The rice root-knot nematode, *Meloidogyne graminicola*, on deep water rice *(Oryza sativa* subsp. *indica)*

[redacted]

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SUMMARY

In a series of experiments designed to simulate deep water rice growing conditions, *Meloidogyne graminicola*

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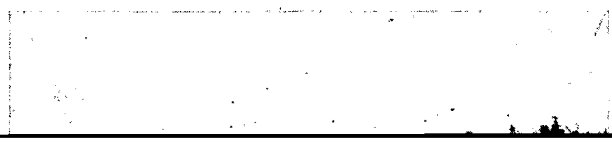


the biggest producer of the crop with over 1.8 million ha under deep water cultivation (Kanter, 1978).

In Bangladesh we observed that *M. graminicola* was associated with yellowing and stunting of

Table 1

Effect of *Meloidogyne graminicola* on growth and elongation of deep water rice (cv. Habiganj VIII) before and after flooding

Treatment	*Plant height (cm)* (1)			*Plants emerging above water (%) 18 days* [redacted]	*Top dry weight (g) 18 days* [redacted]
	i) *14 days* [redacted]	ii) *At flooding*	iii) *18 days* [redacted]		
[redacted]					
Untreated	47.3	60.5	103.2	100	0.43
Plants infested with *M. graminicola*	41.9 N.S.	48.1 **	54.1 ***	27.8	0.19 **

(1) Means of 18 plants. N.S.: Not significant, ** Significantly different ($P < 0.01$), *** Significantly different ($P < 0.001$).

Results

M. graminicola significantly reduced ($P < 0.01$) growth of deep water rice plants in upland conditions before flooding and the reduction in growth was even more marked ($P < 0.001$) during flooding (Tab. 1). Rice plants with nematodes had severely galled roots but there was no significant difference in fresh root weight between infested and control roots. Mean root populations of *M. graminicola* were 339 females/g root before flooding and 490 females/g root eighteen days after flooding. All rice plants without nematodes grew very rapidly after submergence in water. They increased in height by as much as 55 cm in eighteen days and they all [redacted]

of 44 days to stimulate rapid growth to a height greater than 50 cm. Pots were removed from the water and allowed to drain. All pots were inoculated with 1 000 *M. graminicola* juveniles/pot into holes around the rice roots and covered with additional sterilised soil. The pots were then immediately separated into three treatments with 24 pots per treatment. Treatments were, 1 : shallow flooding-pots immersed in water to a depth of 10 cm above soil level, 2 : deep flooding-pots immersed in water to a depth of 50 cm above soil level, and 3 : well drained soils watered normally. All treatments were maintained for 27 days at a temperature of 22-29° in a heated glasshouse. Pots were removed from each treatment every two to four days, roots were washed [redacted]

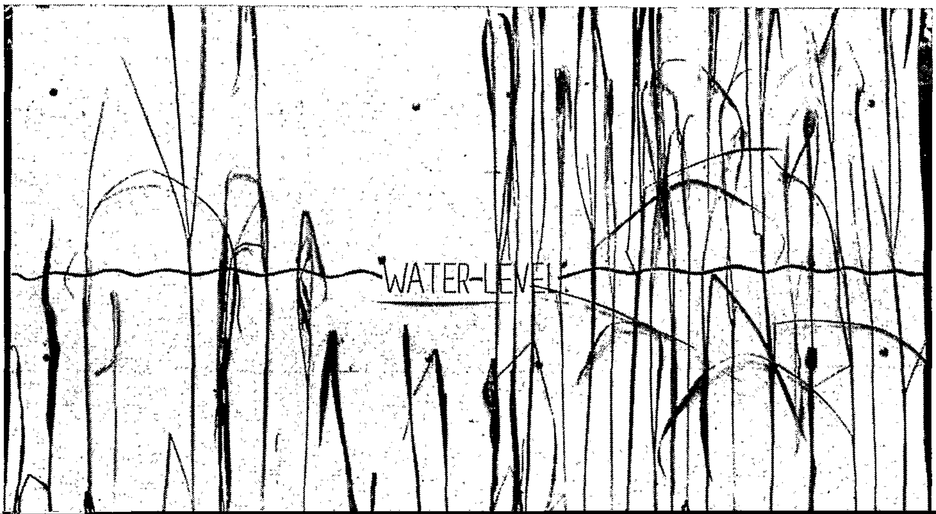

WATER-LEVEL

Table 2

Development of *M. graminicola* in flooded rice roots

Days after flooding	*Treatment*	*Nos. of nematode stages/root system* (1)			
		Juveniles	*Immature* ♀♀	*Mature* ♀♀	*Mature* ♀♀ + *eggs*
8	a. Well drained	0	0	< 1	14
	b. Flooded	1	< 1	1	11
22	a. Well drained	56	17	9	19
	b. Flooded	6	3	6	7
36	a. Well drained	14	18	17	394
	b. Flooded	80	87	86	500

(1) Means of 3 replicates.

Survival in deep water rice soils

Materials and methods

A galvanised water tank 1.83 m deep was used to simulate deep water rice growing conditions. The tank was painted internally with non-toxic paint and fitted with a submerged heating coil and water circulator. It was set in a heated glasshouse and water in the tank was maintained at 28-31° throughout the experiment. Deep water rice seeds cv. Habiganj II were germinated in water before planting out singly into 15 cm pots in heat sterilised clay loam. Pots were placed in perforated trays and suspended over the tank with their bases just submerged in the water. Soils with eight day old rice seedlings were inoculated with 2 000 juveniles of *M. graminicola* per pot in each of four treatments with seven replicates per treatment. Seven pots without nematodes were included as controls in each treatment. All pots were left on the surface of the water for one week after inoculation of nematodes and then, over a three week period, pots of some treatments were gradually lowered into the water. Four treatments were established on the basis of soil depths in water, 1 : soil level above surface of water, 2 : soil level just below water surface, 3 : at a depth of 29 cm, and 4 : at a depth of 1 m. The pots were lowered at the rate of growth of the rice, which was stimulated by flooding, and upper leaves always remained above water level. NPK fertiliser was added to the water in the tank at commencement of the experiment. Rice plants were left at their different depths in the water for five months until maturity. The pots were then lifted from the tank and roots were carefully removed leaving the soil in the pots. Roots were washed free of adhering soil, weighed and stained, and numbers of mature female nematodes in the roots counted.

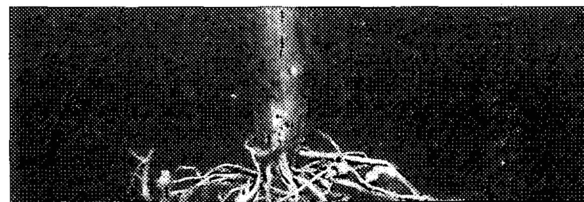
All the pots containing soil from the deep water tank were allowed to drain and then planted to seedlings of rice cv. BR3, sown as a pre-flood crop in Bangladesh. They were arranged in a fully randomised design on a bench in a heated glasshouse at a temperature of 26-32° and watered normally. After six weeks, roots were removed from the pots, washed free of soil, weighed and stained, and numbers of female *M. graminicola* counted.

Results

Rice plants at 1 m depth had become detached from their anchor roots in the pots and had assumed their natural floating habit. Roots remaining in these pots were old anchor roots and some nodal roots.

No *M. graminicola* were found in flooded rice roots after five months submergence in water depths of 29 cm and 1 m (Tab. 3). Few nematodes were found in roots from saturated soils or in roots growing in soils just below the water surface. Although no nematodes were present in deep flooded rice roots many had survived in the soil. When soils were removed from the water, planted to rice and kept well drained for six weeks, large numbers of *M. graminicola* developed in all the roots, including those growing in soils which had previously been submerged in 1 m of water (Tab. 4), causing severe root galling in all treatments (Fig. 3). *M.*

graminicola was also recovered from the rice roots growing in some of the soils which had not been inoculated with nematodes showing that there was movement of nematodes in the flood water, although not in all treatments (Tab. 4). This uneven movement could be accounted for by the pattern of water circulation in the tank.



absent from irrigated rice plants under constant irrigation but, should the irrigation stop, newly formed roots will become galled. Movement of viable eggs or juveniles does occur in flood water, as shown by the presence of nematodes in roots growing in untreated control soils in deep water. This indicates that the nematode will be rapidly and widely disseminated in the open flood waters of deep water rice areas, making any attempts to restrict their spread very difficult. In our experiments, the life cycle (J2 to J2) was nineteen days at 22-29°. A life cycle of 23-27 days at 26° has been recorded with a U.S.A. isolate of *M. graminicola* (Yik & Birchfield, 1979), and an isolate from India took 26-51 days according to the time of year (Patnaik, 1969).

There is clear evidence from our studies and earlier observations in Bangladesh that *M. graminicola* can cause substantial losses of deep water rice by preventing emergence above water once they have become submerged during abrupt flooding. It appears that root infection in the early stages of growth prevents the vigorous growth needed to avoid drowning out as was suggested in an earlier paper (Page *et al.*, 1979). Although plants infested with *M. graminicola* were shorter than the controls before flooding, the depth of submergence in water was comparatively moderate and growth or survival of the rice plants with nematodes in water was not related to the height of plants at flooding. Deep water rice can normally withstand submergence for a limited period and some varieties grow as fast as 25 cm per day (Kanter, 1978). The mean increase in height of plants without nematodes during flooding was 43 cm with a maximum of 55 cm. Increasing the water depth over the period would have stimulated greater growth.

Drowning out of deep water rice is likely to be most serious when rapid flooding occurs early in the monsoon period. In some areas in Bangladesh deep water rice is sown directly in well drained soils and often has to withstand drought for long periods until the onset of flooding which may be eight weeks or more after sowing. This allows time for populations of *M. graminicola* to build up in rice roots and drought conditions have been shown to increase numbers of the nematode (Rao & Israel, 1971). Our results indicate that rice raised in flooded soils would escape invasion by *M. graminicola*. Submergence can occur at any time during the growing season but plants subjected to a gradual

be associated with *M. graminicola* in the field because root populations vary considerably (Page & Bridge, 1978), however, the nematode is potentially a very important pest of deep water rice which has hitherto gone unrecognised. In Bangladesh the nematode was found in 30% of deep water rice fields sampled (Page *et al.*, 1979). Other root nematodes found on deep water rice in Bangladesh, such as *Hirschmanniella oryzae* and *Tylenchorhynchus annulatus* (Page *et al.*, 1979) could have a similar effect on the growth or elongation capacity of the plants.

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