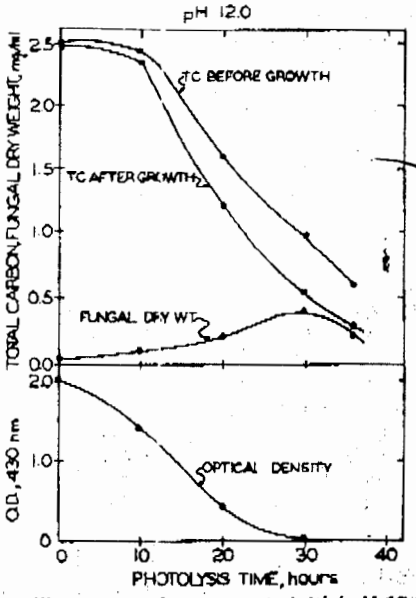

Fig. 3—Aspergillus sp. growth response to initial pH 12.0, 0.5% w/v, photooxidized sodium ligninsulfonate.

also be considered for use with other recalcitrant materials.

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Arsenic Toxicity to Cotton and Soybeans[1]

Lloyd E. Deuel and Allen R. Swoboda[2]

ABSTRACT

Arsenic toxicity levels for 'Lankert' cotton (Gossypium hirsutum L.) and 'Patterson' soybeans (Glycine max L. merr.) were determined in a greenhouse experiment using an Amarillo fine sandy loam and a Houston Black clay. The treatments ranged from 28 to 280 kg As/ha in the Amarillo soil and from 56 to 560 kg As/ha in the Houston Black soil. The vegetative cotton yields were significantly decreased below the checks at the 56 and 280 kg/ha rates of applied As in the Amarillo and Houston Black soils, respectively. Soybeans were found to be more sensitive to As than cotton. Vegetative soybean yields were significantly decreased at the applied rates of 28 kg As/ha in the Amarillo soil and 168 kg As/ha in the Houston Black soil. Yield limiting As concentrations in plant tissue were 4.4 ppm and greater in cotton, and 1 ppm and greater in soybeans. Water soluble As levels of 8 ppm in the Amarillo soil and 28 ppm in the Houston Black soil were required for a significant decrease in the vegetative growth of cotton. The water soluble As levels detrimental to soybeans were 3 and 12 ppm in the Amarillo and Houston Black soils, respectively.

Additional Index Words: soluble arsenic, arsenic extraction, arsenic toxicity, cotton, and soybeans.

Arsenicals have been used in agriculture to combat "pests" for more than a century. More recently organic arsenicals have been introduced for use as herbicides. Their low cost and effectiveness have been instrumental in keeping arsenic on the market. However, they are pollutants by today's standards and their continued use can only be justified from a benefit-risk viewpoint.

In 1922, Stewart (12) reported that 75 ppm As in a calcareous Bench loam caused only slight detrimental affects to the more As sensitive plants, but that 25 ppm As in the soil appeared to have stimulated them. From these results he concluded that small quantities may be beneficial to some plants.

Albert and Arndt (1) found that 1 ppm of soluble As retarded the top and root growth of cowpeas. Machlis (8) used Sudan grass and bush beans as the indicator crops

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Table 1—Correlation coefficients for yield vs. extractable arsenic

Treatment	Average yield: Cotton	Average yield: Soybeans†
kg As/ha	g/pot	g/pot
	Amarillo soil	
0	2.91 a*	(8.75) a*
28	2.27 ab	(4.80) b
56	1.89 bc	2.95 c
84	1.20 cd	1.31 cd
112	0.94 cde	0.31 d
140	0.94 cde	
168	0.86 cde	
196	0.32 de	
224	0.34 de	
252	0.17 e	
280	0.15 e	
	Houston soil	
0	2.65 a	(10.45) a
56	2.69 a	(7.58) ab
112	2.54 ab	(7.82) ab
168	2.33 ab	(5.25) bc
224	1.89 abc	(4.28) bcd
280	1.60 bc	3.39 cd
336	1.36 c	1.67 d
392	1.40 c	1.87 d
448	1.62 bc	1.29 de
504	1.28 c	0.05 e
560	1.25 c	0.25 e

* Any two numbers in the same column not followed by the same letter are significantly different at the 0.05 level.
† A number followed by ( ) indicates the plants set fruit.

to demonstrate that As can accumulate in plant tops. However, several studies indicated that the possible poisoning of man and animals by ingesting contaminated plants was remote, since the levels of As toxic to man and animals were also toxic to plants (1, 5, 9, 13). Recently Jacobs et al. (4) reported that, with the exception of potato peelings, As levels in the edible portions of vegetables grown on a soil treated with 180 kg As/ha, were below the tolerance limit of 2.6 ppm. However, the yields were depressed considerably at this rate.

The objective of the present study was to determine the levels of As that adversely affect the vegetative growth of cotton and soybeans grown on two Texas soils in the greenhouse.

MATERIALS AND METHODS

An Amarillo fine sandy loam and a Houston Black clay were chosen for this study because they are predominant soil types of the major cotton stripping areas of Texas. Arsenic acid is the primary desiccant used to aid in the stripping of cotton in these areas.

A randomized block design with 11 treatment rates and 2 replications was used. A 2-kg sample of each soil was placed in 44 plastic pots. Eleven As treatments in quadruplicate were made on each soil as shown in Table 1. Stock mixtures of As were prepared by mixing As_2O_3 with a sample of each soil to give final mixtures of 2 mg As/g of soil and 10 mg As/g of soil. A prescribed amount of a stock mixture was added to each pot to give the desired treatment. A portion of the soil previously weighed was removed before the addition of the stock mixtures so that the final weight in each pot was 2 kg. Stock mixtures provided a method whereby the As could be applied in sufficient bulk to aid in the mechanical mixing of the As into the soil. Mixing was accomplished with a "V" shaped tumbling mixer.

The soils were placed in a greenhouse and brought to field capacity with distilled H_2O. Field capacity was 15% and 28%, by weight, for the Amarillo and Houston Black soils, respectively. The soils were allowed to dry for 4 or 5 days and then brought back to field capacity. This cycle was continued for 2 months to allow for complete reaction of the As with the soil. After 2 months the pots were subdivided at random into 2 groups such that each level of As was represented in duplicate for both soils.

One group of pots was seeded with 'Lankert' cotton (*Gossypium hirsutum* L.) and the other with 'Patterson' soybeans (*Glycine max* L. merr.). The planted pots were brought to field capacity with distilled water and checked daily throughout the 6-week growing period to maintain the soils at field capacity. Each crop received an application of 112 kg N/ha applied as NH_4NO_3 in solution when the plants were 2 weeks old. No other fertilizer was applied. The cotton and soybeans were thinned to 2 and 5 plants/pot, respectively, just prior to the application of N.

The crops were harvested at 6 weeks by excising the plant at the soil line. They were then placed in a forced draft oven and dried at 105C for 24 hours. Oven dry weights of the plants in each pot were determined to give the yield per pot. Since some of the soybeans had set fruit a note was made of this while recording yield data.

Arsenic contents of the plants grown in the greenhouse were determined by the method described by Liederman, Bowen, and Milner (7), with a slight modification of the acid used to digest the plants. A ternary acid mixture consisting of 200 ml conc. H_2SO_4, 1000 ml conc. HNO_3, and 400 ml 70% $HClO_4$ was employed in the digestion procedure.

After the plants were harvested, soil samples were taken from each pot and extracted with hot (95C) distilled H_2O, 1*N* NH_4Cl and 0.5*N* HCl. Three, 15-ml increments were used to facilitate the extraction of about 5 g of soil. Alternate shaking and centrifugation was used to separate the supernatant liquid from the soil. The extract was brought to volume in a 50-ml volumetric flask with distilled H_2O. A suitable aliquot was taken for the determination of As using the arsine evolution procedure (7).

Analyses of variance were determined on the yield data for both cotton and soybeans on the two soils at the corresponding As treatment levels. A Tukey D test was employed to determine which yields were significantly different. Correlation coefficients were also determined between mean yields of each crop and the extractable soil As levels.

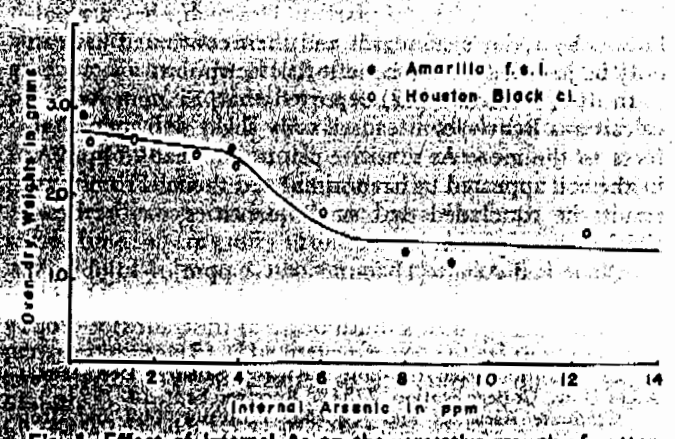

Fig. 1—Effect of internal As on the vegetative growth of cotton.

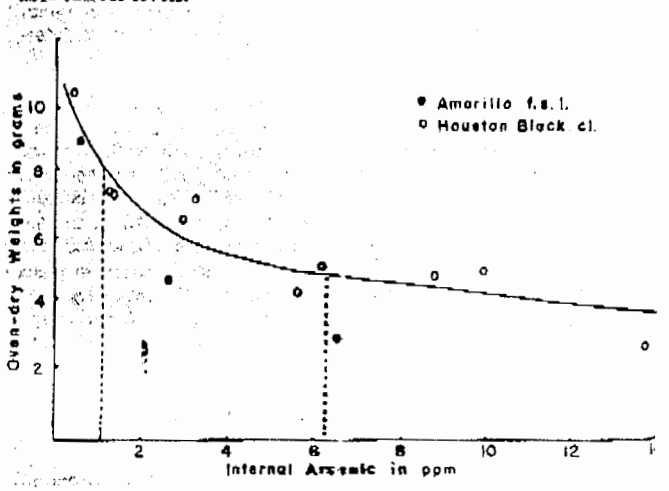

Fig. 2—Effect of internal As on the vegetative growth of soybeans.

RESULTS AND DISCUSSION

The yields for the cotton grown on the Amarillo and Houston Black soils, were reduced by As applications (Table 1). The analyses of variance indicated that the yields decreased with increased As at the 1% level of significance. The cotton grown on the Amarillo soil was more seriously affected at the lower rates of applied As than the cotton grown on the Houston Black soil. Vegetative yields were significantly reduced below the check at the 56 kg/ha treatment in the Amarillo soil. A significant yield reduction was observed for cotton plants grown on the Houston Black clay at the treatment level of 280 kg/ha.

The vegetative yields for the soybeans grown on the Amarillo and Houston Black soils are given in Table 1, along with the As levels which inhibited fruiting. Soybeans generally require more than 6 weeks to set fruit even in the greenhouse. However, the short daylength encountered induced early flowering and fruitage of the Patterson variety of soybeans. The pods formed were about 5 cm long. Analyses of variance suggested the vegetative soybean yields decreased with increased As at the 1% level of significance. Soybeans were found to be more sensitive to As than cotton. Yield decreases were observed at As concentrations of 28 and 168 kg/ha in the Amarillo and Houston Black soils, respectively. The soybeans did not set fruit beyond the 28 kg As/ha treatment in the Amarillo soil. However, in the Houston Black clay fruiting was observed at all treatments below 224 kg As/ha in one replication and 280 kg As/ha in the other.

There was a slight increase in the vegetative yields of both crops grown in the Houston Black clay; although, the increase was not significant. This occurred at the 56 and 112 kg/ha rates of applied As for the soybeans and cotton, respectively. The increase is possibly due to the release of some phosphorus by the added arsenic. Several workers have demonstrated that a replacement for one by the other from soil complexing agents can occur (2, 3, 6, 10, 11).

The data for the averaged vegetative cotton yields for both soils and the plant As contents are plotted in Fig. 1. The yields and internal As contents for the soybeans grown on both soils are shown in Fig. 2. The tissue yields

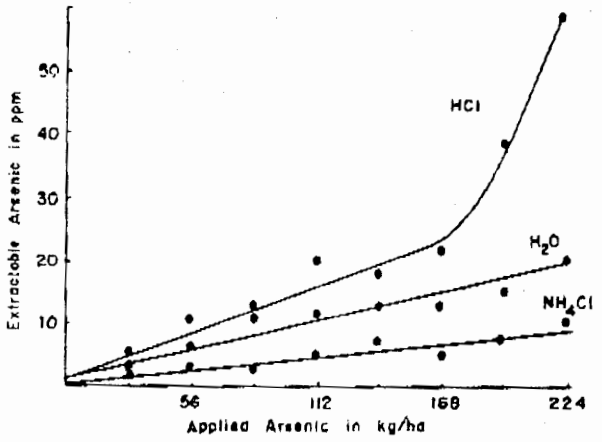

Fig. 3—Extractable As corresponding to the applied rates in an Amarillo fine sandy loam.

Table 2—Effect of arsenic on the fruiting and vegetative growth of cotton and soybeans

Soil	Crop	Extractant H_2O	HCl	NH_4Cl
Amarillo	Soybeans	-.943	-.915	-.914
Houston		-.968	-.931	-.938
Amarillo	Cotton	-.951	-.830	-.960
Houston		-.984	-.895	-.915

* All of the correlation coefficients are significant at the 0.05 level.

from some of the treatments were not sufficient for chemical analysis and several of the samples were lost in the initial digestion procedure. The curves indicated that As exerted the same toxic effect once taken up by the plant, regardless of the soil. An internal As concentration exceeding 4.4 ppm caused a significant decrease in the vegetative growth of cotton in both soils. It is interesting to note that the decrease was about 50% of the vegetative growth, and that cotton demonstrates a threshold limit for As. An internal As concentration of 1 ppm induced a significant decrease in the vegetative growth of soybeans, but did not prevent fruiting. No fruit was set in the soybeans when the internal As concentration exceeded 6.2 ppm. However, fruit was set and maturing at internal levels exceeding the tolerance limit of 2.6 ppm As established for many vegetable crops (4).

Since As toxicity to plants is directly related to the soluble level in the soil, a measure of the soluble As content should be more informative than the total As. The data for the soluble As, determined with 3 extractants at the different levels of applied As, is graphically depicted in Fig. 3 for the Amarillo soil and Fig. 4 for the Houston Black clay soil. Correlation coefficients determined for the averaged yields of both crops and the As extracted by each solution are given in Table 2. Although the correlation coefficients were all significant at the 5% level or better, the curves shown in Fig. 3 and 4 suggest that hot (95C) distilled H_2O is the preferable extractant for soluble As in the Amarillo and Houston Black clay soils. The hot H_2O extracted similar quantities of As for both soils at comparable rates of applied As. The other extractants varied between soils. Water soluble As levels of 8 ppm in the Amarillo and 28 ppm in the Houston Black clay were required for a significant decrease in the vegetative growth of cotton. The corresponding values for soybeans were 3 and 12 ppm As in the Amarillo and Houston Black soils, respectively. The toxic levels may have been slightly exaggerated due to the high root density, uniform As distribution in the soil, and the higher soil temperatures ob-

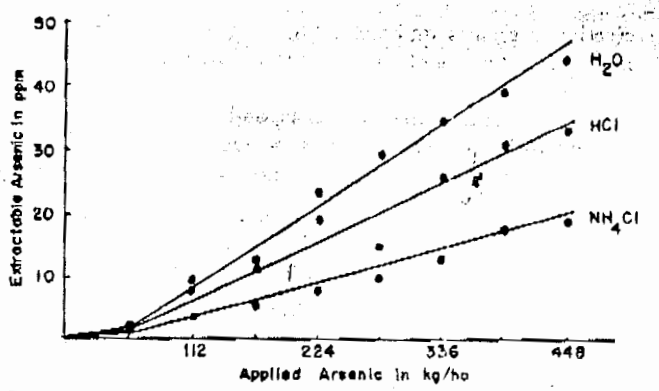

Fig. 4—Extractable As corresponding to the applied rates in a Houston Black clay.

tained in the greenhouse pots. The higher soil temperature would tend to induce a greater soluble level of As in the soil.

The data indicates that a narrower range between tolerable levels of soluble As and the levels which effect yields exists in the Amarillo soil than in the Houston Black soil. However, a greater hazard of crops exceeding the allowable As level probably exists in the Houston Black clay due to the more subtle effect of soluble As in this soil.

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Water Soluble Organic Substances Leachable from Feedlot Manure[1]

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ABSTRACT

Water extracts of feedlot manure and soil and of grassland soil were compared with water from shallow wells near to and remote from feedlots and with water from a local river. Thin-layer and column chromatography failed to reveal water-soluble organics unique to feedlot ground waters. Free phenolics could readily be leached from feedlot manure and from the upper few centimeters of feedlot soil, but only trace amounts of low-molecular-weight organics were encountered in the ground water samples examined. The major organic constituents in all the well waters appeared to be polymerized materials. Mildly reductive degradation of the organic polymers in leachates prepared from feedlot manure, feedlot soil, and grassland soil yielded identifiable phenolics; the same procedure failed to reveal phenolics in ground waters. It was concluded that there is no uniform or continuing movement of organic material from feedlots through the soil profile to the ground water under the feedlot sites involved.

Additional Index Words: phenolics, ground water.

Feedlot seepages are believed to contribute to the organic and mineral nutrient enrichment of lakes and streams and to produce high rates of oxygen demand, bad tastes and odors, undesirable algal growths, and wide-ranging effects on the biota associated with the water bodies (12, 15). The urea excreted in animal urine is rapidly transformed to ammonia and this, in turn, may undergo volatilization or be microbially oxidized to nitrite and nitrate. Ground water in the vicinity of feedlots frequently is high in nitrate (1, 17). However, little is known about the fate in soil of the water-soluble organic products of animal excretion other than urea and the extent to which such products can be detected in soil leachates. The current work was undertaken to compare the water-soluble organic material of feedlot manure and soil with the organic materials found in leachates of grassland soil and in ground water in the vicinity of and remote from feedlots.

Surface and ground waters have been found to contain traces of a wide variety of organic compounds. Lamar and Goerlitz (10) concluded that much of the organic matter in surface waters consists of a mixture of carboxylic acids having aromatic and olefinic unsaturations. Middleton et al. (12) isolated a large number of organic compounds, mostly in parts per billion concentrations, from surface waters variously contaminated with petrochemical and industrial wastes. Schnitzer and Des Jardins (16) analyzed the aqueous leachate collected in a field lysimeter from a humic podzol and found that about 87% of the dry, ash-free weight of the leachate was fulvic acid, with the remainder consisting mostly of polysaccharides and nitrogenous compounds.

Usually only low yields of phenolic substances are extractable from soils and peats (6). Christman and Ghasemi (5) observed trace amounts of phenols in water extracts of soils and sawdusts of different tree species. Most of the water-extractable material appeared to be polymeric, from which different phenols were released upon oxidative degradation with copper oxide. Schnitzer and Des Jardins (16) obtained no free phenols in the

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