IMPACT OF ENDOMYCORRHIZAL FUNGI ON PLANT TRACE ELEMENT UPTAKE AND NUTRITION

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ABSTRACT

Several endomycorrhizal plant nutrient trials were undertaken from 1987-98 at Eastleigh, Forest of Dean, England. The mycorrhizal inoculum contained three species, namely, *Glomus Mosseae*, *Glomus Calendonium*, and E3 spores and mycelium in a peat carrier. The plants grown were standard commercially available broad beans, peas, runner beans, carrots, parsnip, onion, parsley, ryegrass, clover and potatoes. Treatments included no addition, added mycorrhizal inoculum with and without added fertiliser or rock phosphate and wood ash. The main findings were: (1) the sterilisation of soil has a significant effect on endomycorrhizal activity and trace element uptake; (2) endomycorrhizal effect on trace element uptake varies with plant species (foodstuff); (3) addition of fertiliser and rock phosphate to soil reduces mycorrhizal colonisation and plant trace element content (except phosphorous); and (4) mycorrhiza enhances the trace element plant uptake following the addition of wood ash.

INTRODUCTION

Mycorrhiza are a group of fungi living in a symbiotic, or mutually beneficial, relationship with most land plants. These fungi draw sugars from the plant and in exchange act as a root extension and thereby enhance the plant uptake of trace elements and other nutrients. The physiological processes stimulated by mycorrhizal symbiosis include increased plant growth, more rapid and uniform growth, increased stress resistance, enhanced disease resistance or tolerance to root pathogens, increased size, colour and number of flowers and enhanced nutrient composition (Saif and Khan, 1977; Abbott and Robson, 1982; Nelson and Safir, 1982; Gianinazzi-Pearson, 1986). Early studies showed remarkable crop yield increases after the pre-inoculated addition to plants of vesicular-arbuscular mycorrhiza (VAM) to maize, barley and wheat grown on nutrient deficient soils (Saif and Khan, 1977). An explanation for this is the fact that mycorrhizae extend up to 7 cm from the root surfaces thereby increasing the volume of soil from which nutrients can be extracted (Koide, 1991). This function is disproportionately important for nutrients which have narrow diffusion zones around roots, particularly phosphorus, zinc and copper (Lambert *et al*., 1979). Several factors have been found to influence mycorrhizal fungal activity, including changes in soil texture and chemistry, temperature and pH, moisture and organic matter content, and the application of lime, fertiliser and chemical pesticides

(Lambert *et al*., 1979; Trappe *et al*., 1984; Dodd and Jeffries, 1989). Most studies have reported the effects of minor elements (especially phosphorus, potassium, calcium, magnesium and sulphur) on mycorrhizal activity and farm crop yields. Only a couple of reported studies have evaluated the trace element changes in plants or related foodstuffs and mycorrhizal infection (Lambert *et al.*, 1979; Jakobsen, 1983; Nielson and Jenson, 1983; Krishna and Bagyaraj, 1984; Rogers and Williams, 1986; Eivazi and Weir, 1989) . To date, iron, zinc, caesium, copper, cobalt, selenium, manganese and boron have been studied. This paper reports the findings of several mycorrhizal plant nutrient trials undertaken from 1987-98 at Eastleigh, Forest of Dean, England.

METHODS

The Eastleigh research site consisted of a plot of unsterilised soil (sandy-loam, pH 7.2, organic matter content, typically 8.2 %) which had remained uncultivated for at least 5 years.The mycorrhizal inoculum (Rothamsted, Herts., UK) used contained three species, namely, *Glomus Mosseae*, *Glomus Calendonium*, and E3 spores and mycelium in a peat carrier. The plants grown were standard commercially available broad beans, peas, runner beans, carrots, parsnip, onion, parsley, ryegrass, clover and potatoes. Treatments included no addition, added mycorrhizal inoculum with and without added fertiliser or rock phosphate and wood ash. Mycorrhiza was introduced at root level (6-10 cm) using a double-drill depth relative to the plant seed. NPK fertiliser (8.25.25), rock phosphate (Gafsa) and wood ash (produced by burning local native hardwood) were branded along the rows as a surface treatment at the equivalent of 2 cwt per acre. Seeds were planted in mid-March and harvesting was undertaken at traditional times, for example, beans (mid-July), carrots (end August), parsnips and potatoes (October-November). All plant materials were carefully cleaned to remove surface soil, weighed and stored at 4°C until delivery to the laboratory. All samples were dried at 110°C for 3 days, weighed, and dry-ashed at 450°C for 12 hours. The homogenised ash (~0.25g ash weight) were dissolved in 1 ml 12M Aristar™ nitric acid and diluted with 1% nitric acid before analysis by inductively coupled plasma mass spectrometry (ICP-MS) with 100 μg/l indium internal standardisation. Quality control analysis was performed using

RESULTS AND DISCUSSION

Table 1 summarises the zinc uptake by plant species as a function of mycorrhizal innoculum treatment. The results are presented as “normalised values”, with no addition (NM) representing the baseline plant nutrient content, shown as 100 units. Plants indicating a positive effect following treatment have values >100, and conversely, reduced trace element uptake is represented by values <100. Figures 1 and 2 report the results for copper and selenium using the same format. The values represent the average response for all the plants studied.

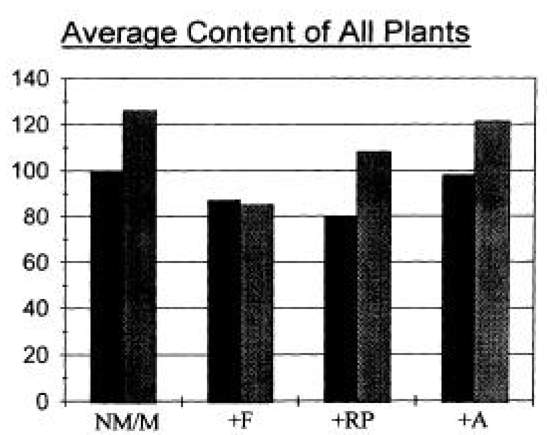
Plants grown with no added mycorrhizal innoculum but with added NPK fertiliser (F), or rock phosphate (RP) and wood ash (A) all show reduced plant uptake of trace elements, especially zinc and copper, with a significant variation between plant species (or foodstuffs). Only broad beans show a small zinc reduction following treatment. Rock phosphate has a major influence on zinc uptake by root vegetables (parsnip>carrot~potato>onion). Mycorrhizal innoculum addition (M) has a dramatic effect on increasing trace element uptake (especially zinc) in all plant species, with the order of the effect being: broad beans>peas>potato~onion>carrot>parsnip~ryegrass and clover. Mycorrhiza enhances the trace element uptake in conjunction with wood ash (M+A). In contrast, the addition of fertiliser (M+F) and rock phosphate (M+RP) to soil reduces mycorrhizal colonisation and most plant trace element content. The only element to show raised levels following treatment is phosphorus, especially with the addition of both F and RP.

Table 1. Zinc uptake by plants with and without endomycorrhizal treatment*.

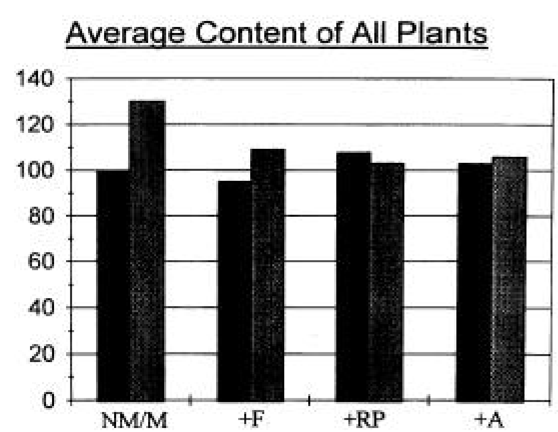
Treatment	Broad bean	Pea	Carrot	Potato	Parsnip	Onion	Ryegrass & Clover
NM	100	100	100	100	100	100	100
NM + F	95	59	59	60	58	65	37
NM + RP	92	73	47	49	45	54	92
NM + A	91	70	65	69	50	57	77
M	134	125	118	121	114	120	113
M + F	32	42	51	60	53	51	44
M + RP	74	73	58	68	102	100	98
M + A	112	93	68	77	144	84	81

* "normalised values": 100 units for baseline plant nutrient content (NM)

Figures 1 and 2: Copper and selenium uptake by plants with and without endomycorrhizal treatment.



Copper



Selenium

In addition to studying the impact of endomycorrhizal fungi on plant trace element uptake some data was obtained on germination rates and crop yields. As an example, after a period of 6 weeks post-treatment the germination rate for broad beans was: no addition (NM) 78%, fertiliser addition (NM+F), mycorrhizal innoculum addition (M) 94%, and mycorrhizal innoculum and fertiliser addition (M+F) 78%. Similarly, crop yield data for carrots are reported in Table 2 as weight of carrots (kg) per equal row length.

Table 2: Crop yield data for carrots with and without endomycorrhizal treatment.

Treatment	Symbol	Crop yield
No addition	NM	7.5
+ Fertiliser	NM + F	3.5
+ Rock phosphate	NM + RP	2.5
+ Wood ash	NM + A	4.5
Mycorrhiza	M	12
+ Fertiliser	M + F	13
+ Rock phosphate	M + RP	10
+ Wood ash	M + A	13

Endomycorrhizal root colonisation increases plant size and yield (as well as plant nutrient content). However, the relationship between plant size, yield and the effects of M + F are complex.

In summary these results show the importance of endomycorrhizal colonisation of agricultural soils. In particular, the benefits to plant nutrient uptake and thereby plant health and nutrient value are obvious. However, as shown by the various treatment profiles, the addition of other common agricultural media, namely fertiliser, rock phosphate and wood ash can result in both beneficial and harmful effects on the activity of mycorrhiae. More extensive studies need to be undertaken, especially in relation to the impact of environmental stress conditions (draught, extreme winter) and under the influence of chemical pollutant loadings.

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