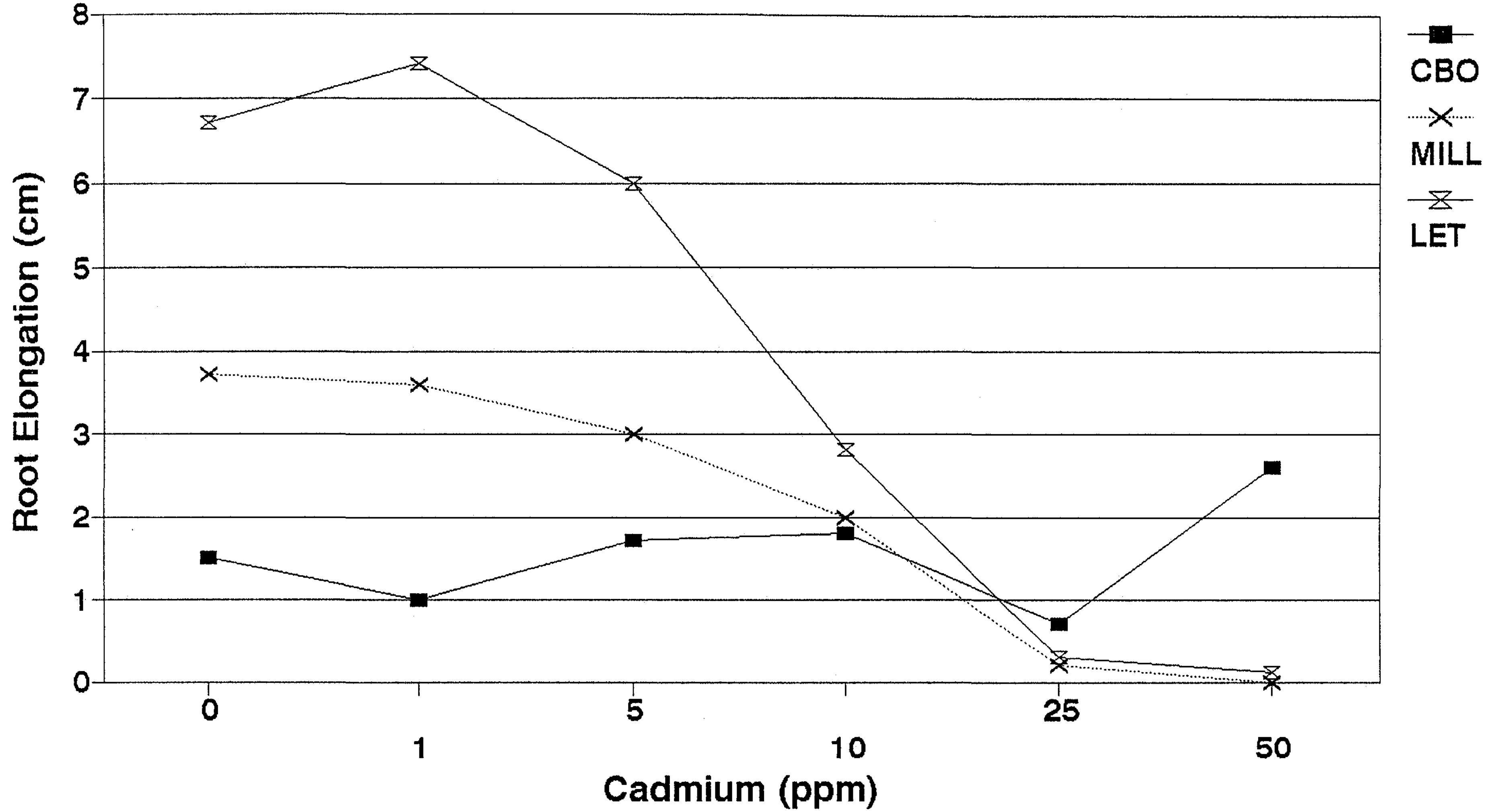


Figure 53. Root elongation in relation to dose rate for three species. CBO = cherrybark oak, MILL = millet, LET = lettuce

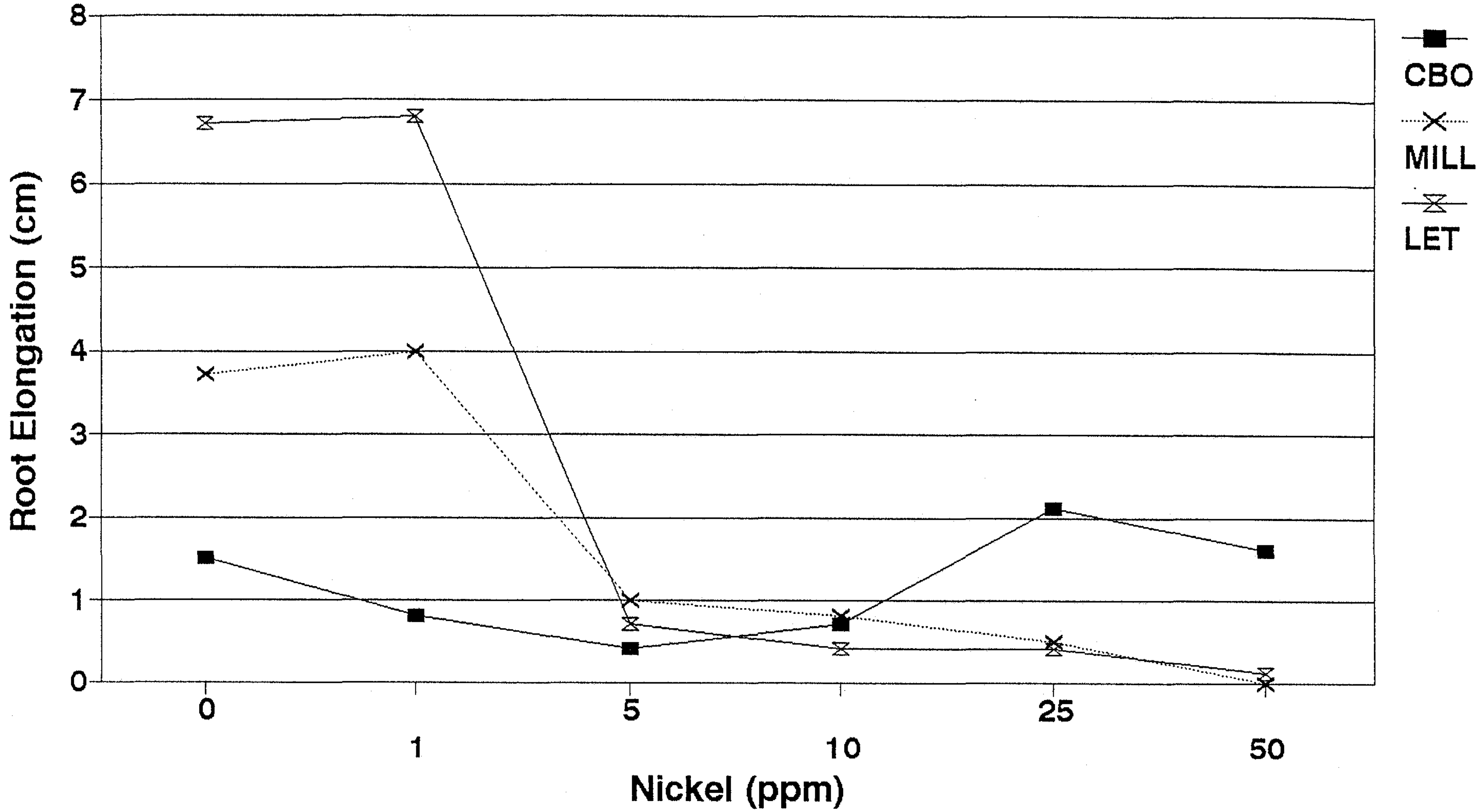


Figure 54. Root elongation in relation to dose rate for three species. CBO = cherrybark oak, MILL = millet, LET = lettuce

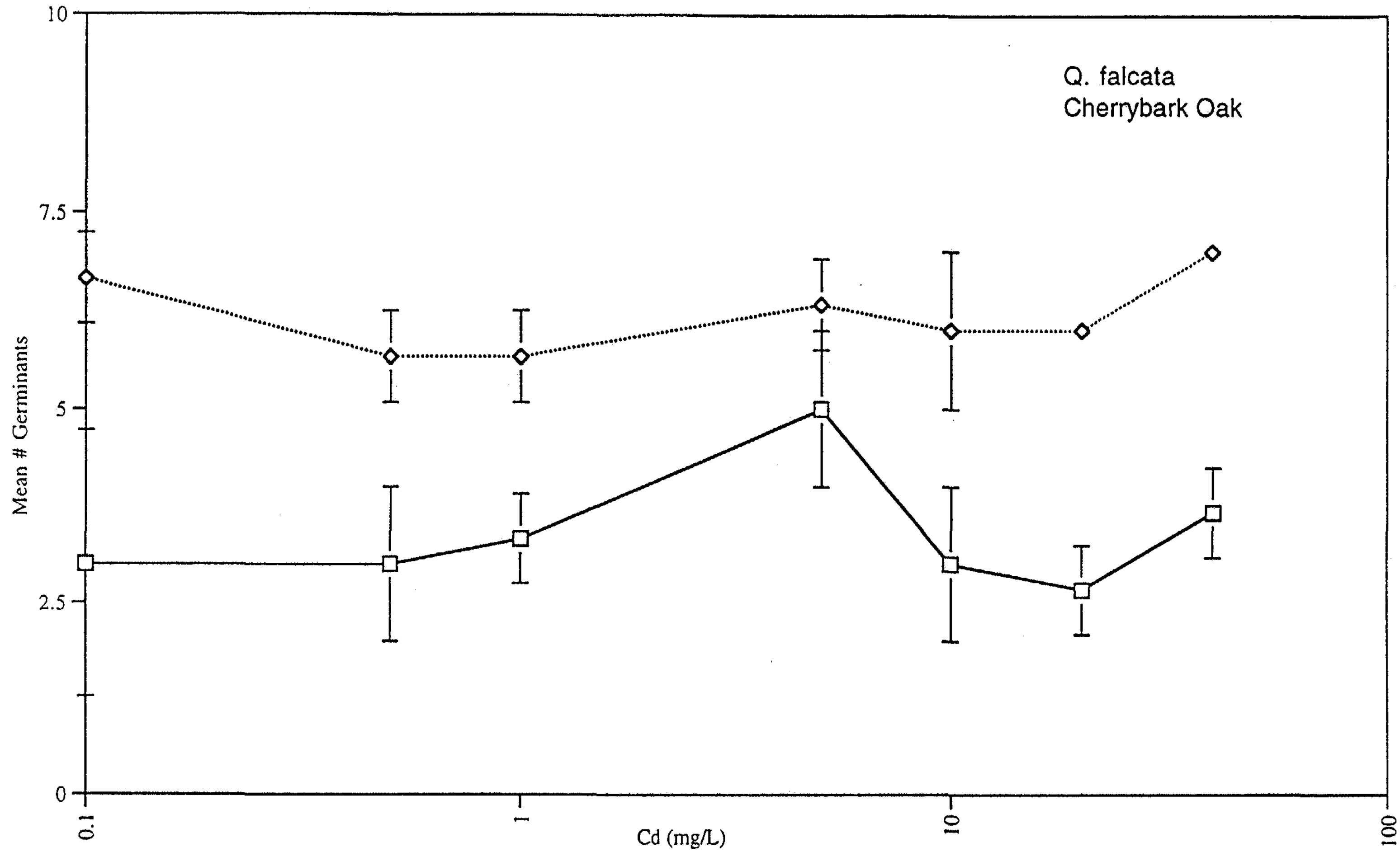


Figure 55. Influence of cadmium on seed germination in *Q. falcata* . Squares represent data taken on Day 5; diamonds represent data taken on Day 10.

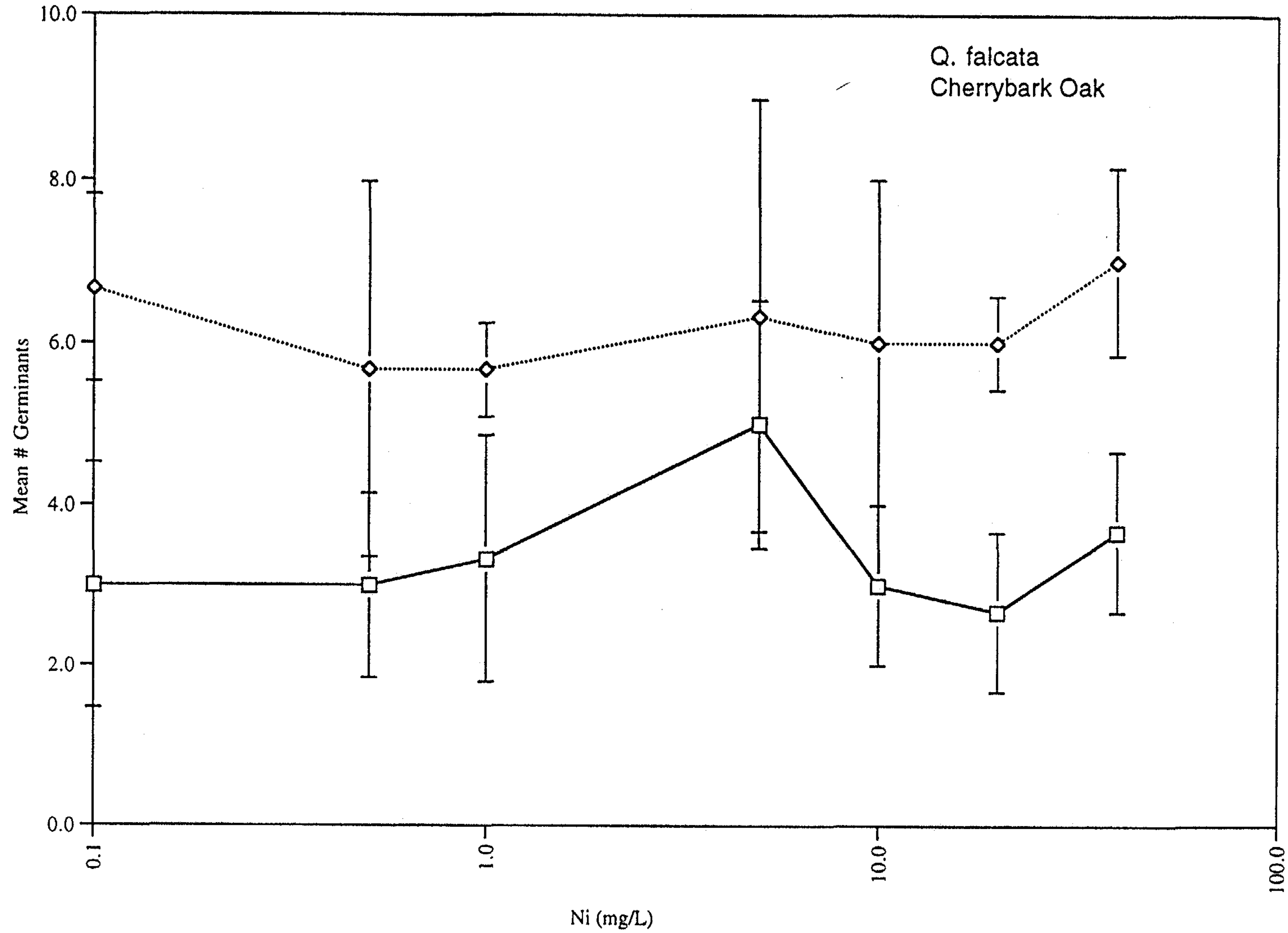


Figure 56. Influence of nickel on seed germination in *Q. falcata*. Squares represent data taken on Day 5; diamonds represent data taken on Day 10.

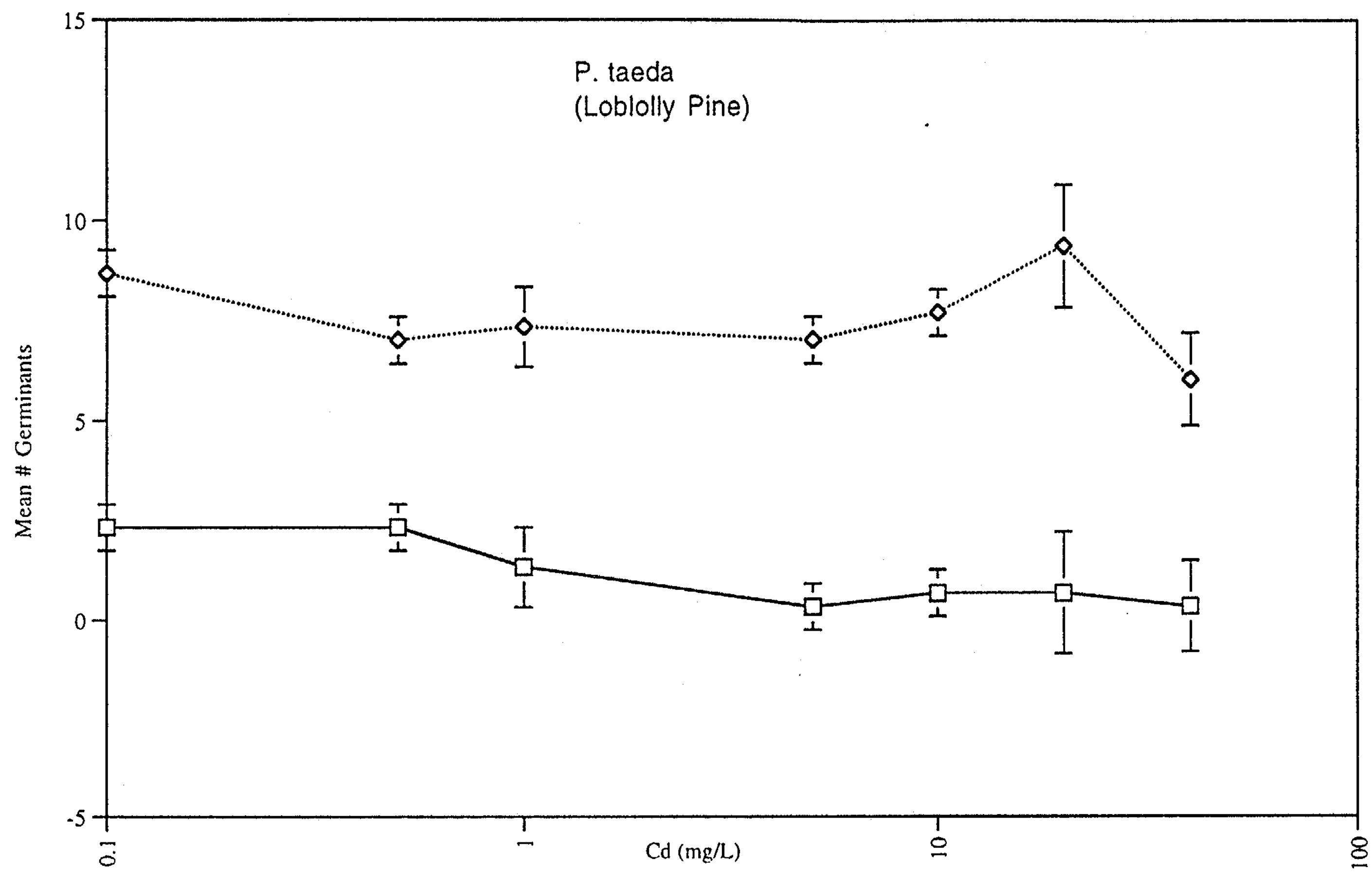


Figure 57. Influence of cadmium on seed germination in *P. taeda*. Squares represent data taken on Day 5; diamonds represent data taken on Day 10.

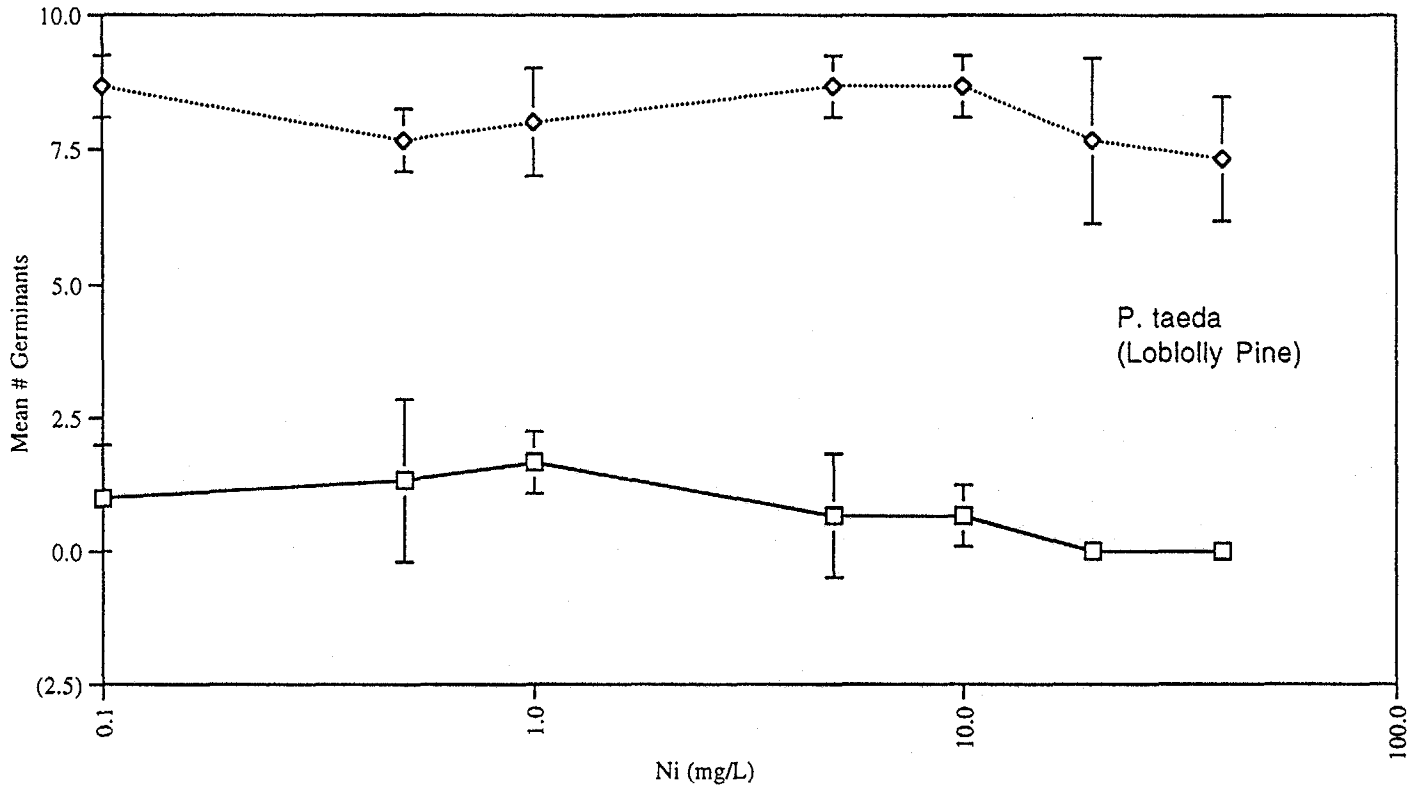


Figure 58. Influence of nickel on seed germination in *P. taeda*. Squares represent data taken on Day 5; diamonds represent data taken on Day 10.

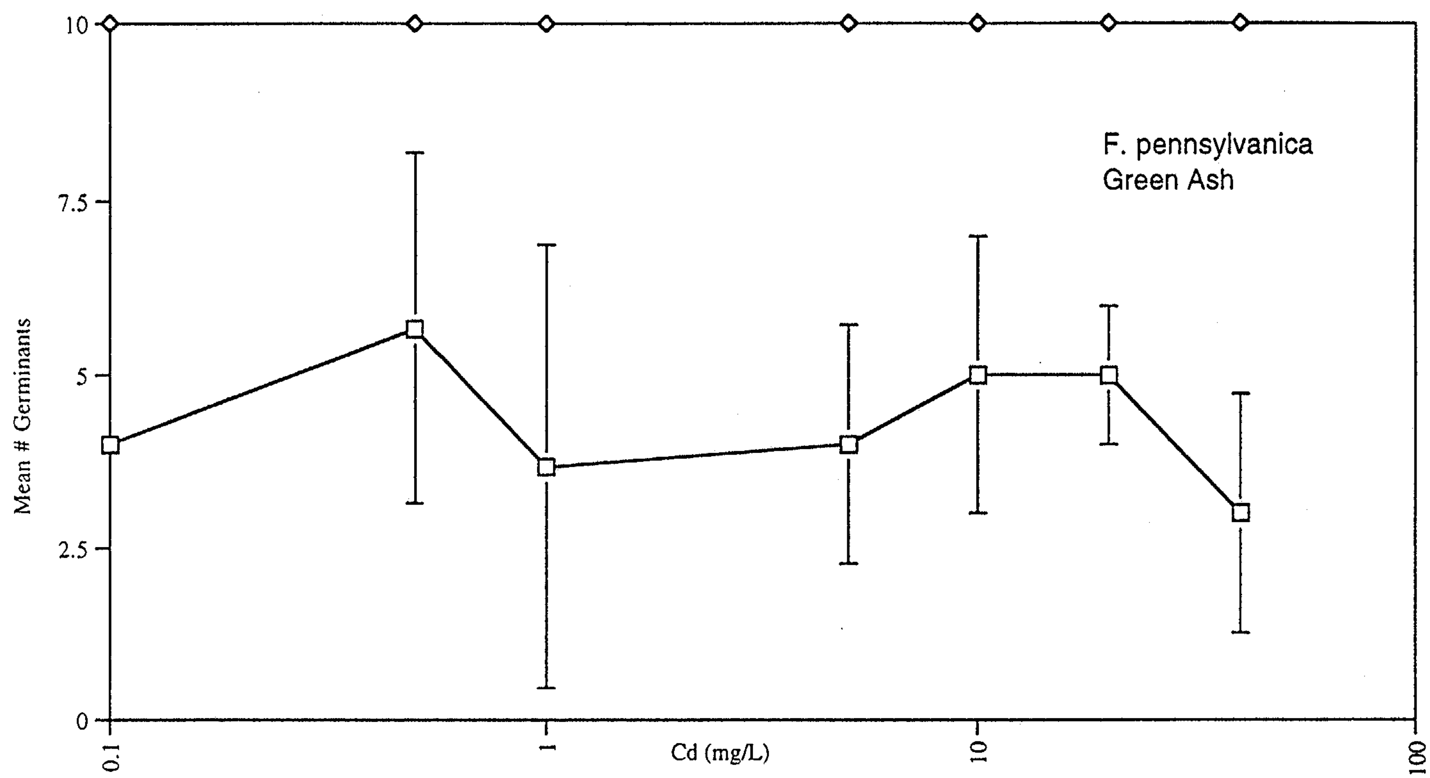


Figure 59. Influence of cadmium on seed germination in *F. pennsylvanica* . Squares represent data taken on Day 2; diamonds represent data taken on Day 5.

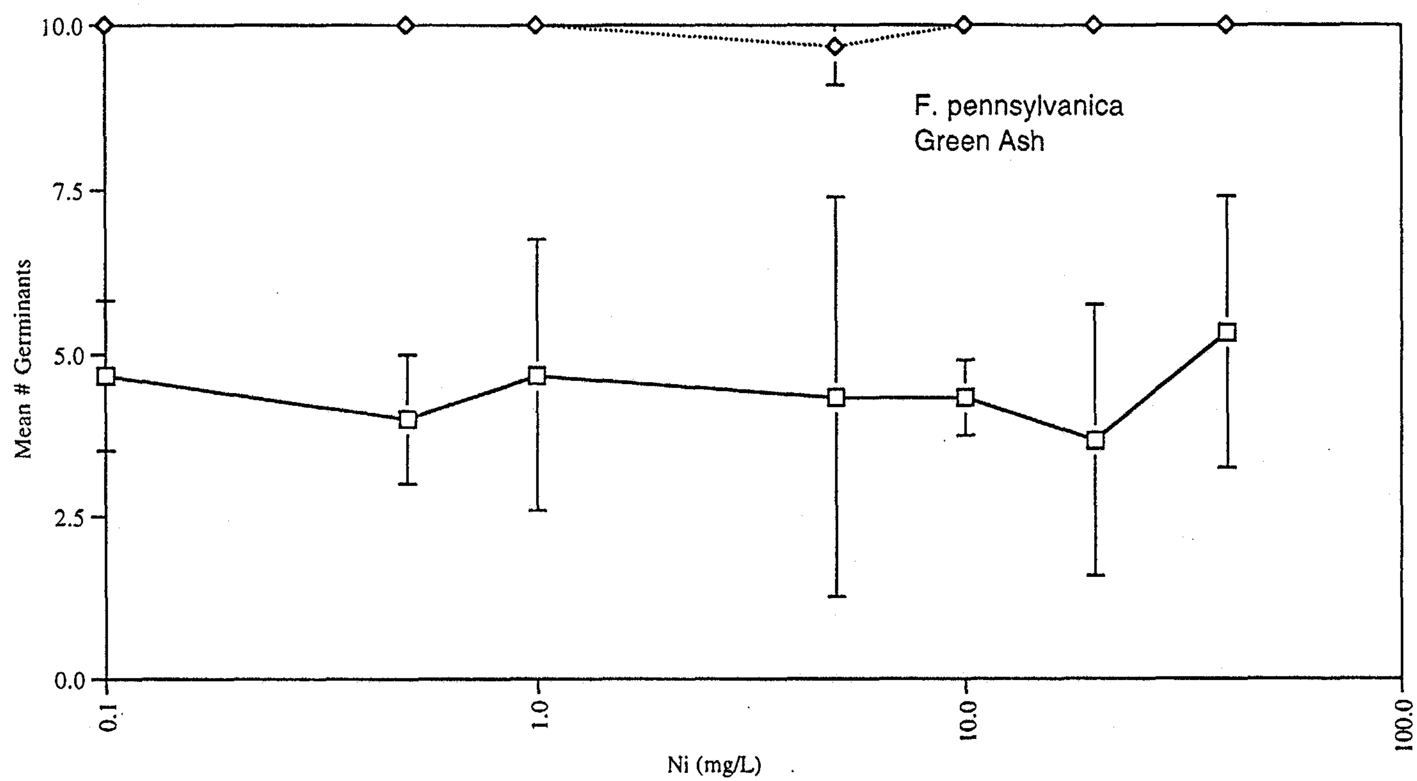


Figure 60. Influence of nickel on seed germination in *F. pennsylvanica* . Squares represent data taken on Day 2; diamonds represent data taken on Day 5.

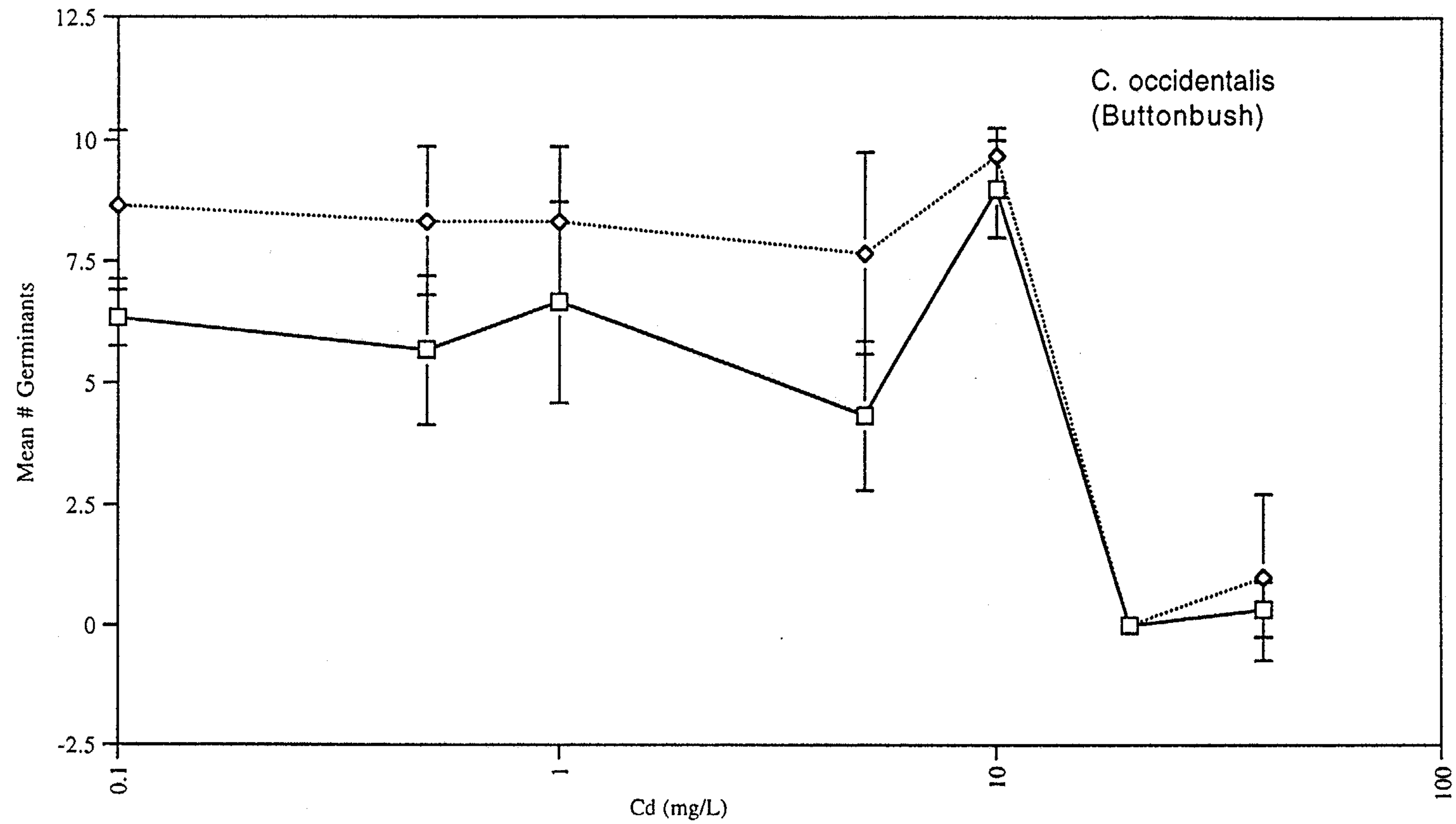


Figure 61. Influence of cadmium on seed germination in C. occidentalis . Squares represent data taken on Day 8; diamonds represent data taken on Day 10.

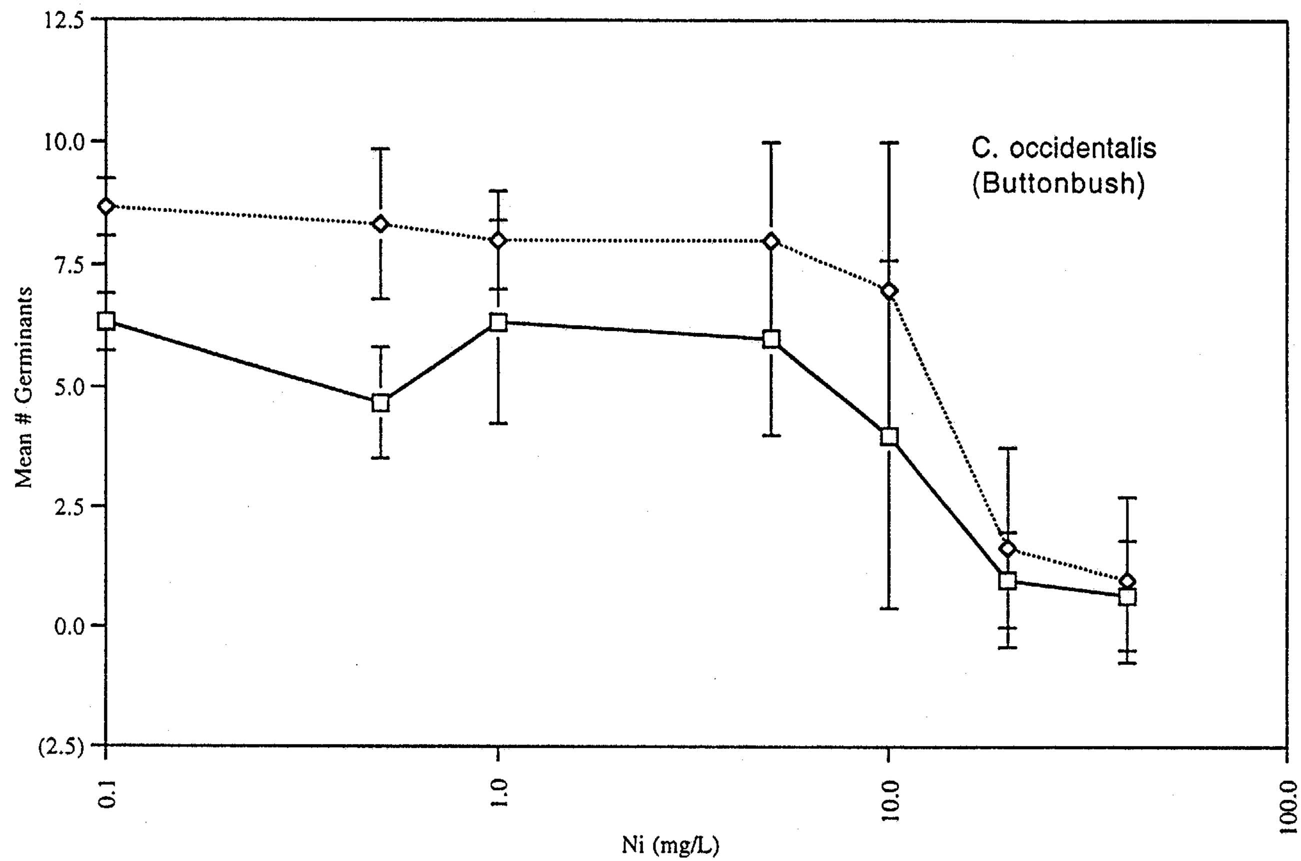


Figure 62. Influence of nickel on seed germination in C. occidentalis . Squares represent data taken on Day 8; diamonds represent data taken on Day 10.

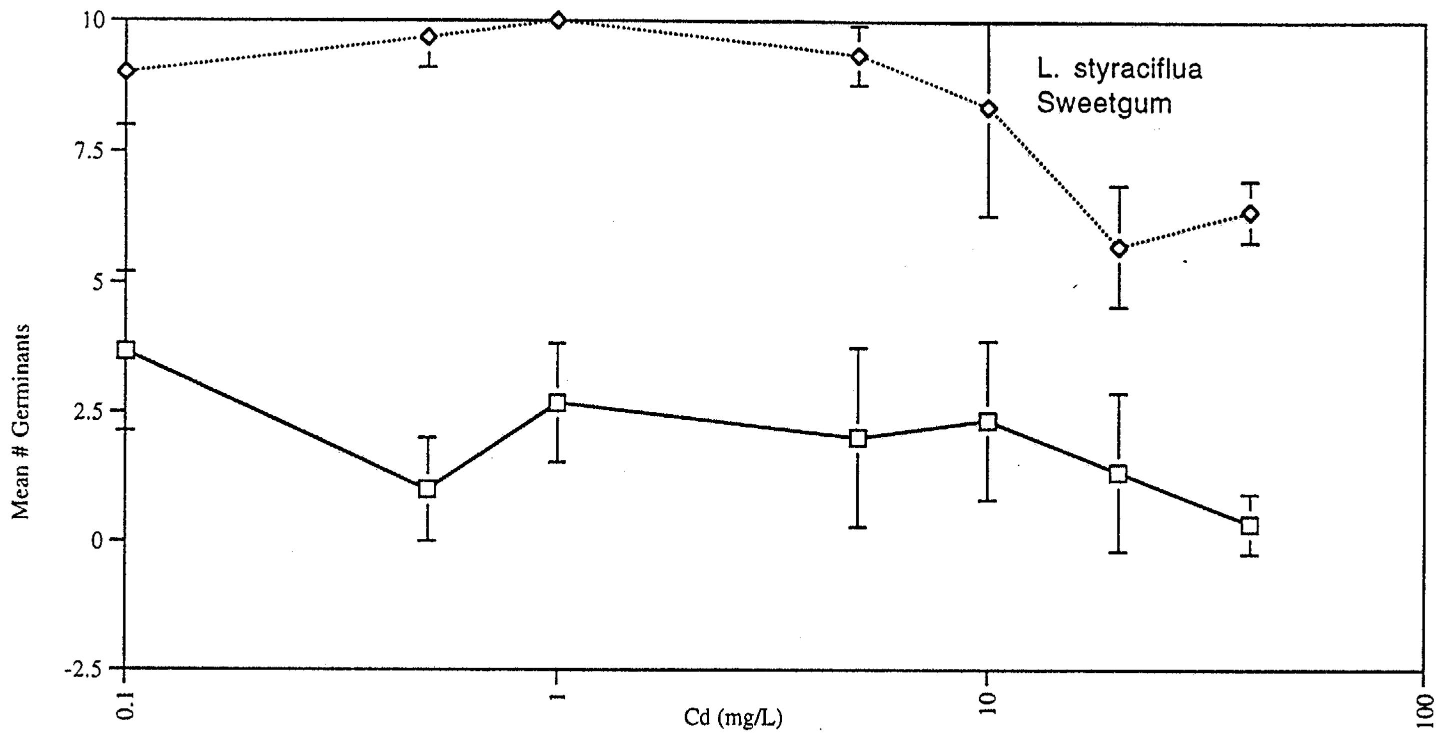


Figure 63. Influence of cadmium on seed germination in *L. styraciflua*. Squares represent data taken on Day 5; diamonds represent data taken on Day 10.

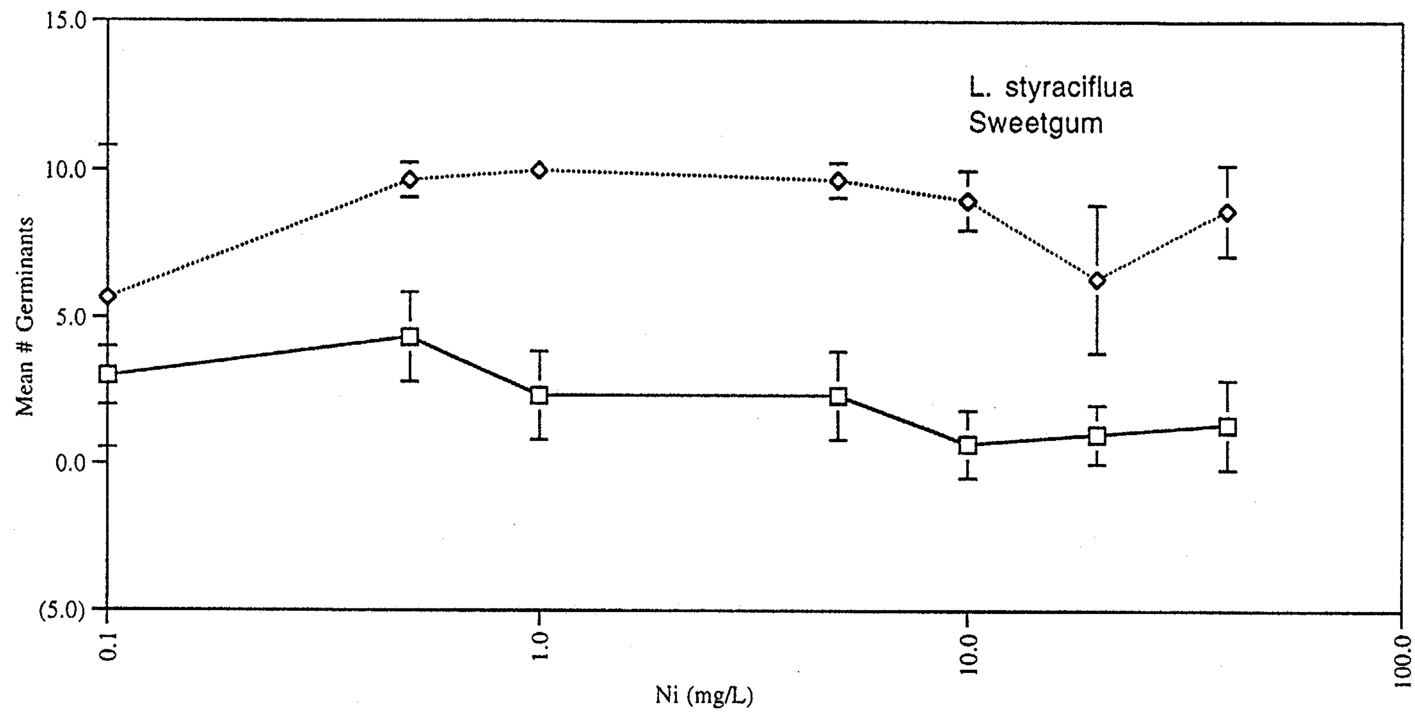


Figure 64. Influence of nickel on seed germination in *L. styraciflua*. Squares represent data taken on Day 5; diamonds represent data taken on Day 10.

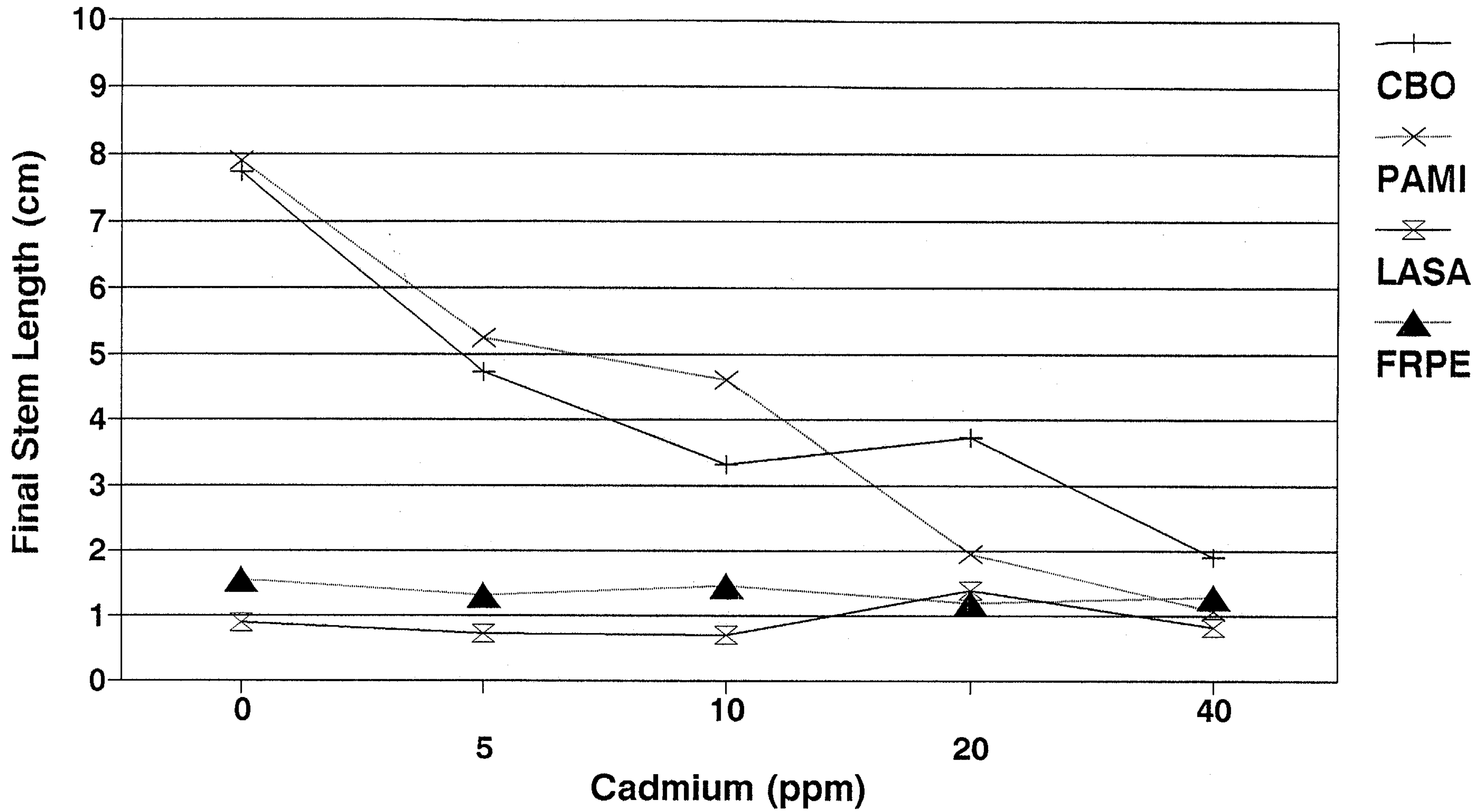


Figure 65. Stem elongation of four species to cadmium dose rates.

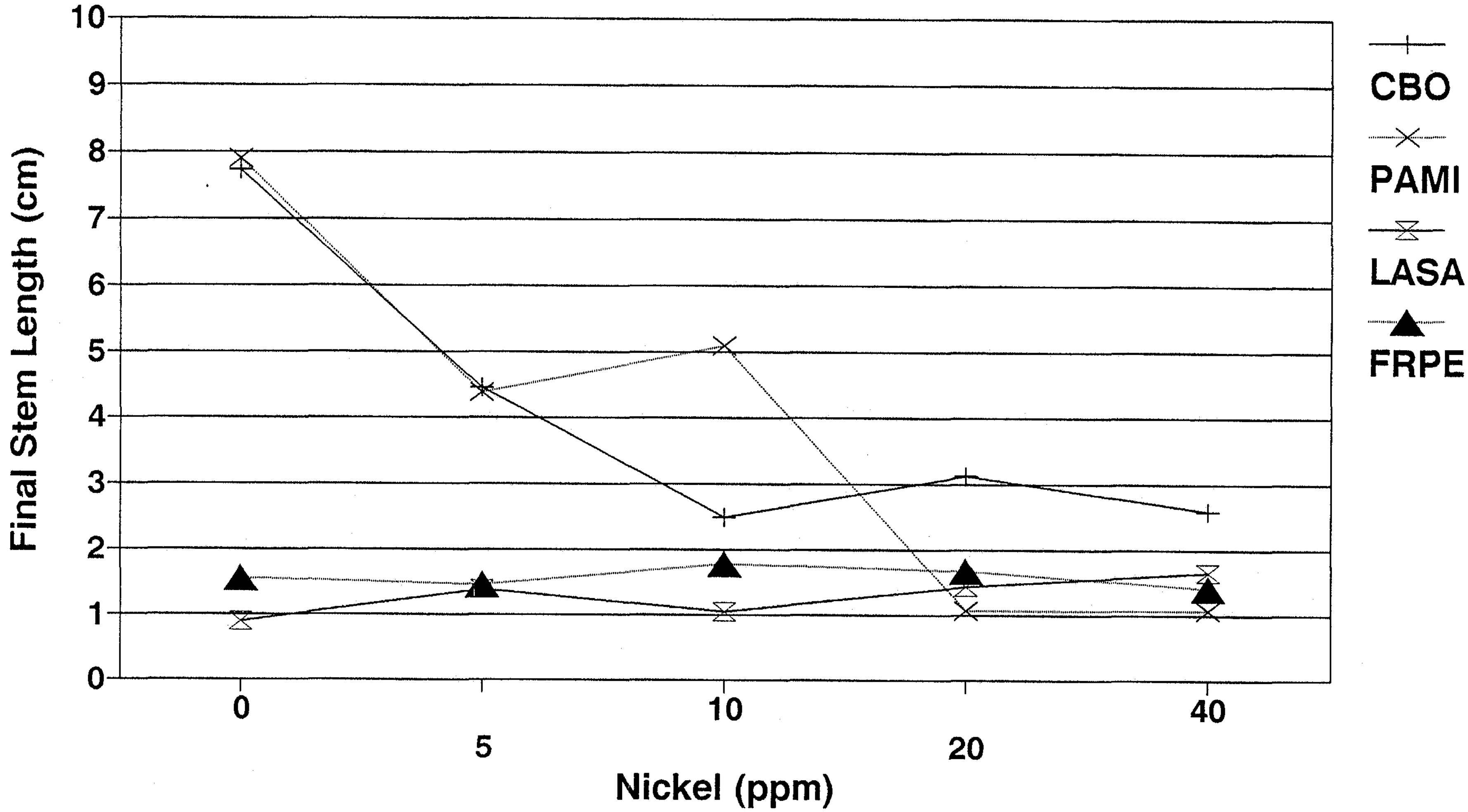


Figure 66. Stem elongation of four species to nickel dose rates.

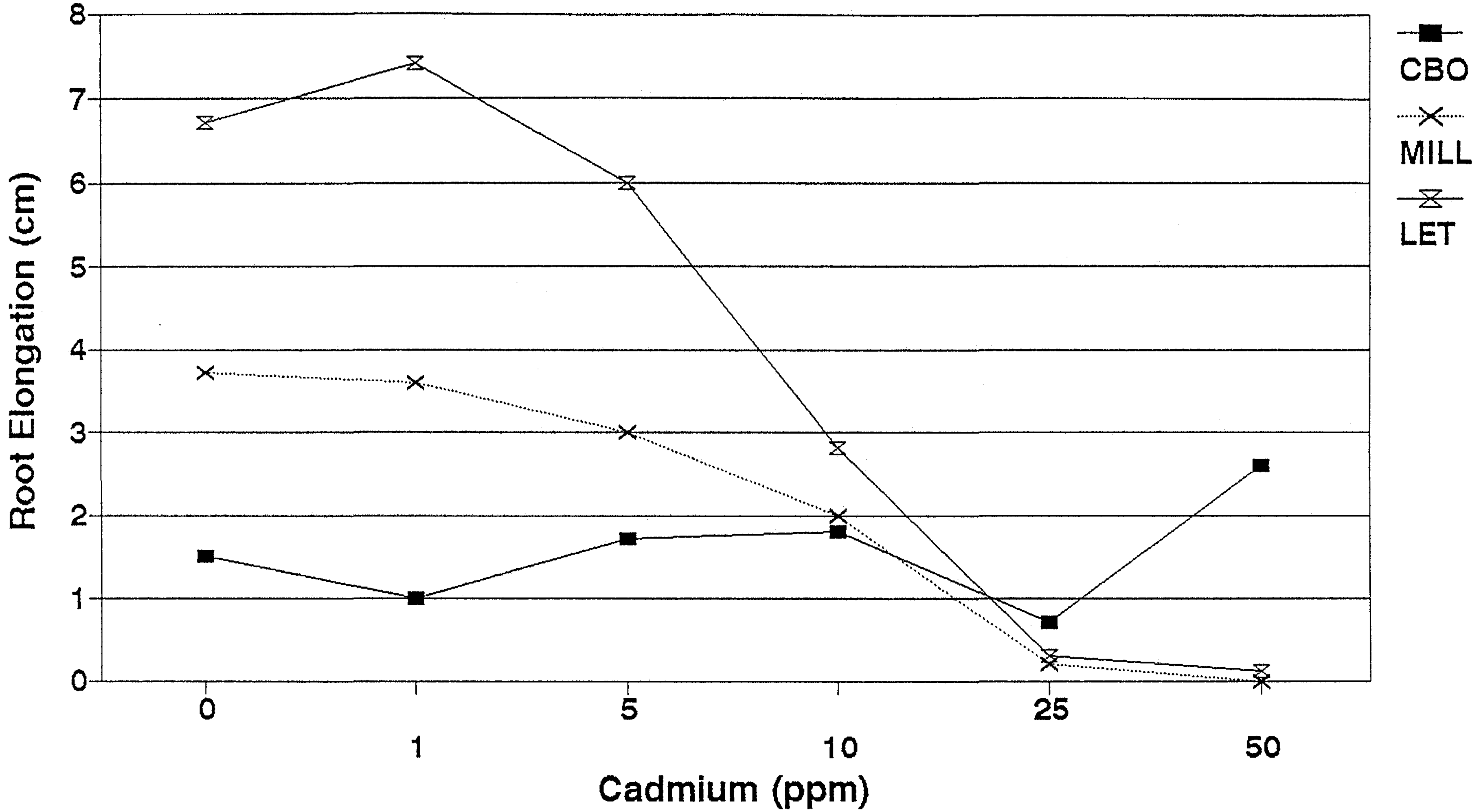


Figure 67. Root elongation in relation to dose rate for three species. CBO = cherrybark oak, MILL = millet, LET = lettuce

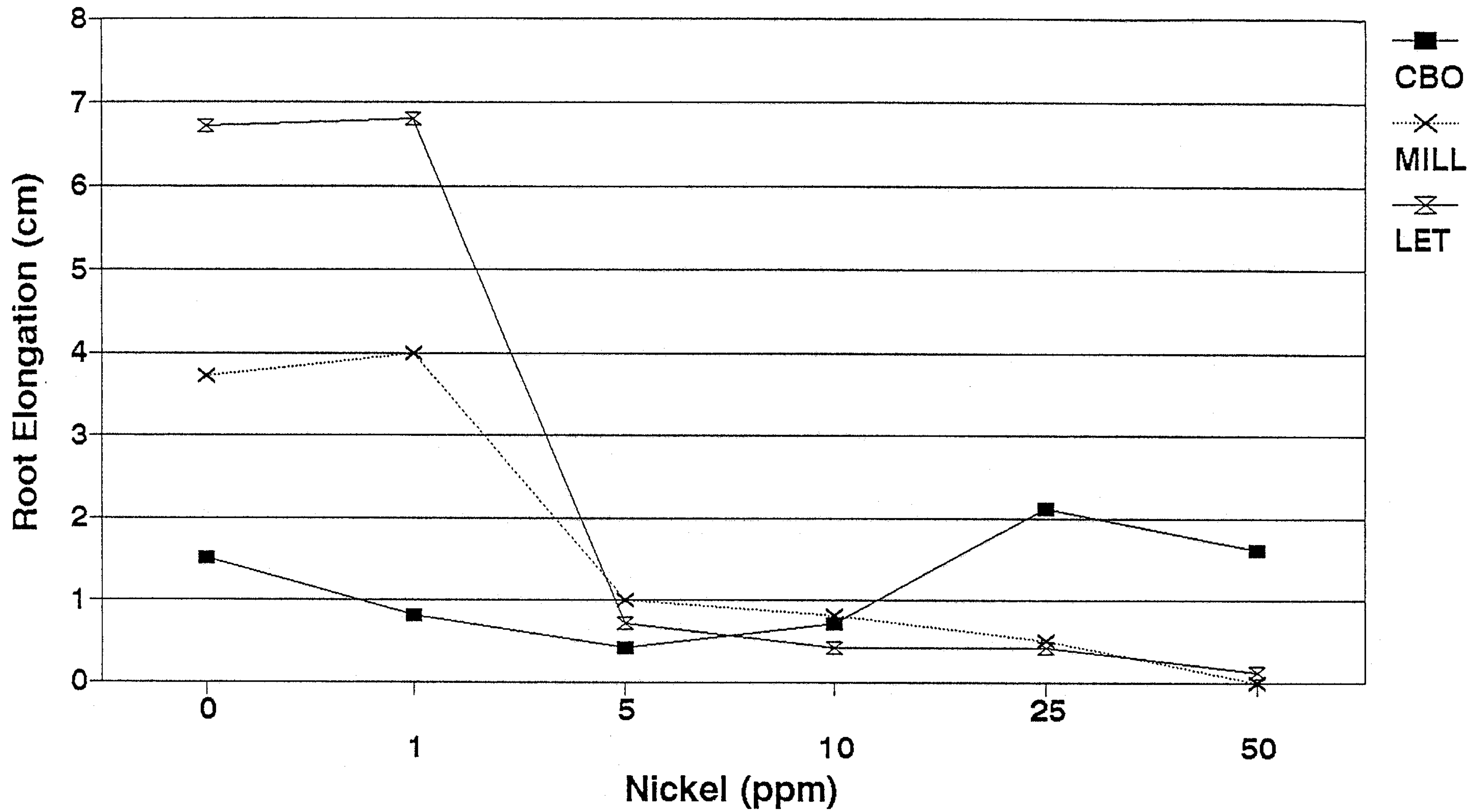


Figure 68. Root elongation in relation to dose rate for three species. CBO = cherrybark oak, MILL = millet, LET = lettuce

Appendix 1. Statistical analysis of seed germination data.

Probit analysis was performed on the seed germination data using TOXCALC statistical software from Tidepool Scientific Software.

Species	Chem	NOEL(ppm)	LOEL(ppm)	EC Value(ppm)
LIST	PCE	10	50	UTA
LIST	NI	50	>50	UTA
LIST	MEOH	0.5	5	UTA
LIST	Cd	10	50	UTA
LIST	ATRA	1	5	UTA
LIST	ANTH	1	5	UTA
LASA	PCE	UTA	UTA	UTA
LASA	NI	50	>50	UTA
LASA	MEOH	5	>5	UTA
LASA	Cd	UTA	UTA	UTA
LASA	ATRA	50	>50	UTA
LASA	ANTH	50	>50	UTA
CEOC	PCE	50	>50	UTA
CEOC	NI	25	50	UTA
CEOC	MEOH	5	25	UTA
CEOC	Cd	25	50	UTA
CEOC	ATRA	25	50	EC05=17.97
CEOC	ANTH	25	50	UTA
RASA	PCE	50	>50	UTA
RASA	NI	50	>50	UTA
RASA	MEOH	5	>5	EC10=2.38
RASA	Cd	50	>50	UTA
RASA	ATRA	50	>50	UTA
RASA	ANTH	50	>50	EC10=28.16
QUFA	PCE	50	>50	UTA
QUFA	NI	50	>50	UTA
QUFA	MEOH	25	>25	UTA
QUFA	Cd	50	>50	UTA
QUFA	ATRA	50	>50	UTA
QUFA	ANTH	50	>50	UTA
PAMI	PCE	50	>50	UTA
PAMI	NI	50	>50	EC10=49.56
PAMI	MEOH	2.5	5	EC10=2.61
PAMI	Cd	25	50	EC10=29.6
PAMI	ATRA	50	>50	EC10=34.84
PAMI	ANTH	25	50	EC10=9.94
SACE	PCE	50	>50	UTA
SACE	NI	50	>50	UTA
SACE	MEOH	25	>25	UTA
SACE	Cd	50	>50	UTA
SACE	ATRA	50	>50	UTA
SACE	ANTH	50	>50	UTA

-Proportion Germinated

Start Date:		Test ID:	2	Sample ID:	
End Date:		Lab ID:		Sample Type:	
Sample Date:		Protocol: MBP 90-Anderson et al.		Test Species:	CEOC
Comments:					

Conc-%	1	2	3	4	5
B-Control	0.4000	0.8000	0.8000	0.2000	0.2000
0.5	0.6000	0.8000	0.6000	0.8000	0.4000
5	0.4000	0.6000	0.4000	0.4000	0.2000
25	0.2000	0.0000	0.4000	0.4000	0.0000

			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
B-Control	0.4800	1.0000	0.7653	0.4636	1.1071	42.454	5				5	12
0.5	0.6400	1.3333	0.9342	0.6847	1.1071	19.050	5	-1.010	2.230	0.3730	5	16
5	0.4000	0.8333	0.6808	0.4636	0.8861	21.953	5	0.505	2.230	0.3730	5	10
*25	0.2000	0.4167	0.3666	0.0000	0.6847	94.548	5	2.384	2.230	0.3730	3	5

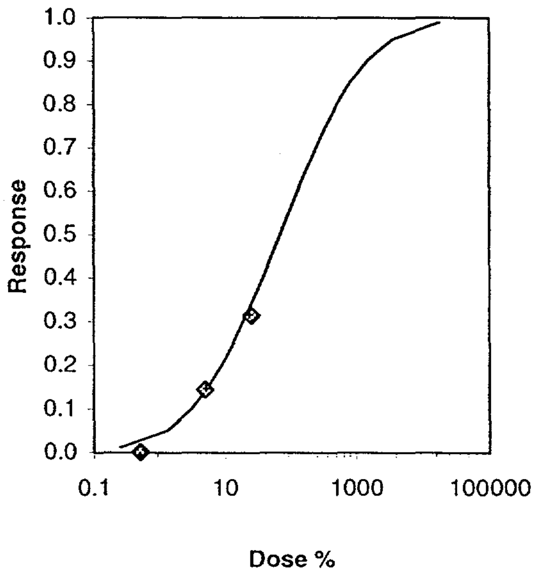
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)	0.9262	0.868	-0.0644	-1.2416
Bartlett's Test indicates equal variances (p = 0.31)	3.5512	11.345		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSB	MSE	F-Stat	F-Prob	df
Dunnett's Test	5	25	11.18	20	0.3337	0.2832	0.0699	4.0502	0.0255	3, 16

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	0.9548	2.2106	-3.3779	5.2875	0.4167	0.0158	6.6349	0.9	1.8338	1.0473	6
Intercept	3.2491	2.5588	-1.7662	8.2644							
TSCR	0.4064	0.1228	0.1658	0.6471							

Point	Probits	%	95% Fiducial Limits
EC01	2.674	0.2496	
EC05	3.355	1.2915	
EC10	3.718	3.1016	
EC15	3.964	5.6016	
EC20	4.158	8.9607	
EC25	4.326	13.409	
EC40	4.747	37.023	
EC50	5.000	68.204	
EC60	5.253	125.65	
EC75	5.674	346.92	
EC80	5.842	519.12	
EC85	6.036	830.44	
EC90	6.282	1499.8	
EC95	6.645	3601.9	
EC99	7.326	18633	



-Proportion Germinated

t Date:		Test ID:	62	Sample ID:	
Date:		Lab ID:		Sample Type:	
ple Date:		Protocol:	MBP 90-Anderson et al.	Test Species:	CEOC
nments:					

onc-ppm	1	2	3	4	5
B-Control	0.4000	0.8000	0.8000	0.2000	0.2000
0.5	0.2000	0.4000	0.4000	0.8000	0.8000
1	0.4000	1.0000	0.2000	0.6000	0.6000
5	0.8000	0.8000	0.8000	0.6000	0.8000
10	1.0000	0.8000	0.8000	1.0000	0.8000
25	0.6000	0.8000	0.6000	0.4000	0.8000
50	0.0000	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed		
onc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.4800	1.0000	0.7653	0.4636	1.1071	42.454	5			5	12
0.5	0.5200	1.0833	0.8095	0.4636	1.1071	35.372	5	29.00	16.00	5	13
1	0.5600	1.1667	0.8532	0.4636	1.3453	38.181	5	29.50	16.00	4	14
5	0.7600	1.5833	1.0629	0.8861	1.1071	9.301	5	34.00	16.00	5	19
10	0.8800	1.8333	1.2024	1.1071	1.3453	10.848	5	37.00	16.00	3	22
25	0.6400	1.3333	0.9342	0.6847	1.1071	19.050	5	31.50	16.00	5	16
*50	0.0000	0.0000	0.0045	0.0045	0.0045	0.000	5	15.00	16.00	0.0005	0.0005

iliary Tests	Statistic	Critical	Skew	Kurt
piro-Wilk's Test indicates normal distribution (p > 0.01)	0.9708	0.91	0.2962	0.0829
ality of variance cannot be confirmed				

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
l's Many-One Rank Test	25	50	35.355	

-Proportion Germinated

Start Date:	Test ID: 2	Sample ID:	
End Date:	Lab ID:	Sample Type:	
Sample Date:	Protocol: MBP 90-Anderson et al.	Test Species:	CEOC
Comments:			

Conc-%	1	2	3	4	5
B-Control	0.4000	0.8000	0.8000	0.2000	0.2000
0.1	0.6000	0.4000	0.2000	0.2000	0.6000
0.5	0.8000	0.8000	0.4000	0.6000	0.8000
1	0.8000	0.4000	0.8000	0.4000	0.4000
5	0.2000	0.8000	0.4000	0.6000	0.0000
10	0.6000	0.4000	0.8000	0.4000	0.6000
50	1.0000	0.8000	0.2000	0.2000	0.8000

			Transform: Arcsin Square Root					1-Tailed				
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD		
B-Control	0.4800	1.0000	0.7653	0.4636	1.1071	42.454	5				5	12
0.1	0.4000	0.8333	0.6768	0.4636	0.8861	31.213	5	0.471	2.409	0.4523	5	10
0.5	0.6800	1.4167	0.9784	0.6847	1.1071	19.425	5	-1.135	2.409	0.4523	5	17
1	0.5600	1.1667	0.8537	0.6847	1.1071	27.103	5	-0.471	2.409	0.4523	5	14
5	0.4000	0.8333	0.6283	0.0000	1.1071	67.561	5	0.729	2.409	0.4523	4	10
10	0.5600	1.1667	0.8497	0.6847	1.1071	20.667	5	-0.450	2.409	0.4523	5	14
50	0.6000	1.2500	0.8974	0.4636	1.3453	45.432	5	-0.704	2.409	0.4523	4	15

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.9652		0.91		-0.2397	-0.5857
Bartlett's Test indicates equal variances (p = 0.44)					5.8168		16.812			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSB**	**MSE**	**F-Stat**	**F-Prob**	**df**
Dunnett's Test	50	>50		2	0.3851	0.0768	0.0882	0.8714	0.5281	6, 28

-Proportion Germinated

Date:		Test ID:	62	Sample ID:	
Date:		Lab ID:		Sample Type:	
ple Date:		Protocol: MBP	90-Anderson et al.	Test Species:	LASA
ments:					

onc-%	1	2	3	4	5
B-Control	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	1.0000	1.0000
50	0.6000	1.0000	1.0000	1.0000	1.0000

			Transform: Arcsin Square Root					Rank	1-Tailed
onc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical
B-Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5		
0.5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
10	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
25	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
50	0.9200	0.9200	1.2534	0.8861	1.3453	16.384	5	25.00	16.00

liary Tests	Statistic	Critical	Skew	Kurt
iro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.3883	0.91	-4.1486	23.085
lity of variance cannot be confirmed				

thesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
's Many-One Rank Test	50	>50		2

-Proportion Germinated

Start Date:	Test ID: 62	Sample ID:
End Date:	Lab ID:	Sample Type:
Sample Date:	Protocol: MBP 90-Anderson et al.	Test Species: LASA
Comments:		

Conc-%	1	2	3	4	5
B-Control	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	0.8000	1.0000
50	1.0000	1.0000	1.0000	1.0000	1.0000

			Transform: Arcsin Square Root					Rank	1-Tailed
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical
B-Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5		
0.5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
10	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
25	0.9600	0.9600	1.2977	1.1071	1.3453	8.207	5	25.00	16.00
50	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.3883	0.91	-4.1486	23.085
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	50	>50		2

-Proportion Germinated

Date:		Test ID:	70	Sample ID:	
Date:		Lab ID:		Sample Type:	
ple Date:		Protocol:	MBP 90-Anderson et al.	Test Species:	LASA.MEOH
ments:					

nc-ppm	1	2	3	4	5
B-Control	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000	1.0000
2.5	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	0.8000	1.0000	0.8000	0.8000

			Transform: Arcsin Square Root					Rank	1-Tailed		
nc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5			0	25
0.1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00	0	25
0.2	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00	0	25
0.5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00	0	25
1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00	0	25
2.5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00	0	25
5	0.8800	0.8800	1.2024	1.1071	1.3453	10.848	5	20.00	16.00	3	22

liary Tests	Statistic	Critical	Skew	Kurt
iro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.5202	0.91	1.1291	6.1818
lity of variance cannot be confirmed				

thesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
's Many-One Rank Test	5	>5		

-Proportion Germinated

Date:	Test ID: 62	Sample ID:	
Date:	Lab ID:	Sample Type:	
ple Date:	Protocol: MBP 90-Anderson et al.	Test Species:	LASA
ments:			

onc-%	1	2	3	4	5
B-Control	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	1.0000	1.0000
50	0.8000	1.0000	1.0000	1.0000	1.0000

			Transform: Arcsin Square Root					Rank	1-Tailed
onc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical
B-Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5		
0.5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
10	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
25	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	5	27.50	16.00
50	0.9600	0.9600	1.2977	1.1071	1.3453	8.207	5	25.00	16.00

liary Tests	Statistic	Critical	Skew	Kurt
iro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.3883	0.91	-4.1486	23.085
lity of variance cannot be confirmed				

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
's Many-One Rank Test	50	>50		2

-Proportion Germinated

Start Date:	Test ID: 2	Sample ID:
End Date:	Lab ID:	Sample Type:
Sample Date:	Protocol: MBP 90-Anderson et al.	Test Species: LIST
Comments:		

Conc-%	1	2	3	4	5
B-Control	1.0000	0.8000	0.8000	0.8000	1.0000
0.1	1.0000	1.0000	1.0000	1.0000	0.6000
0.5	1.0000	0.8000	1.0000	1.0000	0.8000
1	1.0000	1.0000	1.0000	1.0000	0.8000
5	0.2000	0.6000	0.0000	0.0000	0.0000
10	1.0000	1.0000	0.8000	0.8000	0.8000
50	0.0000	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.8800	1.0000	1.2024	1.1071	1.3453	10.848	5			3	22
0.1	0.9200	1.0455	1.2534	0.8861	1.3453	16.384	5	31.00	16.00	1	23
0.5	0.9200	1.0455	1.2500	1.1071	1.3453	10.434	5	30.00	16.00	2	23
1	0.9600	1.0909	1.2977	1.1071	1.3453	8.207	5	32.50	16.00	1	24
*5	0.1600	0.1818	0.2699	0.0000	0.8861	147.686	5	15.00	16.00	2	4
10	0.8800	1.0000	1.2024	1.1071	1.3453	10.848	5	27.50	16.00	3	22
*50	0.0000	0.0000	0.0045	0.0045	0.0045	0.000	5	15.00	16.00	0.0005	0.0005

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)	0.9144	0.91	0.7569	3.4549
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	1	5	2.2361	100

-Proportion Germinated

ırt Date:	Test ID: 2	Sample ID:	
d Date:	Lab ID:	Sample Type:	
mple Date:	Protocol: MBP 90-Anderson et al.	Test Species:	LIST
mments:			

Conc-%	1	2	3	4	5
B-Control	1.0000	0.8000	0.8000	0.8000	1.0000
0.1	0.8000	1.0000	1.0000	0.8000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	0.6000	1.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000
50	0.8000	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.8800	1.0000	1.2024	1.1071	1.3453	10.848	5			3	22
0.1	0.9200	1.0455	1.2500	1.1071	1.3453	10.434	5	30.00	16.00	2	23
0.5	1.0000	1.1364	1.3453	1.3453	1.3453	0.000	5	35.00	16.00	0	25
1	0.9200	1.0455	1.2534	0.8861	1.3453	16.384	5	31.00	16.00	1	23
*5	0.0000	0.0000	0.0045	0.0045	0.0045	0.000	5	15.00	16.00	0.0005	0.0005
10	1.0000	1.1364	1.3453	1.3453	1.3453	0.000	5	35.00	16.00	0	25
50	0.1600	0.1818	0.2214	0.0000	1.1071	223.607	5	16.50	16.00	1	4

‹iliary Tests	Statistic	Critical	Skew	Kurt
apiro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.7349	0.91	2.5671	12.57
ıality of variance cannot be confirmed				

ɔothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
el's Many-One Rank Test	1	5	2.2361	100

-Proportion Germinated

Start Date:	Test ID: 2	Sample ID:
End Date:	Lab ID:	Sample Type:
Sample Date:	Protocol: MBP 90-Anderson et al.	Test Species: LIST
Comments:		

Conc-%	1	2	3	4	5
B-Control	1.0000	0.8000	0.8000	0.8000	1.0000
0.1	1.0000	0.8000	1.0000	0.8000	1.0000
0.5	1.0000	1.0000	0.8000	1.0000	0.8000
1	1.0000	0.8000	1.0000	1.0000	0.8000
5	1.0000	1.0000	1.0000	1.0000	1.0000
10	1.0000	0.8000	1.0000	1.0000	1.0000
50	0.2000	0.4000	0.6000	0.6000	0.6000

			Transform: Arcsin Square Root					Rank	1-Tailed
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical
B-Control	0.8800	1.0000	1.2024	1.1071	1.3453	10.848	5		
0.1	0.9200	1.0455	1.2500	1.1071	1.3453	10.434	5	30.00	16.00
0.5	0.9200	1.0455	1.2500	1.1071	1.3453	10.434	5	30.00	16.00
1	0.9200	1.0455	1.2500	1.1071	1.3453	10.434	5	30.00	16.00
5	1.0000	1.1364	1.3453	1.3453	1.3453	0.000	5	35.00	16.00
10	0.9600	1.0909	1.2977	1.1071	1.3453	8.207	5	32.50	16.00
*50	0.4800	0.5455	0.7613	0.4636	0.8861	24.676	5	15.00	16.00

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.8884	0.91	-0.676	-0.5326
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	10	50	22.361	10

-Proportion Germinated

rt Date:		Test ID: 2		Sample ID:	
l Date:		Lab ID:		Sample Type:	
nple Date:		Protocol: MBP 90-Anderson et al.		Test Species:	LIST
nments:					

Conc-%	1	2	3	4	5
B-Control	1.0000	0.8000	0.8000	0.8000	1.0000
0.5	0.8000	1.0000	1.0000	1.0000	0.8000
5	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.8800	1.0000	1.2024	1.1071	1.3453	10.848	5			3	22
0.5	0.9200	1.0455	1.2500	1.1071	1.3453	10.434	5	30.00	17.00	2	23
*5	0.0000	0.0000	0.0045	0.0045	0.0045	0.000	5	15.00	17.00	0.0005	0.0005
*10	0.0000	0.0000	0.0045	0.0045	0.0045	0.000	5	15.00	17.00	0.0005	0.0005

iliary Tests	Statistic	Critical	Skew	Kurt
piro-Wilk's Test indicates normal distribution (p > 0.01)	0.8885	0.868	#######	-0.4967
ality of variance cannot be confirmed				

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
l's Many-One Rank Test	0.5	5	1.5811	200

-Proportion Germinated

Start Date:	Test ID: 2	Sample ID:	
End Date:	Lab ID:	Sample Type:	
Sample Date:	Protocol: MBP 90-Anderson et al.	Test Species:	LIST
Comments:			

Conc-%	1	2	3	4	5
B-Control	1.0000	0.8000	0.8000	0.8000	1.0000
0.1	1.0000	0.8000	1.0000	1.0000	1.0000
0.5	1.0000	0.8000	1.0000	0.8000	1.0000
1	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	0.8000	1.0000	1.0000
50	0.6000	0.2000	0.4000	0.8000	0.6000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.8800	1.0000	1.2024	1.1071	1.3453	10.848	5			3	22
0.1	0.9600	1.0909	1.2977	1.1071	1.3453	8.207	5	32.50	16.00	1	24
0.5	0.9200	1.0455	1.2500	1.1071	1.3453	10.434	5	30.00	16.00	2	23
1	1.0000	1.1364	1.3453	1.3453	1.3453	0.000	5	35.00	16.00	0	25
5	1.0000	1.1364	1.3453	1.3453	1.3453	0.000	5	35.00	16.00	0	25
10	0.9600	1.0909	1.2977	1.1071	1.3453	8.207	5	32.50	16.00	1	24
50	0.5200	0.5909	0.8055	0.4636	1.1071	30.117	5	16.50	16.00	5	13

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)	0.9339	0.91	-0.5157	1.8556
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	50	>50		2

-Proportion Germinated

t Date:		Test ID: 2		Sample ID:	
Date:		Lab ID:		Sample Type:	
ıple Date:		Protocol: MBP 90-Anderson et al.		Test Species:	LIST
ıments:					

Conc-%	1	2	3	4	5
B-Control	1.0000	0.8000	0.8000	0.8000	1.0000
0.1	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	0.8000	0.8000	1.0000	0.8000	1.0000
1	1.0000	1.0000	1.0000	1.0000	1.0000
5	0.0000	0.0000	0.0000	0.8000	0.0000
10	0.4000	1.0000	0.6000	1.0000	1.0000
50	0.0000	0.6000	0.0000	0.2000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.8800	1.0000	1.2024	1.1071	1.3453	10.848	5			3	22
0.1	1.0000	1.1364	1.3453	1.3453	1.3453	0.000	5	35.00	16.00	0	25
0.5	0.8800	1.0000	1.2024	1.1071	1.3453	10.848	5	27.50	16.00	3	22
1	1.0000	1.1364	1.3453	1.3453	1.3453	0.000	5	35.00	16.00	0	25
5	0.1600	0.1818	0.2214	0.0000	1.1071	223.607	5	16.50	16.00	1	4
10	0.8000	0.9091	1.1213	0.6847	1.3453	28.075	5	27.00	16.00	2	20
*50	0.1600	0.1818	0.2699	0.0000	0.8861	147.686	5	15.00	16.00	2	4

iliary Tests	Statistic	Critical	Skew	Kurt
piro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.8751	0.91	1.5264	4.0569
ality of variance cannot be confirmed				

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
l's Many-One Rank Test	10	50	22.361	10

-Proportion Germinated

Start Date:	Test ID:	70	Sample ID:		
End Date:	Lab ID:		Sample Type:		
Sample Date:	Protocol:	MBP 90-Anderson et al.	Test Species:	PAMI-ANTH	
Comments:					

Conc-ppm	1	2	3	4	5
B-Control	0.8000	0.6000	0.8000	0.6000	1.0000
0.5	1.0000	0.8000	0.4000	0.6000	0.6000
1	0.8000	0.4000	1.0000	0.8000	0.6000
5	1.0000	0.6000	0.8000	1.0000	0.2000
10	0.8000	0.4000	0.6000	0.4000	0.6000
25	0.4000	0.8000	0.6000	0.6000	0.4000
50	0.2000	0.6000	0.4000	0.0000	0.0000

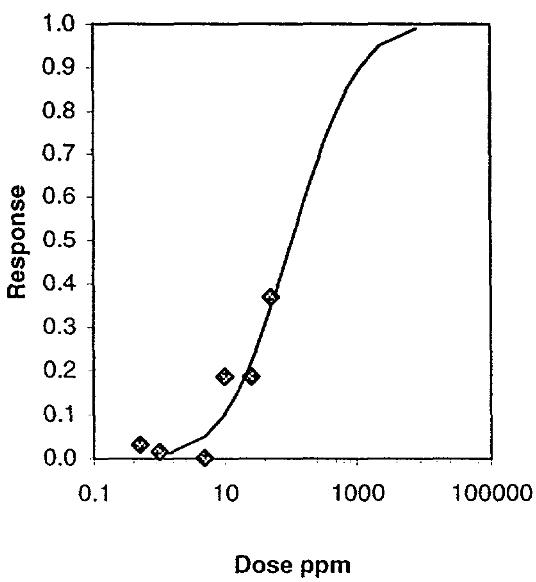
			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
B-Control	0.7600	1.0000	1.0663	0.8861	1.3453	17.924	5				4	19
0.5	0.6800	0.8947	0.9819	0.6847	1.3453	25.686	5	0.489	2.409	0.4158	4	17
1	0.7200	0.9474	1.0261	0.6847	1.3453	24.421	5	0.233	2.409	0.4158	4	18
5	0.7200	0.9474	1.0295	0.4636	1.3453	35.895	5	0.214	2.409	0.4158	3	18
10	0.5600	0.7368	0.8497	0.6847	1.1071	20.667	5	1.255	2.409	0.4158	5	14
25	0.5600	0.7368	0.8497	0.6847	1.1071	20.667	5	1.255	2.409	0.4158	5	14
*50	0.2400	0.3158	0.4069	0.0000	0.8861	98.395	5	3.820	2.409	0.4158	3	6

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.9674		0.91		-0.1729	-0.4271
Bartlett's Test indicates equal variances (p = 0.51)					5.2332		16.812			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSB**	**MSE**	**F-Stat**	**F-Prob**	**df**
Dunnett's Test	25	50	35.355		0.3996	0.2617	0.0745	3.5136	0.0102	6, 28

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	1.2377	1.3919	-1.4904	3.9658	0.2105	0.4754	13.277	0.98	2.0328	0.808	6
Intercept	2.4841	1.9328	-1.3042	6.2723							
TSCR	0.2174	0.0623	0.0953	0.3395							

Point	Probits	ppm	95% Fiducial Limits
EC01	2.674	1.4229	
EC05	3.355	5.056	
EC10	3.718	9.939	
EC15	3.964	15.682	
EC20	4.158	22.532	
EC25	4.326	30.749	
EC40	4.747	67.313	
EC50	5.000	107.84	
EC60	5.253	172.78	
EC75	5.674	378.23	
EC80	5.842	516.17	
EC85	6.036	741.64	
EC90	6.282	1170.2	
EC95	6.645	2300.3	
EC99	7.326	8173.4	



-Proportion Germinated

t Date:	Test ID: 70	Sample ID:	
Date:	Lab ID:	Sample Type:	
ıple Date:	Protocol: MBP 90-Anderson et al.	Test Species:	PAMI-ATRA
ıments:			

ɔnc-ppm	1	2	3	4	5
B-Control	0.8000	0.6000	0.8000	0.6000	1.0000
0.5	0.8000	1.0000	1.0000	0.6000	0.8000
1	0.4000	0.2000	1.0000	0.8000	0.8000
5	0.6000	0.4000	0.8000	0.6000	0.4000
10	0.8000	0.8000	0.4000	0.4000	0.6000
25	1.0000	0.8000	0.6000	0.6000	0.4000
50	0.4000	1.0000	0.4000	0.4000	0.8000

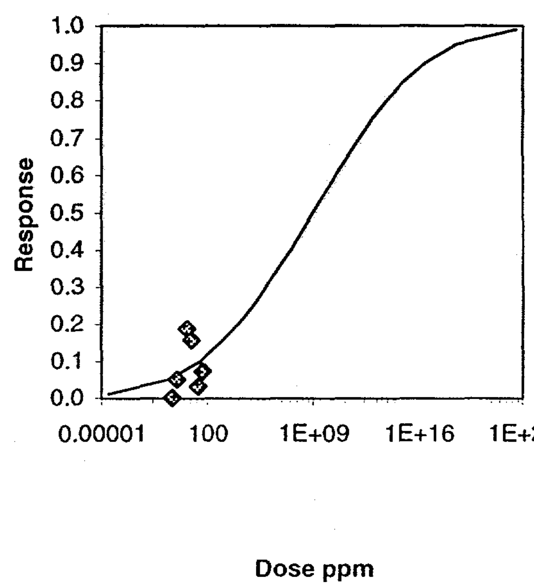
			Transform: Arcsin Square Root						1-Tailed		Number	Total
ɔnc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
B-Control	0.7600	1.0000	1.0663	0.8861	1.3453	17.924	5				4	19
0.5	0.8400	1.1053	1.1582	0.8861	1.3453	16.679	5	-0.582	2.409	0.3802	3	21
1	0.6400	0.8421	0.9416	0.4636	1.3453	38.004	5	0.790	2.409	0.3802	4	16
5	0.5600	0.7368	0.8497	0.6847	1.1071	20.667	5	1.372	2.409	0.3802	5	14
10	0.6000	0.7895	0.8940	0.6847	1.1071	23.632	5	1.092	2.409	0.3802	5	15
25	0.6800	0.8947	0.9819	0.6847	1.3453	25.686	5	0.535	2.409	0.3802	4	17
50	0.6000	0.7895	0.9013	0.6847	1.3453	34.206	5	1.045	2.409	0.3802	4	15

ıliary Tests					Statistic		Critical		Skew	Kurt
ɔiro-Wilk's Test indicates normal distribution (p > 0.01)					0.9606		0.91		0.1302	-0.7841
ıett's Test indicates equal variances (p = 0.76)					3.3532		16.812			
ɔthesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSB	MSE	F-Stat	F-Prob	df
ıett's Test	50	>50			0.365	0.0588	0.0623	0.9446	0.4795	6, 28

Maximum Likelihood-Probit

ımeter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
e	0.1716	0.5896	-0.9841	1.3273	0.2105	1.2724	13.277	0.87	9.0103	5.8275	13
ɔept	3.4538	0.9828	1.5276	5.3801							
R	0.2074	0.0929	0.0253	0.3896							

t	Probits	ppm	95% Fiducial Limits
1	2.674	#######	
5	3.355	0.266	
)	3.718	34.841	
5	3.964	934.38	
)	4.158	12758	
5	4.326	120157	
)	4.747	3E+07	
)	5.000	1E+09	
)	5.253	3E+10	
5	5.674	9E+12	
)	5.842	8E+13	
5	6.036	1E+15	
)	6.282	3E+16	
5	6.645	4E+18	
)	7.326	#######	



-Proportion Germinated

Start Date:		Test ID:	70	Sample ID:	
End Date:		Lab ID:		Sample Type:	
Sample Date:		Protocol:	MBP 90-Anderson et al.	Test Species:	PAMI-Cd
Comments:					

Conc-ppm	1	2	3	4	5
B-Control	0.8000	0.6000	0.8000	0.6000	1.0000
0.5	0.4000	0.8000	0.6000	1.0000	1.0000
1	0.8000	1.0000	0.8000	1.0000	0.2000
5	1.0000	1.0000	0.6000	1.0000	0.8000
10	0.8000	0.8000	0.6000	0.8000	1.0000
25	0.6000	0.6000	1.0000	0.4000	0.6000
50	0.2000	0.2000	0.6000	0.4000	0.4000

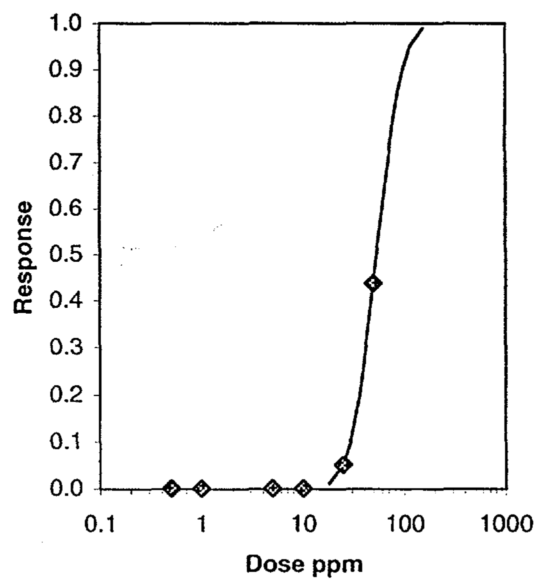
			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
B-Control	0.7600	1.0000	1.0663	0.8861	1.3453	17.924	5				4	19
0.5	0.7600	1.0000	1.0737	0.6847	1.3453	26.959	5	-0.048	2.409	0.3691	3	19
1	0.7600	1.0000	1.0737	0.4636	1.3453	33.642	5	-0.048	2.409	0.3691	3	19
5	0.8800	1.1579	1.2058	0.8861	1.3453	17.113	5	-0.910	2.409	0.3691	2	22
10	0.8000	1.0526	1.1106	0.8861	1.3453	14.625	5	-0.289	2.409	0.3691	4	20
25	0.6400	0.8421	0.9376	0.6847	1.3453	26.021	5	0.840	2.409	0.3691	4	16
*50	0.3600	0.4737	0.6366	0.4636	0.8861	27.958	5	2.805	2.409	0.3691	5	9

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.965		0.91		-0.4973	0.4276
Bartlett's Test indicates equal variances (p = 0.70)					3.8146		16.812			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSB**	**MSE**	**F-Stat**	**F-Prob**	**df**
Dunnett's Test	25	50	35.355		0.3541	0.1702	0.0587	2.8995	0.0251	6, 28

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	4.9357	4.9491	-4.7644	14.636	0.2105	#######	13.277	1	1.7311	0.2026	3
Intercept	-3.544	8.218	-19.651	12.563							
TSCR	0.2105	0.0411	0.13	0.291							

Point	Probits	ppm	95% Fiducial Limits
EC01	2.674	18.186	
EC05	3.355	24.992	
EC10	3.718	29.608	
EC15	3.964	33.195	
EC20	4.158	36.353	
EC25	4.326	39.301	
EC40	4.747	47.833	
EC50	5.000	53.834	
EC60	5.253	60.588	
EC75	5.674	73.741	
EC80	5.842	79.721	
EC85	6.036	87.306	
EC90	6.282	97.882	
EC95	6.645	115.96	
EC99	7.326	159.36	



 ToxCalc v5.0 Reviewed by:______

-Proportion Germinated

t Date:		Test ID: 70		Sample ID:	
Date:		Lab ID:		Sample Type:	
ıple Date:		Protocol: MBP 90-Anderson et al.		Test Species:	PAMI-MEOH
ıments:					

onc-ppm	1	2	3	4	5
B-Control	0.8000	0.6000	0.8000	0.6000	1.0000
0.1	1.0000	1.0000	1.0000	0.6000	0.6000
0.2	0.8000	0.8000	0.6000	0.4000	0.4000
0.5	1.0000	0.6000	0.8000	0.2000	0.6000
1	0.6000	0.2000	0.6000	1.0000	0.6000
2.5	0.4000	0.6000	0.4000	1.0000	0.4000
5	0.2000	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root						1-Tailed		Number	Total
onc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
B-Control	0.7600	1.0000	1.0663	0.8861	1.3453	17.924	5				4	19
0.1	0.8400	1.1053	1.1616	0.8861	1.3453	21.653	5	-0.579	2.409	0.3960	2	21
0.2	0.6000	0.7895	0.8940	0.6847	1.1071	23.632	5	1.049	2.409	0.3960	5	15
0.5	0.6400	0.8421	0.9376	0.4636	1.3453	34.759	5	0.783	2.409	0.3960	4	16
1	0.6000	0.7895	0.8934	0.4636	1.3453	34.907	5	1.052	2.409	0.3960	4	15
2.5	0.5600	0.7368	0.8571	0.6847	1.3453	33.425	5	1.273	2.409	0.3960	4	14
*5	0.0400	0.0526	0.0927	0.0000	0.4636	223.607	5	5.922	2.409	0.3960	1	1

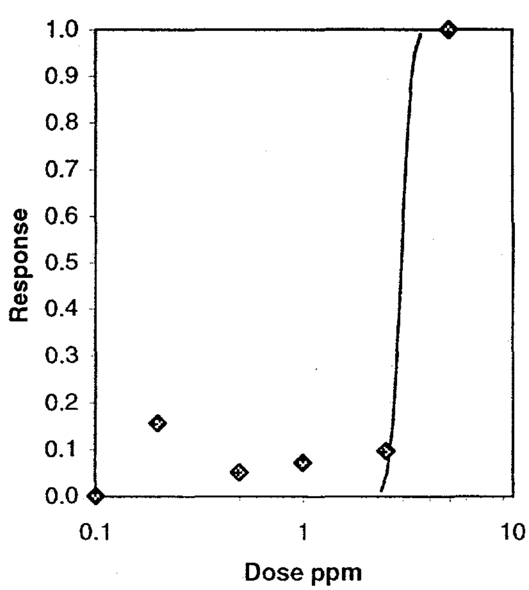
iliary Tests	Statistic	Critical	Skew	Kurt
oiro-Wilk's Test indicates normal distribution (p > 0.01)	0.9663	0.91	0.2744	-0.2865
ett's Test indicates equal variances (p = 0.92)	1.9592	16.812		

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSB	MSE	F-Stat	F-Prob	df
ıett's Test	2.5	5	3.5355		0.3804	0.6072	0.0676	8.9859	1.7E-05	6, 28

Maximum Likelihood-Probit

ımeter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
e	24.369	3849.7	-7521	7569.7	0.2105	0.569	13.277	0.97	0.4699	0.041	25
cept	-6.4517	1531.9	-3009	2996.1							
R	0.2615	0.0523	0.1591	0.364							

t	Probits	ppm	95% Fiducial Limits
1	2.674	2.3685	
5	3.355	2.526	
0	3.718	2.6142	
5	3.964	2.6755	
0	4.158	2.7252	
5	4.326	2.7686	
0	4.747	2.881	
0	5.000	2.9508	
0	5.253	3.0223	
5	5.674	3.145	
0	5.842	3.195	
5	6.036	3.2544	
0	6.282	3.3306	
5	6.645	3.4469	
9	7.326	3.6762	



-Proportion Germinated

Start Date:	Test ID:	11	Sample ID:		
End Date:	Lab ID:		Sample Type:		
Sample Date:	Protocol:	MBP 90-Anderson et al.	Test Species:	PAMI-NI	
Comments:					

Conc-ppm	1	2	3	4	5
B-Control	0.8000	0.6000	0.8000	0.6000	1.0000
0.5	0.8000	1.0000	1.0000	1.0000	1.0000
1	0.8000	0.6000	0.8000	0.8000	0.8000
5	0.4000	0.4000	1.0000	0.8000	1.0000
10	0.8000	0.6000	0.8000	0.6000	0.4000
25	1.0000	0.6000	0.6000	0.8000	0.8000
50	0.6000	0.6000	0.8000	0.8000	0.2000

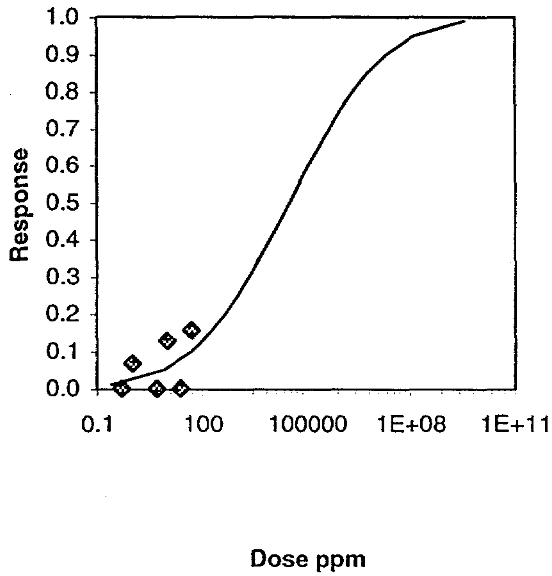
			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
B-Control	0.7600	1.0000	1.0663	0.8861	1.3453	17.924	5				4	19
0.5	0.9600	1.2632	1.2977	1.1071	1.3453	8.207	5	-1.750	2.409	0.3183	1	24
1	0.7600	1.0000	1.0629	0.8861	1.1071	9.301	5	0.026	2.409	0.3183	5	19
5	0.7200	0.9474	1.0334	0.6847	1.3453	32.208	5	0.249	2.409	0.3183	3	18
10	0.6400	0.8421	0.9342	0.6847	1.1071	19.050	5	1.000	2.409	0.3183	5	16
25	0.7600	1.0000	1.0663	0.8861	1.3453	17.924	5	0.000	2.409	0.3183	4	19
50	0.6000	0.7895	0.8900	0.4636	1.1071	29.520	5	1.334	2.409	0.3183	5	15

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.9363		0.91		-0.3551	-0.2892
Bartlett's Test indicates equal variances (p = 0.25)					7.7933		16.812			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSB**	**MSE**	**F-Stat**	**F-Prob**	**df**
Dunnett's Test	50	>50			0.3037	0.0844	0.0437	1.9333	0.1102	6, 28

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	0.4566	1.3999	-2.2873	3.2005	0.2105	0.9553	13.277	0.92	4.5021	2.1903	8
Intercept	2.9445	2.0337	-1.0416	6.9306							
TSCR	0.2147	0.0885	0.0413	0.3882							

Point	Probits	ppm	95% Fiducial Limits
EC01	2.674	0.2551	
EC05	3.355	7.9331	
EC10	3.718	49.564	
EC15	3.964	170.62	
EC20	4.158	455.75	
EC25	4.326	1058.7	
EC40	4.747	8855.4	
EC50	5.000	31776	
EC60	5.253	114025	
EC75	5.674	953702	
EC80	5.842	2E+06	
EC85	6.036	6E+06	
EC90	6.282	2E+07	
EC95	6.645	1E+08	
EC99	7.326	4E+09	



-Proportion Germinated

t Date:	Test ID: 70	Sample ID:	
Date:	Lab ID:	Sample Type:	
nple Date:	Protocol: MBP 90-Anderson et al.	Test Species:	PAMI-PCE
nments:			

onc-ppm	1	2	3	4	5
1	0.8000	0.6000	0.8000	0.6000	1.0000
0.5	0.6000	1.0000	0.6000	0.8000	1.0000
1	0.8000	0.8000	0.8000	0.6000	0.6000
5	0.2000	0.8000	1.0000	0.6000	0.8000
10	1.0000	0.8000	0.8000	0.2000	1.0000
25	0.8000	1.0000	0.4000	0.6000	0.6000
50	0.8000	0.6000	1.0000	0.4000	1.0000

			Transform: Arcsin Square Root						1-Tailed		Number	Total
onc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
B-Control	0.7600	1.0000	1.0663	0.8861	1.3453	17.924	5				4	19
0.5	0.8000	1.0526	1.1140	0.8861	1.3453	20.614	5	-0.284	2.409	0.4039	3	20
1	0.7200	0.9474	1.0187	0.8861	1.1071	11.886	5	0.284	2.409	0.4039	5	18
5	0.6800	0.8947	0.9819	0.4636	1.3453	33.825	5	0.504	2.409	0.4039	4	17
10	0.7600	1.0000	1.0737	0.4636	1.3453	33.642	5	-0.044	2.409	0.4039	3	19
25	0.6800	0.8947	0.9819	0.6847	1.3453	25.686	5	0.504	2.409	0.4039	4	17
50	0.7600	1.0000	1.0737	0.6847	1.3453	26.959	5	-0.044	2.409	0.4039	3	19

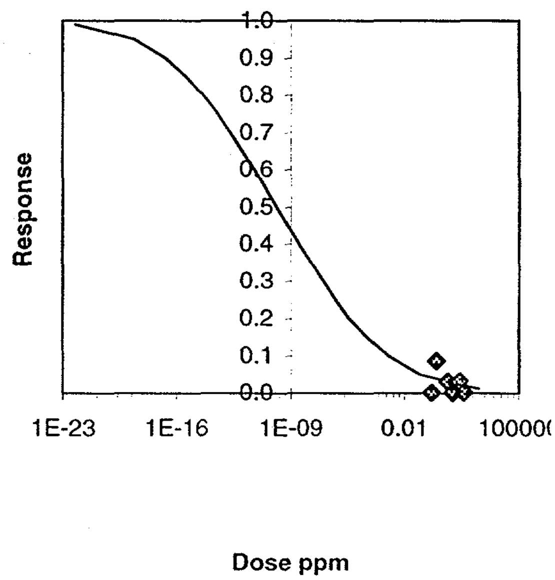
iliary Tests	Statistic	Critical	Skew	Kurt
piro-Wilk's Test indicates normal distribution (p > 0.01)	0.9512	0.91	-0.6042	0.0696
ett's Test indicates equal variances (p = 0.55)	4.9863	16.812		

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSB	MSE	F-Stat	F-Prob	df
nett's Test	50	>50			0.3881	0.0129	0.0703	0.184	0.9789	6, 28

Maximum Likelihood-Probit

meter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
e	-0.1871	1.4558	-3.0404	2.6662	0.2105	0.3472	13.277	0.99	-9.8349	-5.3445	7
cept	3.1598	2.1142	-0.9839	7.3035							
R	0.2088	0.093	0.0265	0.3911							

t	Probits	ppm	95% Fiducial Limits
1	2.674	396.49	
5	3.355	0.0904	
0	3.718	0.001	
5	3.964	#######	
0	4.158	#######	
5	4.326	#######	
0	4.747	#######	
0	5.000	#######	
0	5.253	#######	
5	5.674	#######	
0	5.842	#######	
5	6.036	#######	
0	6.282	#######	
5	6.645	#######	
9	7.326	#######	



 ToxCalc v5.0 Reviewed by:______

-Proportion Germinated

Start Date:	Test ID: 2	Sample ID:	
End Date:	Lab ID:	Sample Type:	
Sample Date:	Protocol: MBP 90-Anderson et al.	Test Species:	QUFA
Comments:			

Conc-ppm	1	2	3	4	5
B-Control	0.2000	0.2000	0.0000	0.0000	0.2000
0.1	0.6000	0.2000	0.0000	0.2000	0.4000
0.5	0.6000	0.2000	0.4000	0.0000	0.6000
1	0.2000	0.4000	0.0000	0.2000	0.4000
5	0.2000	0.2000	0.2000	0.6000	0.0000
10	0.2000	0.6000	0.4000	0.4000	0.0000
50	0.0000	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.1200	1.0000	0.2782	0.0000	0.4636	91.287	5			3	3
0.1	0.2800	2.3333	0.4996	0.0000	0.8861	66.067	5	33.00	16.00	4	7
0.5	0.3600	3.0000	0.5841	0.0000	0.8861	63.379	5	34.50	16.00	4	9
1	0.2400	2.0000	0.4593	0.0000	0.6847	60.861	5	33.00	16.00	4	6
5	0.2400	2.0000	0.4554	0.0000	0.8861	68.835	5	31.50	16.00	4	6
10	0.3200	2.6667	0.5438	0.0000	0.8861	62.290	5	34.50	16.00	4	8
50	0.0000	0.0002	0.0045	0.0045	0.0045	0.000	5	25.00	16.00	0.0005	0.0005

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution ($p > 0.01$)	0.9157	0.91	-0.7187	-0.0358
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	50	>50		

-Proportion Germinated

rt Date:	Test ID:	2		Sample ID:	
l Date:	Lab ID:			Sample Type:	
nple Date:	Protocol:	MBP	90-Anderson et al.	Test Species:	QUFA
nments:					

onc-ppm	1	2	3	4	5
B-Control	0.2000	0.2000	0.0000	0.0000	0.2000
0.1	0.0000	0.4000	0.0000	0.2000	0.2000
0.5	0.4000	0.0000	0.4000	0.2000	0.2000
1	0.2000	0.0000	0.4000	0.4000	0.0000
5	0.4000	0.6000	0.2000	0.0000	0.0000
10	0.2000	0.4000	0.6000	0.2000	0.6000
50	0.6000	0.4000	0.4000	0.4000	0.2000

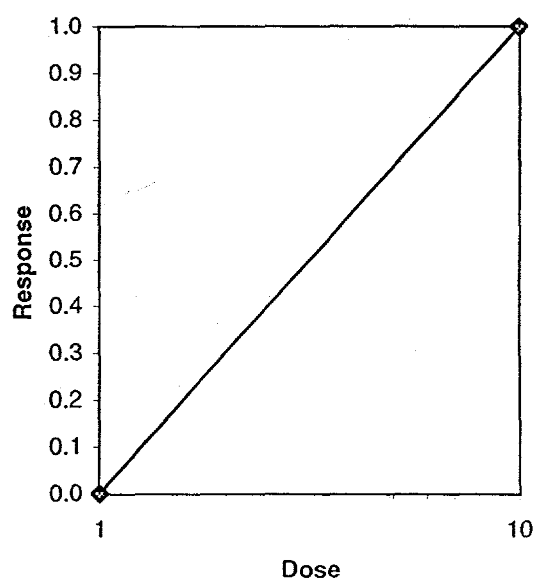
			Transform: Arcsin Square Root						1-Tailed		Number	Total
onc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
B-Control	0.1200	1.0000	0.2782	0.0000	0.4636	91.287	5				3	3
0.1	0.1600	1.3333	0.3224	0.0000	0.6847	95.483	5	-0.242	2.409	0.4403	3	4
0.5	0.2400	2.0000	0.4593	0.0000	0.6847	60.861	5	-0.991	2.409	0.4403	4	6
1	0.2000	1.6667	0.3666	0.0000	0.6847	94.548	5	-0.484	2.409	0.4403	3	5
5	0.2400	2.0000	0.4069	0.0000	0.8861	98.395	5	-0.704	2.409	0.4403	3	6
10	0.4000	3.3333	0.6768	0.4636	0.8861	31.213	5	-2.181	2.409	0.4403	5	10
50	0.4000	3.3333	0.6808	0.4636	0.8861	21.953	5	-2.202	2.409	0.4403	5	10

iliary Tests					Statistic		Critical		Skew	Kurt
piro-Wilk's Test indicates normal distribution (p > 0.01)					0.926		0.91		-0.2606	-1.1563
lett's Test indicates equal variances (p = 0.66)					4.1298		16.812			
othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSB	MSE	F-Stat	F-Prob	df
nett's Test	50	>50			0.0494	0.1326	0.0835	1.5877	0.1877	6, 28

Maximum Likelihood-Probit

meter	Value	SE	95% Fiducial Limits	Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter

t	Probits	ppm	95% Fiducial Limits



-Proportion Germinated

Start Date:	Test ID:	2	Sample ID:	
End Date:	Lab ID:		Sample Type:	
Sample Date:	Protocol: MBP	90-Anderson et al.	Test Species:	QUFA
Comments:				

Conc-ppm	1	2	3	4	5
B-Control	0.2000	0.2000	0.0000	0.0000	0.2000
0.1	0.4000	0.2000	0.2000	0.0000	0.6000
0.5	0.2000	0.4000	0.2000	0.2000	0.0000
1	0.0000	0.0000	0.2000	0.2000	0.4000
5	0.2000	0.2000	0.4000	0.2000	0.4000
10	0.2000	0.0000	0.0000	0.0000	0.2000
50	0.4000	0.6000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					1-Tailed				
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD		
B-Control	0.1200	1.0000	0.2782	0.0000	0.4636	91.287	5				3	3
0.1	0.2800	2.3333	0.4996	0.0000	0.8861	66.067	5	-1.195	2.409	0.4462	4	7
0.5	0.2000	1.6667	0.4151	0.0000	0.6847	60.471	5	-0.739	2.409	0.4462	4	5
1	0.1600	1.3333	0.3224	0.0000	0.6847	95.483	5	-0.239	2.409	0.4462	3	4
5	0.2800	2.3333	0.5521	0.4636	0.6847	21.933	5	-1.479	2.409	0.4462	5	7
10	0.0800	0.6667	0.1855	0.0000	0.4636	136.931	5	0.501	2.409	0.4462	2	2
50	0.2000	1.6667	0.3142	0.0000	0.8861	138.793	5	-0.194	2.409	0.4462	2	5

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.9643		0.91		0.0355	-0.8418
Bartlett's Test indicates equal variances (p = 0.48)					5.5195		16.812			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSB**	**MSE**	**F-Stat**	**F-Prob**	**df**
Dunnett's Test	50	>50			0.0475	0.0832	0.0858	0.9693	0.4638	6, 28

-Proportion Germinated

Date:		Test ID:	2	Sample ID:	
Date:		Lab ID:		Sample Type:	
ple Date:		Protocol: MBP	90-Anderson et al.	Test Species:	QUFA
ments:					

onc-%	1	2	3	4	5
B-Control	0.2000	0.2000	0.0000	0.0000	0.2000
0.1	0.0000	0.0000	0.0000	0.0000	0.0000
0.5	0.0000	0.4000	0.2000	0.0000	0.2000
1	0.0000	0.0000	0.0000	0.4000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.2000
2.5	0.0000	0.0000	0.0000	0.0000	0.0000
25	0.0000	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed		
onc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.1200	1.0000	0.2782	0.0000	0.4636	91.287	5			3	3
0.1	0.0000	0.0002	0.0045	0.0045	0.0045	0.000	5	25.00	16.00	0.0005	0.0005
0.5	0.1600	1.3333	0.3224	0.0000	0.6847	95.483	5	29.00	16.00	3	4
1	0.0800	0.6667	0.1369	0.0000	0.6847	223.607	5	24.00	16.00	1	2
5	0.0400	0.3333	0.0927	0.0000	0.4636	223.607	5	22.50	16.00	1	1
2.5	0.0000	0.0002	0.0045	0.0045	0.0045	0.000	5	25.00	16.00	0.0005	0.0005
25	0.0000	0.0002	0.0045	0.0045	0.0045	0.000	5	25.00	16.00	0.0005	0.0005

iary Tests	Statistic	Critical	Skew	Kurt
iro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.9042	0.91	0.7881	1.5143
lity of variance cannot be confirmed				

thesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
s Many-One Rank Test	25	>25		4

-Proportion Germinated

Start Date:	Test ID:	2	Sample ID:		
End Date:	Lab ID:		Sample Type:		
Sample Date:	Protocol: MBP	90-Anderson et al.	Test Species:	QUFA	
Comments:					

Conc-%	1	2	3	4	5
B-Control	0.2000	0.2000	0.0000	0.0000	0.2000
0.1	0.0000	0.2000	0.0000	0.2000	0.4000
0.5	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.2000	0.2000	0.0000
5	0.0000	0.0000	0.6000	0.0000	0.0000
10	0.2000	0.2000	0.2000	0.2000	0.4000
50	0.2000	0.6000	0.4000	0.6000	0.6000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.1200	1.0000	0.2782	0.0000	0.4636	91.287	5			3	3
0.1	0.1600	1.3333	0.3224	0.0000	0.6847	95.483	5	29.00	16.00	3	4
0.5	0.0000	0.0002	0.0045	0.0045	0.0045	0.000	5	25.00	16.00	0.0005	0.0005
1	0.0800	0.6667	0.1855	0.0000	0.4636	136.931	5	25.00	16.00	2	2
5	0.1200	1.0000	0.1772	0.0000	0.8861	223.607	5	24.00	16.00	1	3
10	0.2400	2.0000	0.5079	0.4636	0.6847	19.467	5	34.00	16.00	5	6
50	0.4800	4.0000	0.7613	0.4636	0.8861	24.676	5	38.50	16.00	5	12

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)	0.9354	0.91	0.8465	1.4242
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	50	>50		2

-Proportion Germinated

t Date:	Test ID: 2	Sample ID:	
l Date:	Lab ID:	Sample Type:	
nple Date:	Protocol: MBP 90-Anderson et al.	Test Species:	QUFA
nments:			

onc-ppm	1	2	3	4	5
B-Control	0.2000	0.2000	0.0000	0.0000	0.2000
0.1	0.4000	0.0000	0.2000	0.2000	0.6000
0.5	0.4000	0.2000	0.6000	0.0000	0.2000
1	0.4000	0.0000	0.6000	0.2000	0.2000
5	0.6000	0.4000	0.2000	0.4000	0.2000
10	0.2000	0.0000	0.6000	0.2000	0.0000
50	0.6000	0.2000	0.2000	0.2000	0.6000

			Transform: Arcsin Square Root						1-Tailed			
onc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD		
B-Control	0.1200	1.0000	0.2782	0.0000	0.4636	91.287	5				3	3
0.1	0.2800	2.3333	0.4996	0.0000	0.8861	66.067	5	-1.180	2.409	0.4519	4	7
0.5	0.2800	2.3333	0.4996	0.0000	0.8861	66.067	5	-1.180	2.409	0.4519	4	7
1	0.2800	2.3333	0.4996	0.0000	0.8861	66.067	5	-1.180	2.409	0.4519	4	7
5	0.3600	3.0000	0.6366	0.4636	0.8861	27.958	5	-1.910	2.409	0.4519	5	9
10	0.2000	1.6667	0.3627	0.0000	0.8861	102.929	5	-0.450	2.409	0.4519	3	5
50	0.3600	3.0000	0.6326	0.4636	0.8861	36.574	5	-1.889	2.409	0.4519	5	9

iliary Tests	Statistic	Critical	Skew	Kurt
piro-Wilk's Test indicates normal distribution (p > 0.01)	0.9599	0.91	-0.2121	-0.6163
lett's Test indicates equal variances (p = 0.85)	2.6597	16.812		

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSB	MSE	F-Stat	F-Prob	df
nett's Test	50	>50			0.0456	0.0859	0.088	0.9766	0.4593	6, 28

-Proportion Germinated

Start Date:		Test ID:	62	Sample ID:	
End Date:		Lab ID:		Sample Type:	
Sample Date:		Protocol: MBP	90-Anderson et al.	Test Species:	RASA
Comments:					

Conc-%	1	2	3	4	5
B-Control	1.0000	1.0000	0.8000	0.8000	1.0000
0.5	0.8000	1.0000	0.8000	1.0000	1.0000
1	1.0000	0.6000	0.8000	1.0000	1.0000
5	1.0000	0.8000	1.0000	1.0000	1.0000
10	0.8000	1.0000	1.0000	0.4000	1.0000
25	0.0000	0.8000	1.0000	0.8000	0.8000
50	0.6000	0.8000	0.8000	0.8000	0.8000

			Transform: Arcsin Square Root					Rank	1-Tailed	Number	Total
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Resp	Number
B-Control	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5			2	23
0.5	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5	27.50	16.00	2	23
1	0.8800	0.9565	1.2058	0.8861	1.3453	17.113	5	26.50	16.00	2	22
5	0.9600	1.0435	1.2977	1.1071	1.3453	8.207	5	30.00	16.00	1	24
10	0.8400	0.9130	1.1655	0.6847	1.3453	24.700	5	26.50	16.00	2	21
25	0.6800	0.7391	0.9333	0.0000	1.3453	56.983	5	21.50	16.00	3	17
50	0.7600	0.8261	1.0629	0.8861	1.1071	9.301	5	19.00	16.00	5	19

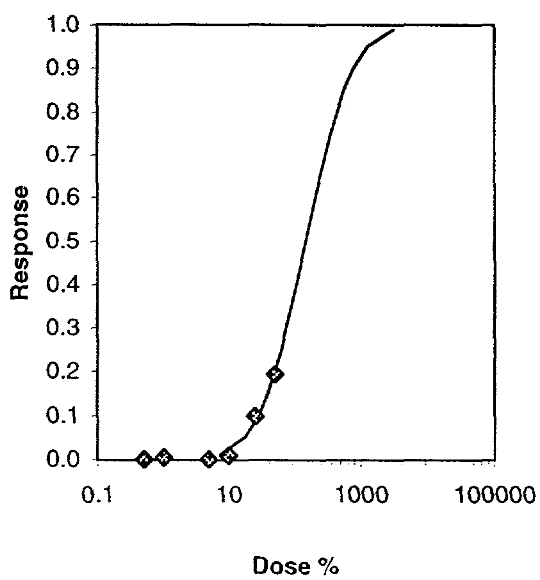
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.8083	0.91	-2.1194	6.9049
Bartlett's Test indicates unequal variances (p = 4.43E-03)	18.845	16.812		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	50	>50		2

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	1.7633	1.9088	-1.9779	5.5045	0.087	0.0507	13.277	1	2.1765	0.5671	6
Intercept	1.1622	3.0425	-4.801	7.1254							
TSCR	0.0859	0.0313	0.0246	0.1472							

Point	Probits	%	95% Fiducial Limits
EC01	2.674	7.1974	
EC05	3.355	17.525	
EC10	3.718	28.164	
EC15	3.964	38.789	
EC20	4.158	50.025	
EC25	4.326	62.226	
EC40	4.747	107.85	
EC50	5.000	150.14	
EC60	5.253	209.01	
EC75	5.674	362.24	
EC80	5.842	450.59	
EC85	6.036	581.12	
EC90	6.282	800.35	
EC95	6.645	1286.2	
EC99	7.326	3131.9	



-Proportion Germinated

t Date:		Test ID: 62		Sample ID:	
Date:		Lab ID:		Sample Type:	
ple Date:		Protocol: MBP 90-Anderson et al.		Test Species:	RASA
ments:					

onc-%	1	2	3	4	5
B-Control	1.0000	1.0000	0.8000	0.8000	1.0000
0.5	0.8000	0.8000	1.0000	1.0000	0.8000
1	1.0000	1.0000	0.8000	1.0000	0.8000
5	1.0000	1.0000	1.0000	1.0000	0.8000
10	1.0000	1.0000	1.0000	1.0000	0.6000
25	0.8000	1.0000	1.0000	0.6000	0.8000
50	0.8000	1.0000	1.0000	0.8000	1.0000

			Transform: Arcsin Square Root					Rank	1-Tailed	Number	Total
onc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Resp	Number
B-Control	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5			2	23
0.5	0.8800	0.9565	1.2024	1.1071	1.3453	10.848	5	25.00	16.00	3	22
1	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5	27.50	16.00	2	23
5	0.9600	1.0435	1.2977	1.1071	1.3453	8.207	5	30.00	16.00	1	24
10	0.9200	1.0000	1.2534	0.8861	1.3453	16.384	5	29.00	16.00	1	23
25	0.8400	0.9130	1.1582	0.8861	1.3453	16.679	5	24.00	16.00	3	21
50	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5	27.50	16.00	2	23

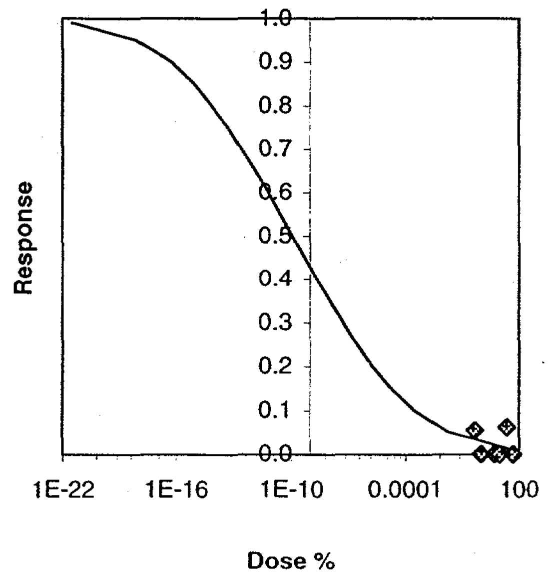
liary Tests	Statistic	Critical	Skew	Kurt
piro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.8781	0.91	-0.8149	-0.0594
ett's Test indicates equal variances (p = 0.85)	2.667	16.812		

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
's Many-One Rank Test	50	>50		2

Maximum Likelihood-Probit

meter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
e	-0.2007	1.2063	-2.565	2.1637	0.087	0.7729	13.277	0.94	-9.9064	-4.9829	8
ept	3.0119	1.6207	-0.1646	6.1885							
R	0.0892	0.0592	-0.0268	0.2051							

t	Probits	%	95% Fiducial Limits
	2.674	48.491	
	3.355	0.0195	
	3.718	0.0003	
	3.964	#######	
	4.158	#######	
	4.326	#######	
	4.747	#######	
	5.000	#######	
	5.253	#######	
	5.674	#######	
	5.842	#######	
	6.036	#######	
	6.282	#######	
	6.645	#######	
	7.326	#######	



-Proportion Germinated

Start Date:	Test ID: 62	Sample ID:	
End Date:	Lab ID:	Sample Type:	
Sample Date:	Protocol: MBP 90-Anderson et al.	Test Species:	RASA
Comments:			

Conc-%	1	2	3	4	5
B-Control	1.0000	1.0000	0.8000	0.8000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	0.8000	0.8000	1.0000
5	0.6000	1.0000	1.0000	1.0000	0.0000
10	0.6000	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	1.0000	1.0000
50	0.6000	1.0000	1.0000	0.6000	0.8000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5			2	23
0.5	1.0000	1.0870	1.3453	1.3453	1.3453	0.000	5	32.50	16.00	0	25
1	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5	27.50	16.00	2	23
5	0.7200	0.7826	0.9844	0.0000	1.3453	59.439	5	25.50	16.00	1	18
10	0.9200	1.0000	1.2534	0.8861	1.3453	16.384	5	29.00	16.00	1	23
25	1.0000	1.0870	1.3453	1.3453	1.3453	0.000	5	32.50	16.00	0	25
50	0.8000	0.8696	1.1140	0.8861	1.3453	20.614	5	23.00	16.00	3	20

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.8108	0.91	-2.0684	8.3798
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	50	>50		2

-Propotion Germinated

rt Date:		Test ID:	70	Sample ID:	
l Date:		Lab ID:		Sample Type:	
nple Date:		Protocol:	MBP 90-Anderson et al.	Test Species:	RASA
nments:					

onc-ppm	1	2	3	4	5
B-Control	1.0000	1.0000	0.8000	0.8000	1.0000
0.1	1.0000	1.0000	0.6000	0.8000	1.0000
0.2	0.8000	0.8000	1.0000	1.0000	1.0000
0.5	0.6000	1.0000	1.0000	1.0000	0.8000
1	1.0000	0.8000	0.4000	0.8000	0.8000
2.5	1.0000	0.6000	0.6000	1.0000	1.0000
5	0.4000	0.6000	0.8000	0.8000	0.6000

			Transform: Arcsin Square Root					Rank	1-Tailed	Number	Total
onc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Resp	Number
B-Control	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5			2	23
0.1	0.8800	0.9565	1.2058	0.8861	1.3453	17.113	5	26.50	16.00	2	22
0.2	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5	27.50	16.00	2	23
0.5	0.8800	0.9565	1.2058	0.8861	1.3453	17.113	5	26.50	16.00	2	22
1	0.7600	0.8261	1.0703	0.6847	1.3453	22.324	5	21.50	16.00	4	19
2.5	0.8400	0.9130	1.1616	0.8861	1.3453	21.653	5	25.50	16.00	2	21
5	0.6400	0.6957	0.9342	0.6847	1.1071	19.050	5	17.00	16.00	5	16

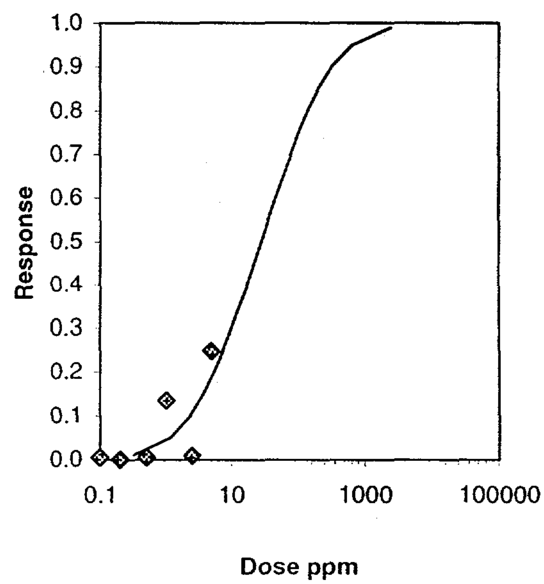
iliary Tests	Statistic	Critical	Skew	Kurt
piro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.898	0.91	-0.6707	-0.7345
lett's Test indicates equal variances (p = 0.83)	2.8518	16.812		

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
l's Many-One Rank Test	5	>5		

Maximum Likelihood-Probit

meter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
e	1.198	1.3793	-1.5054	3.9014	0.087	2.5928	13.277	0.63	1.447	0.8347	5
cept	3.2664	0.7612	1.7745	4.7584							
R	0.0902	0.0406	0.0107	0.1698							

t	Probits	ppm	95% Fiducial Limits
1	2.674	0.32	
5	3.355	1.1859	
0	3.718	2.384	
5	3.964	3.8187	
0	4.158	5.553	
5	4.326	7.6566	
0	4.747	17.202	
0	5.000	27.993	
0	5.253	45.553	
5	5.674	102.34	
0	5.842	141.11	
5	6.036	205.2	
0	6.282	328.68	
5	6.645	660.73	
9	7.326	2448.4	



-Propotion Germinated

Start Date:	Test ID:	70	Sample ID:		
End Date:	Lab ID:		Sample Type:		
Sample Date:	Protocol: MBP	90-Anderson et al.	Test Species:	RASA	
Comments:					

Conc-ppm	1	2	3	4	5
1	1.0000	1.0000	0.8000	0.8000	1.0000
0.5	1.0000	1.0000	0.8000	0.4000	0.8000
1	0.8000	0.8000	1.0000	1.0000	0.0000
5	1.0000	1.0000	1.0000	1.0000	0.8000
10	0.8000	1.0000	0.8000	1.0000	0.8000
25	1.0000	0.8000	1.0000	1.0000	0.6000
50	1.0000	0.8000	0.8000	0.8000	0.6000

			Transform: Arcsin Square Root					Rank	1-Tailed	Number	Total
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Resp	Number
B-Control	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5			2	23
0.5	0.8000	0.8696	1.1179	0.6847	1.3453	24.139	5	24.00	16.00	3	20
1	0.7200	0.7826	0.9810	0.0000	1.3453	57.204	5	24.00	16.00	2	18
5	0.9600	1.0435	1.2977	1.1071	1.3453	8.207	5	30.00	16.00	1	24
10	0.8800	0.9565	1.2024	1.1071	1.3453	10.848	5	25.00	16.00	3	22
25	0.8800	0.9565	1.2058	0.8861	1.3453	17.113	5	26.50	16.00	2	22
50	0.8000	0.8696	1.1106	0.8861	1.3453	14.625	5	21.50	16.00	4	20

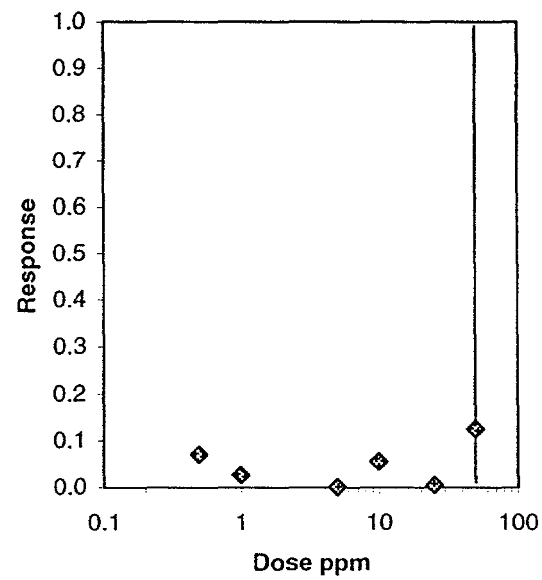
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.8475	0.91	-2.0241	7.0077
Bartlett's Test indicates unequal variances (p = 8.10E-03)	17.344	16.812		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	50	>50		

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	-514107	6E+06	-1E+07	1E+07	0.087	0.0053	13.277	1	1.699	#######	25
Intercept	873456	1E+07	-2E+07	2E+07							
TSCR	0.1169	0.0355	0.0473	0.1865							

Point	Probits	ppm	95% Fiducial Limits
EC01	2.674	50	
EC05	3.355	50	
EC10	3.718	50	
EC15	3.964	50	
EC20	4.158	50	
EC25	4.326	50	
EC40	4.747	50	
EC50	5.000	50	
EC60	5.253	50	
EC75	5.674	50	
EC80	5.842	50	
EC85	6.036	49.999	
EC90	6.282	49.999	
EC95	6.645	49.999	
EC99	7.326	49.999	



-Proportion Germinated

rt Date:		Test ID:	62	Sample ID:	
l Date:		Lab ID:		Sample Type:	
nple Date:		Protocol:	MBP 90-Anderson et al.	Test Species:	RASA
nments:					

Conc-%	1	2	3	4	5
B-Control	1.0000	1.0000	0.8000	0.8000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000	1.0000
1	0.6000	1.0000	0.8000	1.0000	0.6000
5	0.8000	0.8000	0.4000	1.0000	0.8000
10	0.8000	1.0000	0.8000	1.0000	0.8000
25	0.8000	1.0000	1.0000	1.0000	1.0000
50	1.0000	0.8000	1.0000	1.0000	1.0000

			Transform: Arcsin Square Root					Rank	1-Tailed	Number	Total
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Resp	Number
B-Control	0.9200	1.0000	1.2500	1.1071	1.3453	10.434	5			2	23
0.5	1.0000	1.0870	1.3453	1.3453	1.3453	0.000	5	32.50	16.00	0	25
1	0.8000	0.8696	1.1140	0.8861	1.3453	20.614	5	23.00	16.00	3	20
5	0.7600	0.8261	1.0703	0.6847	1.3453	22.324	5	21.50	16.00	4	19
10	0.8800	0.9565	1.2024	1.1071	1.3453	10.848	5	25.00	16.00	3	22
25	0.9600	1.0435	1.2977	1.1071	1.3453	8.207	5	30.00	16.00	1	24
50	0.9600	1.0435	1.2977	1.1071	1.3453	8.207	5	30.00	16.00	1	24

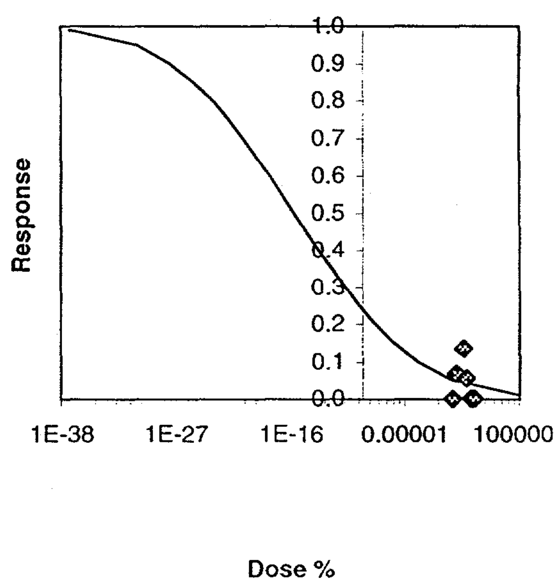
iliary Tests	Statistic	Critical	Skew	Kurt
piro-Wilk's Test indicates normal distribution (p > 0.01)	0.9454	0.91	-0.549	0.7188
ality of variance cannot be confirmed				

othesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
l's Many-One Rank Test	50	>50		2

Maximum Likelihood-Probit

ameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
e	-0.1078	0.515	-1.1172	0.9016	0.087	2.4186	13.277	0.66	-15.593	-9.2791	5
cept	3.3195	0.8565	1.6408	4.9982							
R	0.0854	0.0583	-0.0289	0.1997							

t	Probits	%	95% Fiducial Limits
1	2.674	984286	
5	3.355	0.4671	
0	3.718	0.0002	
5	3.964	#######	
0	4.158	#######	
5	4.326	#######	
0	4.747	#######	
0	5.000	#######	
0	5.253	#######	
5	5.674	#######	
0	5.842	#######	
5	6.036	#######	
0	6.282	#######	
5	6.645	#######	
9	7.326	#######	



 ToxCalc v5.0 Reviewed by:_____

-Proportion Germinated

Start Date:		Test ID:	2	Sample ID:	
End Date:		Lab ID:		Sample Type:	
Sample Date:		Protocol:	MBP 90-Anderson et al.	Test Species:	SACE
Comments:					

Conc-ppm	1	2	3	4	5
B-Control	0.6000	0.0000	0.2000	0.4000	0.2000
0.1	0.6000	0.0000	0.6000	0.0000	0.6000
0.5	0.4000	0.6000	0.2000	0.8000	0.6000
1	0.6000	0.4000	0.6000	0.4000	0.4000
5	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.8000	0.6000	0.4000	0.8000	1.0000
50	0.0000	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed		
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.2800	1.0000	0.4996	0.0000	0.8861	66.067	5			4	7
0.1	0.3600	1.2857	0.5316	0.0000	0.8861	91.287	5	29.50	16.00	3	9
0.5	0.5200	1.8571	0.8055	0.4636	1.1071	30.117	5	34.50	16.00	5	13
1	0.4800	1.7143	0.7653	0.6847	0.8861	14.412	5	34.50	16.00	5	12
5	0.0000	0.0001	0.0045	0.0045	0.0045	0.000	5	20.00	16.00	0.0005	0.0005
10	0.7200	2.5714	1.0261	0.6847	1.3453	24.421	5	38.00	16.00	4	18
50	0.0000	0.0001	0.0045	0.0045	0.0045	0.000	5	20.00	16.00	0.0005	0.0005

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.9056	0.91	-0.5794	0.4856
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	50	>50		

-Proportion Germinated

Date:	Test ID: 2	Sample ID:	
Date:	Lab ID:	Sample Type:	
ple Date:	Protocol: MBP 90-Anderson et al.	Test Species:	SACE
ments:			

nc-ppm	1	2	3	4	5
B-Control	0.6000	0.0000	0.2000	0.4000	0.2000
0.1	0.2000	0.2000	0.6000	0.2000	0.2000
0.5	0.0000	0.4000	0.4000	0.6000	0.2000
1	0.6000	0.6000	0.6000	0.6000	0.6000
5	0.4000	1.0000	0.2000	0.4000	0.6000
10	0.4000	0.0000	0.8000	0.0000	0.2000
50	0.2000	0.0000	0.0000	0.2000	0.2000

			Transform: Arcsin Square Root					Rank	1-Tailed		
nc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical		
B-Control	0.2800	1.0000	0.4996	0.0000	0.8861	66.067	5			4	7
0.1	0.2800	1.0000	0.5481	0.4636	0.8861	34.465	5	27.50	16.00	5	7
0.5	0.3200	1.1429	0.5438	0.0000	0.8861	62.290	5	29.00	16.00	4	8
1	0.6000	2.1429	0.8861	0.8861	0.8861	0.000	5	37.50	16.00	5	15
5	0.5200	1.8571	0.8129	0.4636	1.3453	40.968	5	33.50	16.00	4	13
10	0.2800	1.0000	0.4511	0.0000	1.1071	104.690	5	26.50	16.00	3	7
50	0.1200	0.4286	0.2782	0.0000	0.4636	91.287	5	22.00	16.00	3	3

iary Tests	Statistic	Critical	Skew	Kurt
iro-Wilk's Test indicates normal distribution (p > 0.01)	0.9699	0.91	0.0751	0.1343
lity of variance cannot be confirmed				

thesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
's Many-One Rank Test	50	>50		

-Proportion Germinated

Start Date:	Test ID: 2	Sample ID:	
End Date:	Lab ID:	Sample Type:	
Sample Date:	Protocol: MBP 90-Anderson et al.	Test Species:	SACE
Comments:			

Conc-ppm	1	2	3	4	5
B-Control	0.6000	0.0000	0.2000	0.4000	0.2000
0.1	0.6000	1.0000	0.6000	0.8000	0.2000
0.5	0.8000	0.4000	0.4000	0.6000	0.8000
1	0.4000	1.0000	0.6000	0.4000	0.6000
5	0.4000	0.8000	0.0000	0.2000	0.4000
10	0.8000	1.0000	0.4000	1.0000	0.4000
50	0.4000	0.0000	0.6000	0.0000	0.0000

			Transform: Arcsin Square Root						1-Tailed			
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD		
B-Control	0.2800	1.0000	0.4996	0.0000	0.8861	66.067	5				4	7
0.1	0.6400	2.2857	0.9376	0.4636	1.3453	34.759	5	-2.054	2.409	0.5137	4	16
0.5	0.6000	2.1429	0.8940	0.6847	1.1071	23.632	5	-1.849	2.409	0.5137	5	15
1	0.6000	2.1429	0.8974	0.6847	1.3453	30.073	5	-1.865	2.409	0.5137	4	15
5	0.3600	1.2857	0.5880	0.0000	1.1071	68.521	5	-0.415	2.409	0.5137	4	9
10	0.7200	2.5714	1.0334	0.6847	1.3453	32.208	5	-2.503	2.409	0.5137	3	18
50	0.2000	0.7143	0.3142	0.0000	0.8861	138.793	5	0.870	2.409	0.5137	2	5

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.9708		0.91		0.0374	-0.8296
Bartlett's Test indicates equal variances (p = 0.88)					2.3625		16.812			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSB**	**MSE**	**F-Stat**	**F-Prob**	**df**
Dunnett's Test	50	>50			0.2293	0.3632	0.1137	3.1942	0.0162	6, 28

-Proportion Germinated

Date:		Test ID:	2	Sample ID:	
Date:		Lab ID:		Sample Type:	
ple Date:		Protocol: MBP	90-Anderson et al.	Test Species:	SACE
ments:					

nc-ppm	1	2	3	4	5
B-Control	0.6000	0.0000	0.2000	0.4000	0.2000
0.5	1.0000	0.8000	0.8000	0.8000	0.4000
5	0.2000	0.0000	0.0000	0.0000	0.0000
25	0.6000	0.6000	0.4000	0.0000	0.0000

			Transform: Arcsin Square Root						1-Tailed	
nc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD
B-Control	0.2800	1.0000	0.4996	0.0000	0.8861	66.067	5			
0.5	0.7600	2.7143	1.0703	0.6847	1.3453	22.324	5	-2.795	2.230	0.4554
5	0.0400	0.1429	0.0927	0.0000	0.4636	223.607	5	1.993	2.230	0.4554
25	0.3200	1.1429	0.4914	0.0000	0.8861	92.807	5	0.040	2.230	0.4554

liary Tests	Statistic	Critical	Skew	Kurt
iro-Wilk's Test indicates normal distribution (p > 0.01)	0.9105	0.868	-0.3515	-0.7332
ett's Test indicates equal variances (p = 0.44)	2.7286	11.345		

thesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSB	MSE	F-Stat	F-Prob	df
ett's Test	25	>25			0.2276	0.8087	0.1043	7.7576	2.0E-03	3, 16

-Proportion Germinated

Start Date:		Test ID:	2	Sample ID:	
End Date:		Lab ID:		Sample Type:	
Sample Date:		Protocol:	MBP 90-Anderson et al.	Test Species:	SACE
Comments:					

Conc-ppm	1	2	3	4	5
B-Control	0.6000	0.0000	0.2000	0.4000	0.2000
0.1	0.2000	0.4000	1.0000	0.2000	0.0000
0.5	0.0000	0.0000	0.6000	0.4000	0.2000
1	0.6000	0.6000	0.4000	0.2000	0.0000
5	1.0000	0.8000	0.8000	0.4000	1.0000
10	0.8000	0.6000	1.0000	1.0000	0.8000
50	0.2000	0.2000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root						1-Tailed			
Conc-ppm	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD		
B-Control	0.2800	1.0000	0.4996	0.0000	0.8861	66.067	5				4	7
0.1	0.3600	1.2857	0.5915	0.0000	1.3453	82.805	5	-0.424	2.409	0.5216	3	9
0.5	0.2400	0.8571	0.4069	0.0000	0.8861	98.395	5	0.428	2.409	0.5216	3	6
1	0.3600	1.2857	0.5841	0.0000	0.8861	63.379	5	-0.390	2.409	0.5216	4	9
5	0.8000	2.8571	1.1179	0.6847	1.3453	24.139	5	-2.855	2.409	0.5216	3	20
10	0.8400	3.0000	1.1582	0.8861	1.3453	16.679	5	-3.041	2.409	0.5216	3	21
50	0.0800	0.2857	0.1855	0.0000	0.4636	136.931	5	1.451	2.409	0.5216	2	2

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.9747		0.91		-0.0331	-0.1129
Bartlett's Test indicates equal variances (p = 0.67)					4.0472		16.812			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSB**	**MSE**	**F-Stat**	**F-Prob**	**df**
Dunnett's Test	50	>50			0.229	0.6521	0.1173	5.5612	6.7E-04	6, 28

Species	Chem	NOEL(ppm)	LOEL(ppm)	EC Value(ppm)
LIST	PCE	10	50	UTA
LIST	NI	50	>50	UTA
LIST	MEOH	0.5	5	UTA
LIST	Cd	10	50	UTA
LIST	ATRA	1	5	UTA
LIST	ANTH	1	5	UTA
LASA	PCE	UTA	UTA	UTA
LASA	NI	50	>50	UTA
LASA	MEOH	5	>5	UTA
LASA	Cd	UTA	UTA	UTA
LASA	ATRA	50	>50	UTA
LASA	ANTH	50	>50	UTA
CEOC	PCE	50	>50	UTA
CEOC	NI	25	50	UTA
CEOC	MEOH	5	25	UTA
CEOC	Cd	25	50	UTA
CEOC	ATRA	25	50	EC05=17.97
CEOC	ANTH	25	50	UTA
RASA	PCE	50	>50	UTA
RASA	NI	50	>50	UTA
RASA	MEOH	5	>5	EC10=2.38
RASA	Cd	50	>50	UTA
RASA	ATRA	50	>50	UTA
RASA	ANTH	50	>50	EC10=28.16
QUFA	PCE	50	>50	UTA
QUFA	NI	50	>50	UTA
QUFA	MEOH	25	>25	UTA
QUFA	Cd	50	>50	UTA
QUFA	ATRA	50	>50	UTA
QUFA	ANTH	50	>50	UTA
PAMI	PCE	50	>50	UTA
PAMI	NI	50	>50	EC10=49.56
PAMI	MEOH	2.5	5	EC10=2.61
PAMI	Cd	25	50	EC10=29.6
PAMI	ATRA	50	>50	EC10=34.84
PAMI	ANTH	25	50	EC10=9.94
SACE	PCE	50	>50	UTA
SACE	NI	50	>50	UTA
SACE	MEOH	25	>25	UTA
SACE	Cd	50	>50	UTA
SACE	ATRA	50	>50	UTA
SACE	ANTH	50	>50	UTA