Broadly based resistance to nematodes in the rice and potato crops of subsistence farmers

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INTRODUCTION

Root knot nematodes (*Meloidogyne* spp.) account for the majority of the annual losses attributed to nematode damage in crops (see Box 1). In the tropics, average crop production is reduced by 11-25% as a result of damage by nematodes. Crop resistance is a low-cost option for nematode control in subsistence agriculture. It does not impose unwanted changes on traditional agronomic practices. The range of single traits available for breeding programmes currently limits the number of nematode-resistant crops available. In addition, pathotypes, or species that overcome resistance, often challenge the utility of resistance.

Box 1: Extent of nematode damage to the potato crop.

Developing world countries lose 35% of their potato yield of 105 million tonnes per year to biotic and abiotic causes either before or after harvest. Nematodes and plant diseases are jointly the most important contributors to these losses. Nematodes cause 12% reduction in the world potato harvest. This represents 35 million tonnes world-wide of which 13 million tonnes are lost in the developing world. Individual losses can be higher than this average both nationally and locally. The introduced potato cyst-nematodes are important in cooler soils of Asia such as the mountaine areas of India. *Meloidogyne* spp is abundant in warmer soils and an important agricultural pest throughout Asia, Africa and Latin America. Together cyst and *Meloidogyne* spp cause about 80% of the world's losses due to nematodes of £100 billion per year. Control of *Meloidogyne* on potato provides added benefits. It suppresses damage to other crops grown subsequently in the same soil. The genus is the most economically important nematode of world crops with nearly all the damage occurring in warm soils. Achieving effective control on potato by transgenic approaches provide a paradigm for future control of *Meloidogyne* and other nematodes on many other key crops in the developing world. The two other current target crops within PSRP are banana and rice which suffer estimated annual losses globally of 19.7% and 10% respectively.

The DFID Plant Sciences Research Programme (PSP) has now reduced some of these constraints in two ways. We have established the molecular mapping techniques and strategy to identify the location of genes in West African rice landraces that confer resistance to nematodes. The value of additive natural and transgenic resistance has also been demonstrated, providing a more robust defence. The use of transgenes broadens crop resistance by protecting plants from nematodes for which natural resistance genes are unavailable. Broadly based nematode resistance also avoids the need for farmers to recognise and distinguish nematode species.

Markers to assist breeding for natural resistance in rice

The importance of nematode pests of rice was highlighted by the DFID RNR Annual Report for 1991. In response, PSP developed a research programme that aims to control nematodes on upland rice in West Africa and South Asia. The main pests under study are *Meloidogyne* spp (Fig. 1), *Pratylenchus zeae* and cyst nematodes.

Molecular markers for resistance traits are being sought in progenies derived from African *Oryza glaberrima* landraces. A highly effective trait against *Heterodera* *sacchari* (Fig. 2) has been shown to be monogenic and will now support a breeding programme at WARDA in the Ivory Coast. Preliminary results suggest that other traits for *Meloidogyne graminicola* resistance also exist which may be multigenic in nature. Through marker-assisted breeding it is possible to transfer all the major genetic components to effect resistance to both nematodes if required. Other nematodes targeted are *Hirschmanniella oryzae* and *Ditylenchus angustus*.

Additive resistance for potato

Like rice, potato has many nematode pests. Breeding programmes over 50 years have produced only multigenic resistance to common forms of *Globodera pallida* (a potato cyst nematode, PCN). The efficacy of these cultivars usually declines at a locality with use as the pest evolves to overcome the host plant resistance. Their value is also diminished by a lack of other favoured agronomic traits. One example is cv Maria Huanca in Bolivia. Its partial resistance to *G. pallida* is not enough of an advantage to ensure frequent uptake by farmers.

***Figure 1.* Cross-section through a rice root showing the giant cells and the attached female of *Meloidogyne* feeding from them.**

***Figure 2.* Female and cyst of *Heterodera sacchari* emerging on to the root surface before egg production.**

We have improved the level of resistance of this cultivar using a biosafe form of transgenic resistance reported previously. This new form of cv Maria Huanca does not support any multiplication of *G. pallida* and provides at least partial resistance to all other forms of PCN, *Meloidogyne* and false root knot nematodes (Fig. 3). The additive effects against *G. pallida* have been confirmed in the field within the UK using a partially resistant cultivar, cv Sante, grown in Europe. This improvement to the resistant status of cv Maria Huanca may promote its uptake. If so, it will help many resource-poor farmers in Bolivia that suffer nematode losses on their smallholdings.

The potential of additive resistance for rice

Enhanced resistance can also be envisaged for rice. Over 80% resistance to *Meloidogyne incognita* has been achieved using a similar transgenic approach as for potato. The novel protein is restricted to sites in roots where the nematodes feed (Fig. 4) by using a root-specific, gene promoter that is ‘switched on’ by the feeding activity of the nematode. Adding transgenic resistance to natural resistance against *Heterodera sacchari* bred into an elite line would provide more robust resistance to the cyst nematode, as well as effective protection from *Meloidogy*ne spp. Landraces with multigenic resistance could also be improved additively, providing they are suitable for many growers in West Africa.

Prospects for the future

Resistant cultivars can be provided to growers at no or little extra cost relative to seeds of susceptible plants. The biosafety of any transgenic approach and its acceptability to both farmers and the society in which they live must be assured before adoption can be contemplated. Developing natural resistance and supporting it with additive transgenic resistance can underpin sustainable agriculture without disturbing either the agroecology or agricultural practices of subsistence farmers.

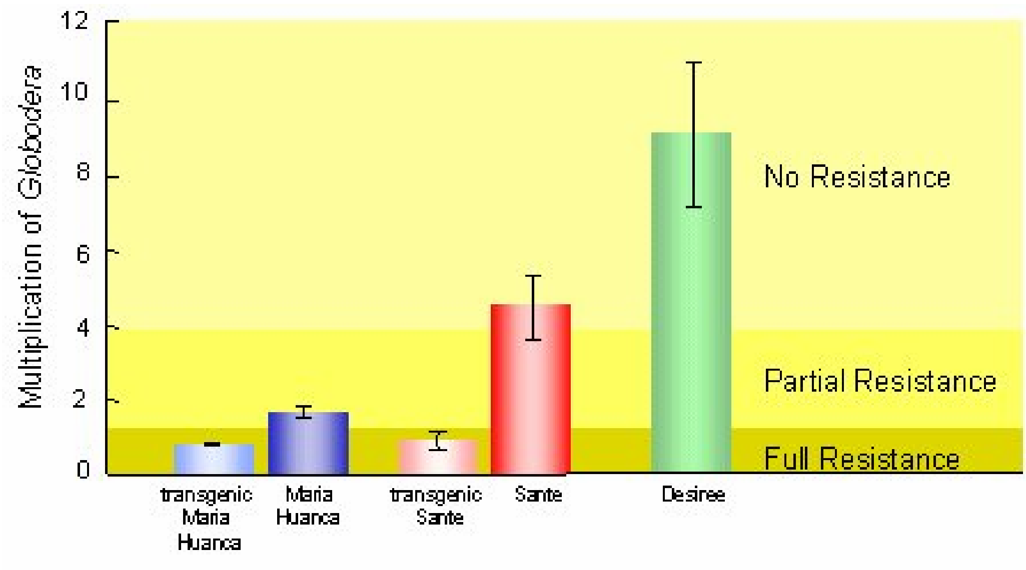

Figure 3. **The partially resistant potato cultivars Maria Huanca and Sante support no multiplication of *Globodera pallida* when additional resistance is also provided by a transgenic approach. Desirée is fully susceptible.**

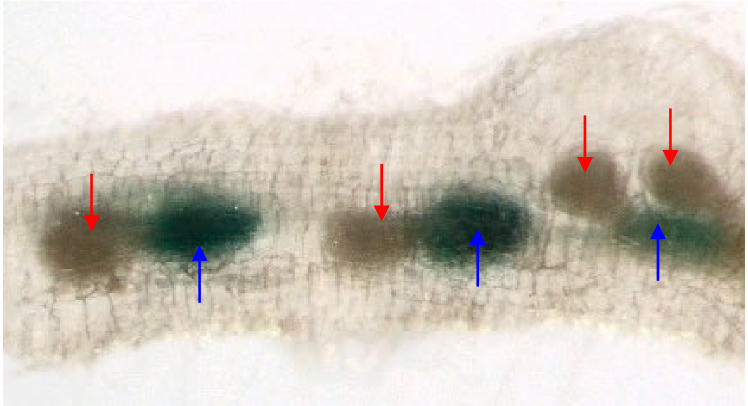

Figure 4. **Four *Meloidogyne incognita* females (↓), each with modified giant plant cells (↑) from which they feed. The blue coloration reports that expression of novel protein is limited to these cells.**