or biweekly waterings which keep the soil surface wet. Cotton or sorghum is planted on most of the area and requires only one to three supplemental irrigations during the growing season. On a limited acreage of irrigated vegetables and sugarbeets, barnyardgrass is becoming a problem. Since these crops require frequent irrigations, it is possible for barnyard grass to germinate before the soil surface crusts.

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The Determination and Distribution of Toxic Levels of Arsenic in a Silt Loam Soil[1]

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Abstract. To evaluate the effect of different soil moisture levels on the phytotoxicity of soil applications of arsenic trioxide (As_2O_3), water and alcohol extractable soil arsenic (As) data were related to the growth and development of 4-month-old Monterey pine *(Pinus radiata* D. Don.) in greenhouse soil cultures. Also, various rates of As_2O_3 and water were applied to the surface of soil columns to determine the effective penetration of soluble As. Under normal moisture regime, 8000 lb/A of As_2O_3 were required for high phytotoxicity on a Chenango silt loam, with excessive moisture resulting in an increase in this phytotoxic effect. With water and alcohol extraction procedures, an adequate range of values was obtained in relation to the total As_2O_3 rates and plant responses. Lethal concentrations of As in the soil columns were limited to the surface 3 in depth in the silt loam.

Introduction

The natural occurrence of arsenic (As) in most soil ranges between a total of 1 and 70 ppm. However, the effective or available-to-plant form, e.g. water-soluble As, is not related to the total and may be very low in soils with relatively high total amounts (7). The phytotoxic effectiveness of As when applied as arsenic trioxide (As_2O_3) has been related to soil moisture, rate of As application, soil texture, and type of vegetative cover (3, 4, 6 8).

In consideration of the first two factors, objectives of this study were to provide an analytical system which would estimate the quantity of effective As in the soil, and to determine the distribution of this effective form through the soil profile.

Materials and Methods

Greenhouse trial and soil analysis. To provide a series of plant responses which would form the basis with which to relate the results of the analytical system, soil pot cultures were established with Chenango silt loam soil using Monterey pine (*Pinus radiata* D. Don.) as an indicator species for woody plant material. The species was selected for its rapid growth (9). Furthermore, it had previously displayed a consistent sensitivity to As toxicity[3].

The soil was obtained from 8 to 12 in depth in the profile to avoid the Ap or A_1 organic matter-incorporated horizons. The soil had a pH value of 4.8, an organic matter concentration of 4.8%, and contained 30, 48, and 17% of sand, silt, and clay, respectively. After collection, the soil was dried at room temperature, sieved (¼ in square), and the As_2O_3 thoroughly incorporated. The soil was treated with N, P, K, Ca, Mg, and S at the rate of 100, 43, 95, 50, 25, and 34 lb/A/½ ft, respectively, to minimize nutrient deficiencies for Monterey pine during the experiment. Rates of As represented 0, 2, 3, 4, and 5 tons/A/½ ft. One-half L of soil was placed in each 4-in pot which then was seeded with 20 Monterey pine.

The soil moisture regime was maintained at the two levels of normal and excessively moist. In the former case, the pots were watered daily on the surface as necessary to support plant growth. In the latter, each pot was placed in a pint container and the water level of this reservoir maintained at 2½ in below the surface of the soil throughout the experiment. These two levels approached soil field capacity and saturation, respectively.

The pots were set out using a split plot designed factorial experiment with three replications and, throughout the 4 months, seedling emergence and survival were noted. At harvest, plant height, and fresh and dry (60 C) seedling top weights were recorded. The soil from each combination of As rate and water treatment was collected, dried at 105 C, passed through a 20-mesh sieve, and stored for analyses.

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A chemical procedure for determining the available or effective level of an element in the soil consists of (a) the extraction of an effective fraction from the soil, and (b) the quantitative determination of the material in the extract. The first is a problem peculiar to soil chemistry; the latter involves application of standard analytical chemistry techniques.

Selection of an extraction solution is largely an empirical procedure based on the degree of correlation observed between the amount of material extracted and some plant response. However, the nature of the extraction medium determines the fraction of the material extracted and in the case of As, it may be expected that extractants found useful for assessing P availability might be employed. Thus, distilled water extractions were conducted on the soil samples to determine if this extractant would be a suitable measure of effective As. This method sometimes gives very reliable results with P availability tests (2).

Though the As application in the greenhouse trials was in the trioxide form, it is not known which reactions and changes took place in the soil during the study. Since the trioxide form of As is only very slightly soluble while the pentoxide form is soluble in alcohol (5) methyl alcohol extractions also were conducted on the soil samples to assist in understanding As soil chemistry.

In soil analysis with water and alcohol extractions, 1 g of the oven-dry soil from each combination of water treatment as As rate from the greenhouse trial was shaken for 60 min with 50 ml of the extractant. Depending on the initial rate of As_2O_3 to the greenhouse soil, aliquots of 1 to 15 ml of the water and alcohol extractions were taken from the filtrates for analyses. The aliquots contained from 0 to 15 μg As, the exact quantity being determined by arsine evolution, comparing standard solutions of As with the appropriate extractant. This arsine evolution procedure with silver diethyldithiocarbamate (AgDDC) color development (1) was found best to meet the requirements of the analysis as it could be adapted to a wide number of the extraction systems.

Leaching columns. To evaluate the problem of fixation[4] and mobility of As in the soil, a series of leaching columns was established. These columns consisted of glass cylinders 24 by 2.95 in, each filled with the Chenango silt loam. To facilitate removal of the soil from the glass columns after treatment, the inside walls were lined with plastic tubing which could be easily withdrawn with a minimum of disturbance to the uniformly-packed soil.

Each column of soil received the equivalent of 1,000 or 8,000 lb/A of As_2O_3 applied to the soil surface which was covered with glass wool to prevent puddling when the water was added. Each amount of As_2O_3 received 1 or 5 L of distilled water which was applied so as to prevent the formation of a head of water and the column tops were kept covered to minimize evaporation. All treated columns were run in duplicate.

The filtrate was collected throughout the experiment, evaporated to dryness, and dissolved in 50 ml of concentrated HCl. Once the soil had drained free, the column of soil was removed within the plastic casing and the samples were taken from the column at depth intervals. All soil samples were oven-dried and 1 g from each was analyzed for water extractable As as outlined previously.

[4]The conversion in the soil of a highly water soluble to a less soluble form.

Results and Discussion

Greenhouse trial and soil analyses. Under conditions of normal watering, 8,000 lb/A of As_2O_3 were required to attain a high phytotoxic effect (Table 1). By high phytotoxic effect is meant reduction of seedling survival to less than 5% of the number of seeds sown per pot accompanied by reduced seedling height and weight of survivors. Excessive moisture reduced the As_2O_3 requirement by 25% for comparable phytotoxicity, the rate being reduced to 6,000 lb/A of As_2O_3. These large amounts of As_2O_3 required to bring about effective phytotoxicity gave rise to the question whether it was the As which brought about the toxic effect or purely a matter of high salt concentration. Specific conductance determinations, however, showed no toxic salt levels.

Table 1. Response of 4-month-old Monterey pine supported by the Chenango silt loam soil with two moisture regimes as related to rate of As_2O_3 applied to the soil surface.

As_2O_3	Seedling survival[a]	Mean shoot length	Mean shoot weights (mg)			
			Fresh		Dry	
lb/A	percent	cm	Per pot	Per seedling	Per pot	Per seedling
Normally watered						
0	65.0	8.94	4660	358	721	55
4,000	16.7	2.75	363	109	78	23
6,000	8.3	2.40	167	100	35	21
8,000	1.6	2.00	27	80	7	22
10,000	0	—	—	—	—	—
Excessively watered						
0	43.3	8.00	3017	348	445	51
4,000	15.0	3.17	423	141	99	33
6,000	1.6	3.00	20	60	9	27
8,000	0	—	—	—	—	—
10,000	0	—	—	—	—	—

[a]Based on an aggregate of 60 seeds sown, replicated three times at 20 seeds per pot.

The As released from the soil by both the water and alcohol extractant procedures is presented on a concentration basis in Table 2. The trend indicates an in-

Table 2. The release of As as determined by water and alcohol extraction procedures on normally and excessively watered Chenango silt loam soil and the associated response of 4-month-old Monterey pine.

As_2O_3 lb/A	Seedling survival percent	Soil As released (ppm)	
		Water	Alcohol
Normally watered			
0	65.0	0.1	0.0
4,000	16.7	384.9	48.1
6,000	8.3	534.9	160.1
8,000	1.6	817.5	209.5
10,000	0	1469.1	280.8
Excessively watered			
0	43.3	0.5	0.0
4,000	15.0	234.2	54.3
6,000	1.6	515.6	88.5
8,000	0	582.6	203.0
10,000	0	884.1	218.6

crease in extractable As as the rate increased. This relationship was expected for, with increase in rate of As_2O_3, the phytotoxic effect on the seedlings increased correspondingly, indicating an increase in As availability. A basic assumption is that the quantity of As extracted is coincident with that which is available to the plant. At the maximum rate of 10,000 lb/A of As_2O_3, the amount of As extracted reached a maximum, the exact value depending on the extractant employed. The water extractant procedure removed approximately 20% of the As which was originally applied as As_2O_3. Similar percentages of the alcohol extractant procedure were not so consistent, the trend indicating increase in percent-of-total extracted with increment in rate of As_2O_3.

Since the degree of phytotoxicity of soil-applied As is dependent upon the availability of this soil As to the plant and since moisture influenced the phytotoxic effect of specific rates of application, the solubility of soil-applied As is considered a major factor affecting this availability and thus its effectiveness as a phytotoxicant. However, excessive watering somewhat reduced the amount of As extractable by water as well as by alcohol, although fewer seedlings survived this treatment as compared to the normally watered soil. The plant response may be explained in part by the depressing influence of excessive water on seed germination and/or seedling survival, but the lower release of As at the excessively watered level requires further investigation.

In most soil analytical procedures for available-to-plant fractions of elements in soil, the extracted level of an element is not a true estimate of that amount which is actually utilized by the plant. A valid criterion in soil testing is the existence of a quantitative relationship between the amounts of the chemically extracted element and the associated plant response. Data in Table 2 show such a relationship.

Leaching columns. The data obtained from the As analyses of the silt loam are presented in Table 3. All As values decreased markedly from a high value at or near the soil surface to a very distinct point below which no appreciable amounts of As were detected.

Table 3. Leaching of As in columns of Chenango silt loam soil as related to rate of As_2O_3 and the amount of water applied to the soil surface.

Water—liters	1	1	5	5	1
As_2O_3—lb/A	1000	8000	1000	8000	Control
Depth—inches	Soil As released—ppm				
1	411.4	2692.4	287.4	946.4	1.1
2	9.7	77.4	138.1	946.4	0.5
3	9.7	91.0	50.3	659.7	1.1
4	5.0	43.5	2.3	235.1	0.5
5	4.5	22.4	2.3	150.9	1.8
6	0.5	6.3	8.8	79.7	1.8
7	0.5	9.1	1.8	51.9	2.3
8	1.8	4.5	0.1	44.7	2.3
9	0.5	4.1	1.1	6.8	1.8
10	2.3	4.5	0.1	4.1	
11	2.7	4.5	8.6	1.3	
12	2.3	2.7	0.1	1.8	
13	2.3	4.5	2.3	4.1	
14	1.1	1.8	0.1	1.3	
15	1.8	1.8			
16					1.8
17					
18					
19	1.8	1.8	0.1	1.3	1.8
Filtrate	Nil	Nil	Nil	76.5	Nil

In certain instances, erratic increases occurred at various depths in the columns, but they were thought to be due to small amounts of As moving through the soil interstices in particle form. Thus, these exceptions were not thought to be of significance in determining the distinct point where the As concentrations dropped from a high to a comparatively low value.

No As which could be attributed to the surface application was found in the filtrates with the exception of the 8,000 lb/A-5 L treatment. The substantial penetration of As in this instance was thought to be due to mass movement in particle form of the surface applied As_2O_3.

The results illustrate that both rate of As_2O_3 and water application have an influence on the extent of leaching, rate being the most important factor. However, the primary objective of the leaching columns was to determine the extent of the soil column containing lethal concentrations of As. With reference to the greenhouse trial and its corresponding soil analyses, 8,000 and 6,000 lb/A of As_2O_3 were required to bring about a high phytotoxic effect under normally and excessively watered conditions. From the water extractant technique, the corresponding lethal concentrations under normally and excessively watered conditions were 817 and 516 ppm, respectively. On comparing these values to those obtained in the leaching columns, lethal concentrations were limited to the surface 3 in of the column.

This experiment was conducted under artificial conditions. The column of soil is not representative of a field soil profile but rather it consists of a portion of the profile that had been sieved, well mixed, and placed in the columns. Also, the quantity of water and manner of application are rarely found under field conditions. In these columns, the flow of water was continuous and, thus, would cause greater leaching than an intermittent flow as experienced under field conditions. Therefore, although these treatments leached the As to a maximum lethal depth of 3 in, it is unlikely that similar rates of surface-applied As_2O_3 will be leached to depths greater than this under field conditions. Surface soil organic matter in a soil profile will fix even more of the applied As than occurred in these columns of mineral soil.[5]

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Rhizome Differentiation in Yellow Nutsedge[1]

D. K. GARG[2], L. E. BENDIXEN[3], and S. R. ANDERSON[3]

Abstract. Rhizome differentiation in yellow nutsedge *(Cyperus esculentus* L.), cultured under 12½, 14, and 15½-hr photoperiods, 21–16, 27–21, and 33–27 C temperatures (day and night, respectively), Hoagland solutions of 1/32, 1/8, and 1/2 strength nitrogen (N), and 0, 10, and 1000 ppm gibberellin (GA), was investigated in controlled-environment chambers.

High levels of N, long photoperiods, and high levels of GA at the shortest photoperiods inhibited tuberization whereas high temperatures at the lowest N level favored tuberization. Shoot formation was promoted by high levels of N, long photoperiods, and high temperatures under 12½ and 14-hr photoperiods while GA had a retarding effect. The higher levels of N, temperature, and GA decreased carbohydrate level whereas the longer photoperiods increased it.

It may be concluded that tuberization is not only the result of surplus carbohydrates in the plant but is controlled also by some GA-like substances regulated in the plant under specific conditions of photoperiod and temperature.

INTRODUCTION

YELLOW nutsedge (*Cyperus esculentus* L.) is a serious weed in fields, gardens, nurseries and other areas. It propagates both by seeds and vegetative parts. Vegetative propagation is rapid, vigorous, and persistent and takes place from a complex underground system consisting of rhizomes, tubers, and a basal bulb. In a developing nutsedge seedling, an area called the "basal bulb" (11) swells at the junction of the mesocotyl and coleoptile. Rhizomes arise from the basal bulb and differentiate into either tubers or shoots. A shoot developing from the rhizome becomes an immediate competitor with neighboring plants for light, moisture, and nutrients, but a tuber creates a more severe problem since the plant can be perpetuated through it.

Although subterranean organs are important sources of reproduction in nutsedge, little work has been reported on this aspect. Knowledge of rhizome differentiation will be of immense use to properly understand growth habit, propagation, and finally the control of this serious plant pest.

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Rhizome differentiation is a phenomenon that might be affected by plant environment, including not only photoperiod and temperature but also soil fertility and plant hormones. Potato leaves growing under long photoperiods have been found to contain unusually large amounts of gibberellin-like substances which inhibit tuber formation. Under short photoperiods, gibberellin (GA) treatments inhibited tuberization in potato (8, 9). Tuberization could be delayed in potato by girdling short-day shoots on forked plants or hastened by girdling long day shoots on similar plants (10). On the other hand, Claver (3) gave evidence that although GA lengthened the period of tuber formation in potato, it promoted tuberization. In earlier works, Driver and Hawkes (4) reported that tuberization in potato was a result of surplus carbohydrates, whereas Gregory (7) concluded that it resulted from a stimulus formed or activated by specific conditions of temperature and photoperiod. This paper presents information on the effect of photoperiod, temperature, nitrogen (N), and GA on rhizome differentiation in nutsedge.

MATERIALS AND METHODS

Seedlings for the experiment were grown in the greenhouse from tubers obtained locally. When seedlings had developed two to three leaves, after removing the tubers, they were transplanted into sand cultures in 5-qt plastic pots in controlled-environment chambers. Each pot contained three plants. Experimental treatments included photoperiods of 12½, 14, and 15½ hr, temperatures of 21–16, 27–21, and 33–27 C (day and night, respectively), complete Hoagland solution of 1/32, 1/8, and 1/2 strength N, and GA at 0, 10, 1000 ppm.

Since only three growth chambers were available, the study was conducted as nine separate experiments in which photoperiod and temperature, each at three levels, in all combinations, were factor variables. At a given photoperiod and temperature, there were nine treatments consisting of three N and three GA levels, in all combinations, replicated six times. The data were analyzed as a factorial, with photoperiod, temperature, N, and GA as the factors.

Each pot, with a hole on one side near the bottom, was connected with tygon tubing to a l-gal jug. The jugs were filled with Hoagland solution of desired N strength