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A NOTE ON ARSENIC TOXICITY IN SOME QUEENSLAND SOILS.

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SUMMARY.

Investigations into the cause of the abnormal growth in bananas on certain soils established the presence of appreciable quantities of arsenic. The affection was shown to be associated with rock outcrops on soils derived from quartzite. Analytical results for arsenic in soils and plants are given, and tomatoes and beans are suggested as suitable indicator crops for arsenic toxicity.

I. INTRODUCTION.

Investigation into the cause of abnormal growth in several Queensland banana plantations revealed the presence of considerable quantities of arsenic in the soil. This note reports the work done in examining the problem.

Arsenic may be present in the soil naturally as a result of the decay of rocks containing the element or it may accumulate over a period of years from the use of arsenical weedicides or insecticides.

Most workers report that arsenic is harmful to higher plants, but some claim that in very small concentrations it can cause some stimulation. Clements and Munson (1937), in a report on arsenic toxicity studies comparing the effect of the trivalent and pentavalent forms under various conditions, gave a comprehensive review of the literature and discussed the matter of arsenic stimulation. Their experiments did not show any beneficial effect from small quantities. Crafts and Rosenfels (1939) examined the effect of arsenic on 80 Californian soils and concluded that toxicity could be correlated with texture, being high in sandy soils and low in clays. In another paper (Rosenfels and Crafts 1939) the same workers showed that toxicity is, in general, inversely proportional to arsenic fixation, and that fixation does not occur at a uniform rate in all soils. Thompson and Batjen (1950) described symptoms of arsenic toxicity in peach trees, and discussed experiments conducted with a view to reducing the effect of the element. They obtained best results by the use of zinc sulphate together with high nitrogen applications to the soil. Phosphates, ferrous sulphate and iron oxide have also been reported to have a beneficial effect by various workers (discussed by Clements and Munson 1937).

II. OCCURRENCE IN QUEENSLAND.

In Queensland, the chief problem is caused by arsenic present naturally as a result of weathering of rocks containing the element, probably in the form of mispickel. Soils from Gilston and Yeppoon have been examined.

1. The Gilston Soil.

This occurs in hilly country south of Brisbane. The soil is immature, developed on quartzite containing a number of mineral veins, and grey to brown in colour. It contains a large percentage of rocks and stones in various states of weathering. Outcrops are common, and the soil cover in places is very shallow.

The first investigation was made following a report that bananas in this area were showing abnormal growth combined with failure to set bunches. The disorder was at first thought to be pathological, but examination along these lines yielded negative results. Chemical analyses showed that the surface soil contained a higher amount of arsenic than normal, and subsequent examination established the fact that abnormal amounts were present throughout the profile. From inspection of the property concerned it was clear that the affected plants were associated with outcrops of rock. In places where the soil had greater depth, less of the disorder was apparent. The surface soil in these areas is a grey-brown or brown loam to clay loam overlying a B horizon composed of red or red-brown clay. In many parts a definite C horizon occurs, yellow in colour, with or without red mottling, and associated with crumbling rock fragments.

2. The Yeppoon Soil.

This soil, occuring near Rockhampton, is also developed on quartzite but is much more mature. Few stones are present in the profile, which has definite horizon differentiation and greater depth. The surface soil is a brown clay loam, and the B horizon a red-brown or red clay. Outcrops are occasionally encountered.

Bananas are the main crop affected in both areas. The leaves display a chlorotic or whitish section at the base and margin, extending towards the midrib between the veins. This results in a somewhat "striped" appearance. In more severe cases, and in older leaves, necrotic areas develop along the margin and extend inward in sections parallel to the veins. The chlorotic stripes are evident even when the leaf is just unfurling. In the plants on the Gilston soil, the disorder shows up during the early summer growing period and continues through the late summer wet period; at Yeppoon, the symptoms are most severe somewhat earlier in the summer. Bunches thrown by affected plants are very small, and the fruit does not fill out.

One case has been observed where similar signs were produced in bananas growing on a different soil following an exceptionally heavy spraying with arsenic pentoxide weedicide. Only two or three leaves on each plant were affected, and normal growth was then resumed. The return to normal growth was presumably made possible by the conversion of the soluble arsenic in the soil to a form unavailable for plant assimilation.

III. PLANT ANALYSES.

Analyses for total arsenic in affected leaves were made by dry ashing at 400°C., followed by Gutzeit determination.

Affected banana leaves contained between 0·25 and 2·0 ppm As, and healthy leaves varied from nil to 0·5 ppm. No arsenic was found in the fruit.

Tomato plants grown on the Gilston soil showed dieback of leaves from the tip, and set small fruit of poor quality. Analysis showed 70 ppm As in the leaf, but only a trace to 1 ppm in samples of the fruit. Because of this relatively large uptake in the leaves, tomatoes may prove to be a useful indicator crop for demonstrating the presence of soluble arsenic in the soil. The quantity of arsenic taken up by bananas is small and somewhat variable, since some apparently healthy leaves contain 0·5 ppm As, while others show toxic symptoms at an arsenic content of 0·25 ppm.

IV. SOIL AND ROCK ANALYSES.

All arsenic determinations were made by the Gutzeit method, the stain being kept to one spot on mercuric chloride treated filter paper rather than on a strip and compared with similarly prepared standards. This limited the range to 1-10 mg. of arsenic, and it was necessary to adjust aliquots accordingly. For the determination of total arsenic, the soil was digested with sulphuric acid, sodium sulphate and starch, and a suitable aliquot taken after dilution. Available arsenic was determined by extracting with 0.1N ammonium acetate or N/100 sulphuric acid.

Table 1 gives the total arsenic figures for samples taken every three inches down the profile from two farms on the Gilston soil type, and the available arsenic from selected samples as indicated

Table 1.

ANALYSIS OF GILSTON SOIL.

Depth.	Total As.		"Available" As. Soluble in N/100 H_2SO_4.	
	Farm A.	Farm B.	Farm A.	Farm B.
in.	ppm.	ppm.	ppm.	ppm.
0– 3	100	130	5	3
3– 6	50	120	2	1
6– 9	45	100	..	..
9–12	50	120	..	..
12–15	45	140	..	..
15–18	50	140	2	2
18–21	..	180	..	..
21–24	..	200	..	..

The values for total arsenic show a concentration of this element at depth which has presumably come from weathering of the parent rock.

Table 2.

ANALYSES OF YEPPOON SOILS.

Farm.	Depth.	Total As.	"Available" As.		
			H_2O.	O. 1N Ammonium acetate	N/100H_2SO_4.
	in.	ppm.	ppm.	ppm.	ppm.
A (Sample 1*)	0–4	70	..	·5	4
	4–8	60	..	·2	2
	8–15	45	..	0	<2
A (Sample 2†)	0–4	75	..	·4	5
	4–8	65	..	0	2
	8–15	40	..	0	2
B	0–6	40	·5	·5	..
	6–14	36	0	0	..
C	0–6	26	·4	·2	..
	6–12	16	·2	·4	..
	18–24	4	0	0	..

* Bananas showing no toxic symptoms.

† Bananas showing toxic symptoms.

Soluble arsenic in the soil has been determined by other workers by extraction with ·1N NaCl (Thompson and Batjen 1950), ·05N HCl (Reed and Sturgis 1936), water (Rosenfels and Crafts 1939) and ·1N ammonium acetate as well as by collodion bag dialyzates (Albert and Arndt 1931). Correlation with plant growth was in all cases better than was found when total arsenic was considered, but it is uncertain which of these extractants is most suitable. Table 2 gives some results obtained for both total and available arsenic with various samples of the Yeppoon soil.

The total arsenic figures are somewhat lower than those for the Gilston soil but available amounts are of the same order. In contradistinction to the results obtained by other workers, as mentioned above, no correlation was obtained between plant symptoms and figures for available arsenic in either soil.

Both of the soils in question contain fair quantities of iron, and it was shown by experiment that they are capable of fixing up to 15 ppm of added arsenic (the arsenic was added in the form of arsenious oxide solution to the soil, which was then extracted with ·1N ammonium acetate). Thus it appears that the soil is not capable of supplying large quantities of arsenic in an available form, though it is likely that small quantities would be available when the soil is subjected to reducing conditions, since Clements and Munson (19) showed the trivalent form to be 10 times as toxic as the pentavalent.

Several selected samples of rock were analysed, and results for the Gilston area are given in Table 3.

Table 3.

ANALYSES OF GILSTON ROCK.

Rock Sample.	Total As.	As soluble in ammonium acetate.
	ppm.	ppm.
1. Weathered sample, many mineral veins present	360	30
2. Similar to 1, but high in iron and badly weathered	100	30
3. Less weathered ; no veins present ..	15	5

These samples were taken from the root zone of affected bananas. The large percentage of decaying rock present means that the roots are entwined with the rock, and in many places the roots penetrate decayed pieces of rock. Similar samples from the Yeppoon area contained between 160 and 500 ppm As.

It seems likely that the main supply of soluble arsenic to which the plant has access is in the area immediately surrounding fragments of decaying rock, probably including the fragments themselves.

In this event, with a small but continuous supply of arsenic coming from the rock, treatment of the soil to correct the trouble is difficult.

V. POT TRIALS.

A pot trial was set up using the Gilston soil, to which was added superphosphate at the rate of 12 cwt. per ac. and ferrous sulphate at amounts varying up to 1 ton per ac. French beans grown in the pots developed a general paling in leaf colour, with interveinal puckering and whitening.

Finally the leaves died back from the tip and margin. Beans grown in sand culture to which was added the equivalent of 3 ppm As as sodium arsenite developed similar symptoms. No definite improvement was obtained as a result of the treatment.

Analysis of the plants for total arsenic showed the presence of 2–5 ppm in the leaves, and 8–10 ppm in the roots. Examination of the roots showed extensive damage to root hairs and rootlets, many of which had died back completely.

An observation trial was also set up, using in one set of pots soil which had been screened as free from stones and decomposing rock as possible, and in another set of pots soil to which an extra amount of rock has been added. Beans were again grown as an indicator crop. They failed completely in the pots containing excessive rock, but in the screened soil the plants grew somewhat better, although the typical symptoms were still apparent.

VI. DISCUSSION.

Investigations to date indicate that arsenical weedicides should be used with care in banana plantations, although most soils can fix in an insoluble form the quantities normally applied. The treatment of soils in which the arsenic is present naturally is hampered by the continual decay of rock, but heavy applications of ferrous sulphate or zinc sulphate may be beneficial.

In suspected areas, beans, which develop characteristic symptoms, or tomatoes, which take up larger amounts of arsenic, should be useful as indicator plants. If arsenic is known to be present naturally in amounts likely to cause trouble, bananas should not be planted in places where a rock outcrop occurs or where the soil cover is very shallow.

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