



attack by fungi (Tyihák *et al.*, 1988; Kraska & Schönbeck, 1992; Manninger *et al.*, 1992). Betaines are known constituents of seaweed extracts; for example, the commercial products derived from *A. nodosum* contain  $\gamma$ -aminobutyric acid betaine,  $\delta$ -aminovaleric acid betaine and glycinebetaine (Blunden *et al.*, 1986). In this communication we report the effects on *M. javanica* and *M. incognita* infestations of tomato plants following soil application of an alkaline extract of *A. nodosum* and of the betaines present in the extract.

## Materials and methods

### SEAWEED EXTRACT

The seaweed extract used was Maxicrop Original (Maxicrop International Ltd), an aqueous alkaline extract of the brown marine alga, *Ascophyllum nodosum*, that contains approximately 8% dissolved solids, of which approximately 58% is organic and 42% inorganic. The extract has a pH value of  $9.0 \pm 0.6$  and a specific gravity of  $1.045 \pm 0.015$ . A typical analysis of the inorganic constituents is given in Table 1, although these values will vary from batch to batch of the product. When assayed for betaines using the method of Blunden *et al.* (1986), the extract was shown to contain  $\gamma$ -aminobutyric acid betaine (51.7 mg/l),  $\delta$ -aminovaleric acid betaine (14.7 mg/l) and glycinebetaine (3.9 mg/l).

### BETAINES

Glycinebetaine hydrochloride was purchased from Sigma Chemical Co.,  $\gamma$ -aminobutyric acid betaine and  $\delta$ -aminovaleric acid betaine were synthesized by N-methylation of the corresponding amino acids using methyl iodide under mildly basic conditions as described by Benoiton and Chen (1976).

### NEMATODES

*Meloidogyne javanica* and *M. incognita* were obtained from stock cultures maintained on tomato plants (*Lycopersicon esculentum* cv. Ailsa Craig). The method used for the collection of eggs from the entire root ball was that of Whapham *et al.* (1994).

The eggs obtained were hatched to release infective second stage juveniles (J2s) over a period of 7 days at 25 °C in beakers containing aerated water.

### INOCULATION AND TREATMENT

In each experiment, a sample of 80 tomato plants, all at the four-leaf stage and planted in 450 cm<sup>3</sup> (approximately) of John Innes No. 1 compost, was divided into two groups of eight experimental sets containing five plants per set, all arranged randomly. One set of eight was used to determine invasion profile, and the second set of eight for egg recovery. The experimental sets were treated with 30 ml per plant of one of the following: i) water as a control; ii) 3.6% Maxicrop Original; iii)  $\gamma$ -aminobutyric acid betaine solution; iv)  $\delta$ -aminovaleric

**Table 1.** Typical composition (mg/kg) of the inorganic components of the solids obtained after evaporating Maxicrop Original to dryness.

Nitrogen	(N)	7500
Phosphorus	(P <sub>2</sub> O <sub>5</sub> )	500
Potassium	(K <sub>2</sub> O)	192 800
Aluminium	(Al)	10
Boron	(B)	30
Bromine	(Br)	800
Calcium	(Ca)	3500
Chlorine	(Cl)	25 500
Copper	(Cu)	12
Iodine	(I)	1100
Iron	(Fe)	290
Magnesium	(Mg)	2000
Manganese	(Mn)	6
Molybdenum	(Mo)	2
Rubidium	(Rb)	20
Selenium	(Se)	8
Sodium	(Na)	5500
Strontium	(Sr)	126
Sulphur	(S)	29 000
Tellurium	(Te)	66
Titanium	(Ti)	100
Zinc	(Zn)	56

acid betaine solution; v) glycinebetaine solution (each betaine being applied in the same quantity as that present in the 3.6% Maxicrop Original); vi) a mixture of  $\gamma$ -aminobutyric acid betaine,  $\delta$ -aminovaleric acid betaine and glycinebetaine in the concentrations applied in iii, iv and v; vii) the residue of 3.6% Maxicrop Original after evaporation to dryness, incineration at 800 °C for 4 h (Maxicrop ash) and resuspension in water; and viii) Maxicrop ash mixed with the three test betaines in the concentrations used in vi. The application rate of 30 ml per plant, although based on earlier work by Whapham *et al.* (1994), was lower than the 50 ml per plant used by them.

Two plastic pipette tips with additional perforations were pushed into the soil, on either side of the tomato stem, to a depth of 2 cm. The inoculum (750 J2s of

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reducing both the number of J2s invading the roots of tomato plants and the number of eggs recovered. Further studies to define the role of betaines are in progress.

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