THE ROLE OF ARBUSCULAR MYCORRHIZAL FUNGI IN SUSTAINABLE TOMATO PRODUCTION

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Thesis submitted for the degree of

Doctor of Philosophy

in

The University of Adelaide

Faculty of Sciences

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The University of Adelaide

South Australia

May 2007

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Summary

The work in this thesis aimed to demonstrate the contribution of arbuscular mycorrhizal (AM) fungi to the yield and fruit quality of field-grown processing tomatoes, and the potential to increase the sustainability of tomato production through greater fertiliser use efficiency by inoculating tomato seedlings with beneficial AM fungi. Previously, the conclusion that tomato growth is unresponsive to AM colonisation, particularly in high-P soils, has often been based on only a part of the tomato life-cycle. However, there is increasing evidence that that positive AM yield responses can occur in soils with relatively high plant-available P, and that AM responsiveness of tomato during vegetative growth may be a poor predictor of reproductive growth.

A preceding industry study found that AM colonisation of field-grown processing tomatoes was very low, mostly less than 5%. The reason for the low colonisation was unclear since previous studies have shown that tomato can become relatively highly colonised by AM fungi. It was not known if farm practices, such as soil cultivation and chemical sterilisation, which have been shown to decrease AM colonisation of tomato and other crops, could have contributed to the low colonisation. Furthermore, it was unclear what contribution AM fungi were making to the yield and fruit quality of tomato in commercial production, and what their potential contribution might be if greater AM colonisation could be achieved through inoculating seedlings.

Yield and fruit quality are important to tomato growers as both are used to calculate payment when the fruits are sold. Large amounts of soluble fertilisers, particularly P, are applied during tomato production with the aim of increasing yield and quality. However, fertiliser use efficiency, particularly P, on tomato farms has been identified as being low, and needing to be improved in order to increase the economic and environmental sustainability of tomato farming. Increasing P, and also other nutrients, such as Zn and Ca, in tomatoes could also

help to improve agricultural sustainability by alleviating human malnutrition in developing countries and, in the case of Ca, have the potential to reduce blossom end rot, which can severely reduce marketable yield.

There is considerable potential for AM fungi to assist in the supply of these nutrients to field-grown tomatoes. AM fungi are widely accepted to increase plant uptake of P. This has mostly been demonstrated in low-P soils, as increases in plant-available P are generally known to be detrimental to AM colonisation and any subsequent growth effects. However, there is increasing evidence of the ability of AM fungi to increase P uptake and yield even in high P soils. There is also good evidence of increased Zn uptake by mycorrhizal supply to plants. Evidence for increased Ca uptake in mycorrhizal plants is in comparison limited and conflicting, but has been demonstrated in some cases. It is possible that AM fungi could allow applications of these nutrients, particularly P, to be reduced while maintaining or increasing fruit yield and quality. However, the ability of indigenous or inoculated AM fungi to do so in the relatively high-P farm soils used in this project was unknown.

In order to address these uncertainties a series of pot studies and a field experiment were conducted using field soils from tomato farms and an adjacent nature reserve for comparison. Data on soil characteristics from five farms, collected during the previous industry study, was analysed in conjunction with data from another farm located nearby with contrasting soil properties. Two farm soils and an unfarmed comparison were selected on the basis of their having contrasting levels of P, Zn and Ca, and pH, with the constraint that they were located within 50 km of each other to minimise travel time in the study area. The two farmed soils had a relatively high concentration of plant-available P (103 and 58 mg/kg Colwell), while plant-available P in the unfarmed soil was probably marginal to that required for healthy tomato growth (27 mg/kg Colwell). Samples of the soils were taken soon after commencement of the work and used in pot studies.

Firstly, a bioassay was conducted to establish the ability of tomato to become colonised in the three field soils. AM colonisation of tomato and medic, which is known to be highly susceptible to AM colonisation, was compared between three harvests over an approx. 16 week period. Vegetative growth was also measured. The total colonisation of tomato mostly did not differ from that of medic at each harvest in any soil. Furthermore, despite the large differences in plant-available P between the three soils, colonisation and vegetative growth of tomato did not differ between soils at any harvest.

In a subsequent pot experiment, the effect of colonisation by AM fungi in the three field soils on the vegetative and reproductive growth, and nutrient status of tomato was determined using the tomato mutant *rmc* (*r*educed *m*ycorrhizal *c*olonisation) and its progenitor 76R. A number of non-destructive vegetative and reproductive growth measurements were repeatedly measured over an approx. 24 week period. Destructive measurements were carried out at two harvests, 39 and 164 days after planting. Tomato 76R was again well colonised in all soils. Tomato *rmc* remained uncolonised, and was therefore an effective non-mycorrhizal control. AM colonisation had little effect on plant growth or nutrient status in any soil at the first harvest, but significant growth and nutrient responses were recorded at the second harvest. In particular, AM colonisation markedly increased vegetative growth in the unfarmed soil. AM colonisation did not affect vegetative growth in either of the farmed soils. However, AM colonisation increased reproductive growth, particularly yield over time, in all soils. AM colonisation increased shoot P concentration and content, but effects on Zn were mixed and largely inconclusive. Shoot Ca concentration and content were mostly reduced by AM colonisation. Similar patterns were observed in fruit nutrient status.

The potential of pre-inoculation with AM fungi to increase AM colonisation and/or AM growth and nutrient effects in the field was considered. A commercial AM fungal inoculum was initially proposed for use, but was found to be unreliable and laboratory cultures of *Scutellospora calospora* and *Glomus mosseae* were used instead. Tomato seedlings were

inoculated by amending a commercial seed-raising medium with an equal mixture of *S. calospora* and *G. mosseae* inocula. Seeds of tomato *rmc*, 76R and the commercial processing tomato cultivar U941 were sown and raised according to the practices followed by a commercial seedling nursery. After 9 weeks a sub-sample of inoculated seedlings of 76R and U941 had become colonised by both AM fungi, although the total colonisation was relatively low (approx. 10%). There was no difference in the shoot or root dry weights between inoculated and non-inoculated seedlings.

The remaining seedlings were then used in the field experiment. Seedlings were transplanted amongst a commercial processing tomato crop on two farms and grown to maturity. A substitute farm with soil of moderate P (66 mg/kg Colwell) was used as tomatoes were no longer being grown on the initial farm with moderate P. Two P treatments, 'normal' and 'reduced' P fertilisation, were imposed in order to investigate the effect of P fertilisation on colonisation by indigenous and inoculated AM fungi, and growth and nutrient status of tomato in the field. Non-destructive growth measurements and soil core samples to assess mycorrhizal colonisation were taken mid-season (approx. 10 weeks after transplanting). Destructive growth measurements and core samples to assess colonisation were taken at harvest (approx. 19 weeks after transplanting).

Colonisation of *rmc* was insubstantial and it again served as an effective non-mycorrhizal control to 76R. Colonisation was insubstantial in all treatments on the farm where soil had moderate plant-available P. On the other farm, where soil had relatively high plant-available P, colonisation of all plants was low mid-season, but was mostly substantial (>20%) in 76R and U941 at harvest. Low colonisation on both farms was probably the result of farming practices, particularly soil cultivation. However, a combination of inoculation and reduced P fertilisation increased colonisation. Colonisation by indigenous AM fungi had no effect on the growth or nutrient status of field grown tomatoes. In contrast, pre-inoculation with AM fungi increased fruit yield by a mean of approx. 40% in 76R and U941. This was the result

of an 18% increase in the fresh weight of individual fruits and, when inoculation was combined with reduced P fertilisation, a 21% increase in the number of fruits on each plant. The increase in the number of fruits on each plant was associated with an increase in the number of flowers at the most advanced growth stage. Inoculation also increased vegetative growth, and fruit P, Zn and Ca contents. A small (4%) decrease in fruit brix was more than offset by increased yield.

This study has shown that while AM fungi indigenous to tomato farm soils have the ability to substantially colonise tomato, they appear to have little effect on tomato growth, yield or nutrition in the field. In contrast, inoculation of tomato seedlings with mutualistic AM fungi during nursery production can substantially increase the growth, yield and fruit nutrient contents of field-grown tomatoes under commercial conditions. This increase could also be enhanced by a reduction in P fertilisation. Increased yield and fruit nutrient contents, and decreased P fertilisation neatly address the aims of increased agricultural sustainability. Incorporating pre-inoculation of tomato into existing farming practices has a potential to increase the productivity and sustainability of processing tomato production worldwide.

Declaration

I declare that this thesis contains no material that has been accepted for the award of any other degree or diploma in any university or tertiary institution. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

I consent to this copy of my thesis, when deposited in the University library, being made available in all forms of media, now or hereafter known.

May 2005

Signed

Ashley William Martin

Acknowledgements

Sally Smith, Andrew Smith and Jamie McMaster for invaluable help as supervisors.

Debbie Miller for technical assistance.

Petra Marschner for advice in the absence of supervisors.

Michelle Lorimer, Biometrics SA, for statistical advice.

ARC, Outsourced Environmental and Unilever for the ARC-Linkage project grant that provided an APAI scholarship.

Leena Martin for help during the field experiment.

My family for patience and encouragement.

Abbreviations

%	percent	min	minute/s
A$	Australian dollar/s	min.	minimum
abs.	absolute	mL	millilitre/s
AM	arbuscular mycorrhizal	mm	millimetre/s
approx.	approximately	n/a	not applicable
cm	centimetre/s	NI	non-inoculated
DAP	Days after planting	NM	non-mycorrhizal
Expt/s	experiment/s	no.	number
FW	fresh weight	ºC	degrees Celsius
g	gram/s	RO	Reverse osmosis
h	hour/s	s	second/s
kPa	kilopascal/s	t.	tonne/s
L	litre/s	µg	microgram/s
M	molar	v/v	volume/volume
meq	milliequivalent/s	w/v	weight/volume
mg	milligram/s	w/w	weight/weight