Table 1. PERCENTAGE PRECIPITATION OF SOLUTES FROM SEA WATER BY VARIOUS METHODS

Solute (0·1 mg/l.)	Method	Percentage precipitated
Glucose	Iron, *p*H 6	16
Glutamic acid	Iron, *p*H 4·5	90
Aspartic acid	Iron, *p*H 4·5	77
Citric acid	Iron, *p*H 4·5	90
Succinic acid	Iron, *p*H 4·5	60
Glycollate	Iron/CMC or albumin, *p*H 4	45
Glycine	Copper, *p*H 9	48
Lysine	Copper, *p*H 9	73

CMC, carboxymethylcellulose.

Park *et al.*[8] the final *p*H was 9·0–9·7, whereas the method of Tatsumoto *et al.*[7] gives a final *p*H of 4 to 5. The latter may also account, at least partly, for the loss of basic amino-acids.

This work was financed by a grant from the Natural Environment Research Council.

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Received November 3, 1966.

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Nickel, Iron, and Manganese in the Metabolism of the Oat Plant

THE first definite report of a toxicity induced in plants by a localized high concentration of nickel appears to be that of Hunter and Vergnano[1], while 2 years later[2] Hunter described the occurrence of an identical condition on what was apparently similar terrain in Southern Rhodesia, namely a poorly drained upland region with outcropping serpentine. An investigation of disease symptoms which appeared in an oat crop growing on just such an area at Wallendbeen, southern New South Wales, in 1960 was attributed to the high incidence of available nickel in the soil. This was substantiated by analysis of the affected plants, which occurred in large patches in the field, and also of soil from both affected and unaffected areas. A further series of sand culture experiments established that nickel, and to a lesser extent cobalt, was capable of reproducing the symptoms in oat plants. The analysis of soil and minerals removed from both outcrops and subsoil indicated that nickel alone was responsible for the condition of the crop, however; the level of cobalt in both soil and affected plants was little different from that in material from unaffected areas.

Later reports by Crooke *et al.*[3] and other workers[4] which suggested that the occurrence of nickel toxicity may be related to local deficiencies of iron were somewhat inconsistent with the conditions at present under investigation, because both soil and plants from the affected area were well endowed with iron (Table 1). Furthermore, the application of additional iron to oat plants grown in soil from the affected area, and in sand culture, in the presence of toxic levels of nickel led to no reduction in the severity of the symptoms. Because manganese was present in abnormally high quantities in both plants and soil from the affected area, a further series of experiments was carried out in sand culture in order to investigate the effect of high levels of manganese alone on the incidence of nickel toxicity symptoms. It has been suggested by several workers that manganese is associated with the metabolism of iron in plants (see, for example, ref. 6). In the current experiments different ratios of iron and manganese were applied to oat plants growing in sand culture in the presence of nickel applied at levels of 0, 10 and 20 p.p.m. The results showed that manganese clearly intensified the severity of the symptoms caused by the presence of high levels of nickel (Fig. 1). Analysis of the plants showed that, as with samples removed from the field, the concentrations of nickel, iron, and manganese were notably greater in affected plants than in healthy plants. The level of iron was higher in plants receiving both additional nickel and manganese than in those receiving iron alone, or in combination with nickel or manganese separately. On the affected areas in the field, the plants showing the most severe symptoms were completely devoid of chlorophyll, the leaf veins showing up as fine brownish-black lines on a white paper-like background. The brown necrotic patches occurring throughout their length gave a characteristic "rippled" effect to the leaves.

Table 1. IRON, MANGANESE, NICKEL, AND COBALT CONTENTS OF MATERIALS FROM AFFECTED AND HEALTHY AREAS OF THE OAT CROP BELIEVED TO BE AFFECTED BY NICKEL

	Plants		Soil*	
	Affected	Healthy	Affected	Healthy
Iron (p.p.m.)	704	88	362	127
Manganese (p.p.m.)	278	66	264	57
Nickel (p.p.m.)	91	16	184	20
Cobalt (p.p.m.)	0·6	0·1	1·6	1·1

* These figures refer to metals extractable from soil using 2·5 per cent acetic acid solution.

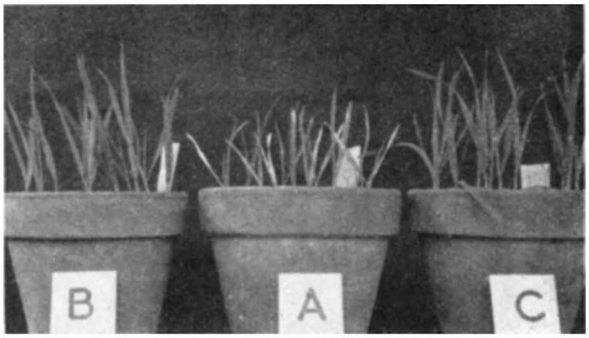

Fig. 1. Effect of manganese on severity of symptoms induced by high levels of nickel on oats grown in sand culture. *A*, 300 p.p.m. manganese, 10 p.p.m. nickel (dry sand basis) and basal nutrient solution. *B*, 300 p.p.m. manganese and basal nutrient solution. *C*, Control, basal nutrient solution only. The experiments were conducted in 6 in. pots, all of which contained 1,800 g of dry sand.

It was concluded that the severity of the toxicity induced by the relatively high concentration of nickel in the areas was increased as a result of the presence of abundant manganese. The two metals working in conjunction apparently had the effect of increasing the rate at which iron was taken into the plant, but had inhibited iron metabolism inside the plant.

I thank Mr. R. Galvin for technical assistance.

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