L'EFFETTO BIOSTIMOLANTE DELLE MICORRIZE

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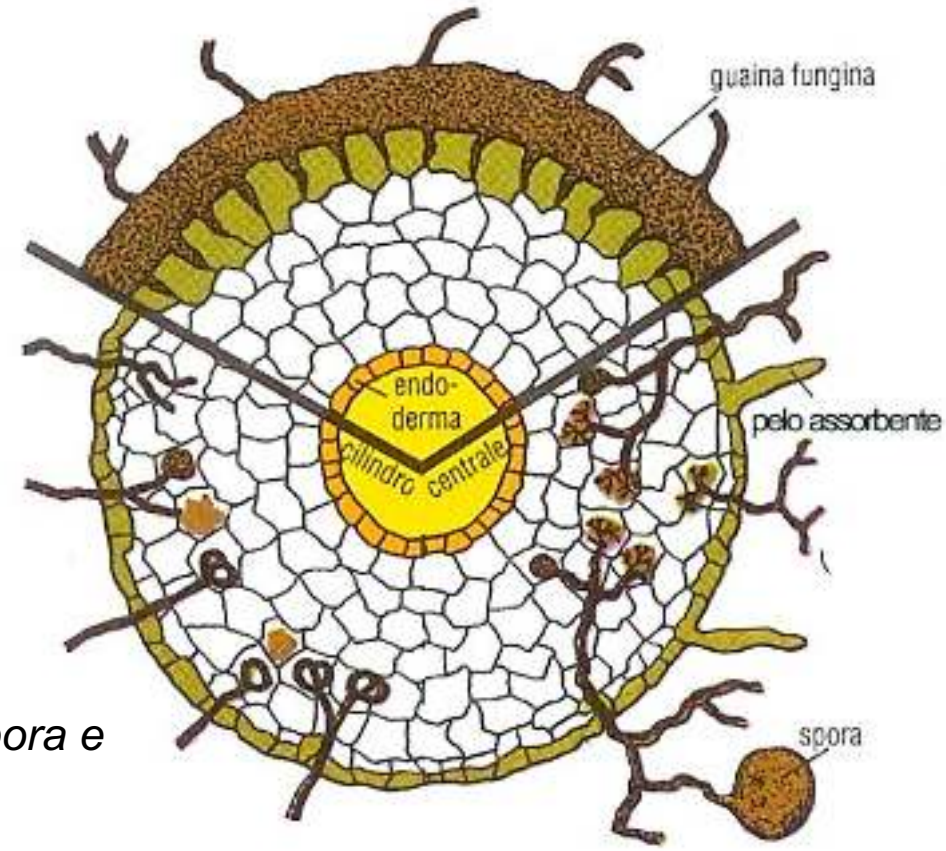
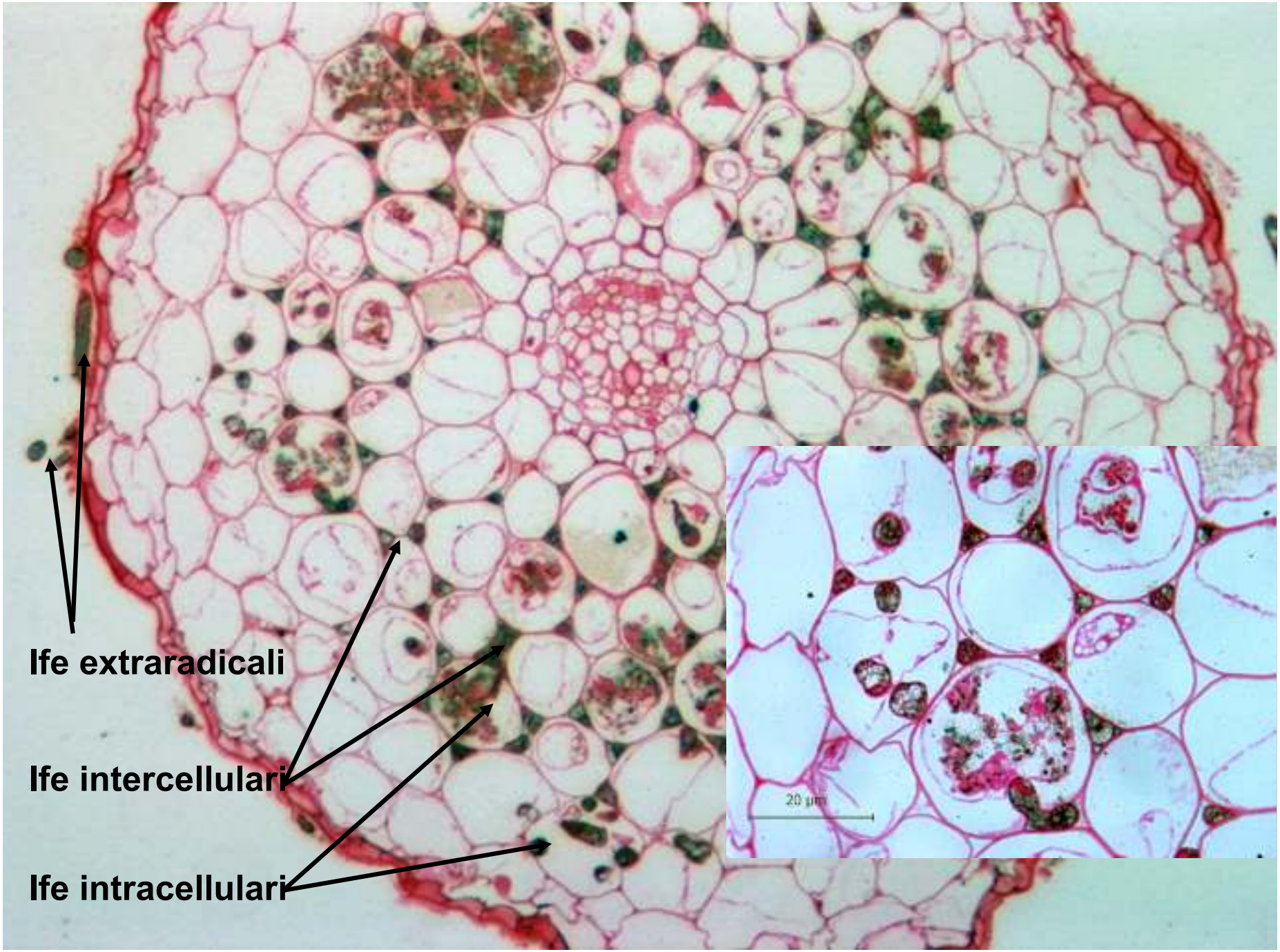
BIOSTIMOLANTI CONFERENCE
Bari, 11 Febbraio 2020

La simbiosi micorrizica

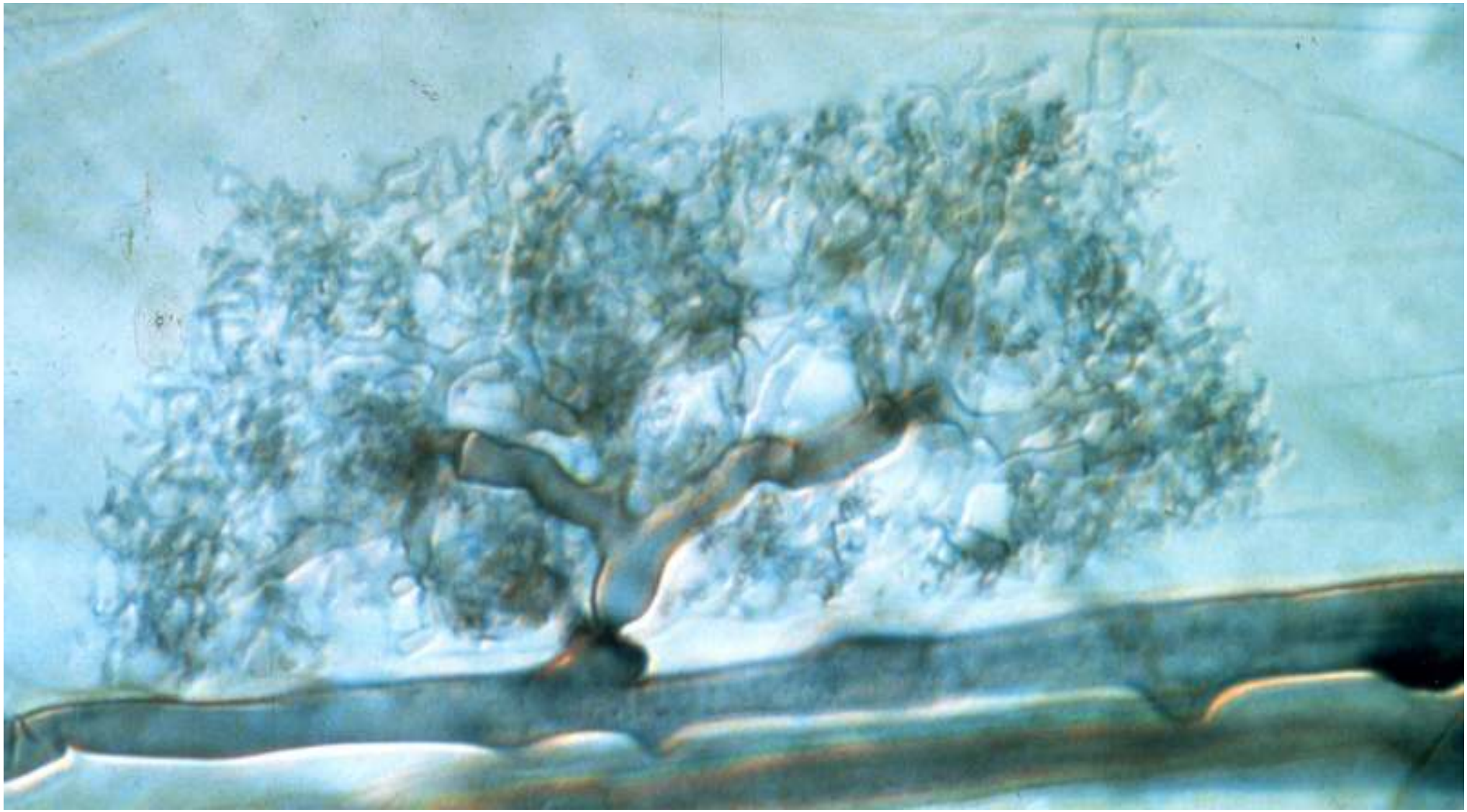
Ectomicorrize:
i funghi crescono in una guaina esterna alle radici.



Endomicorrize arbuscolari:
i funghi (genere *Glomus, Gigaspora, Acaulospora e Sclerocystis)* **crescono all'interno del tessuto radicale.**
Interessano le piante erbacee/arboree tra cui quelle di interesse agrario

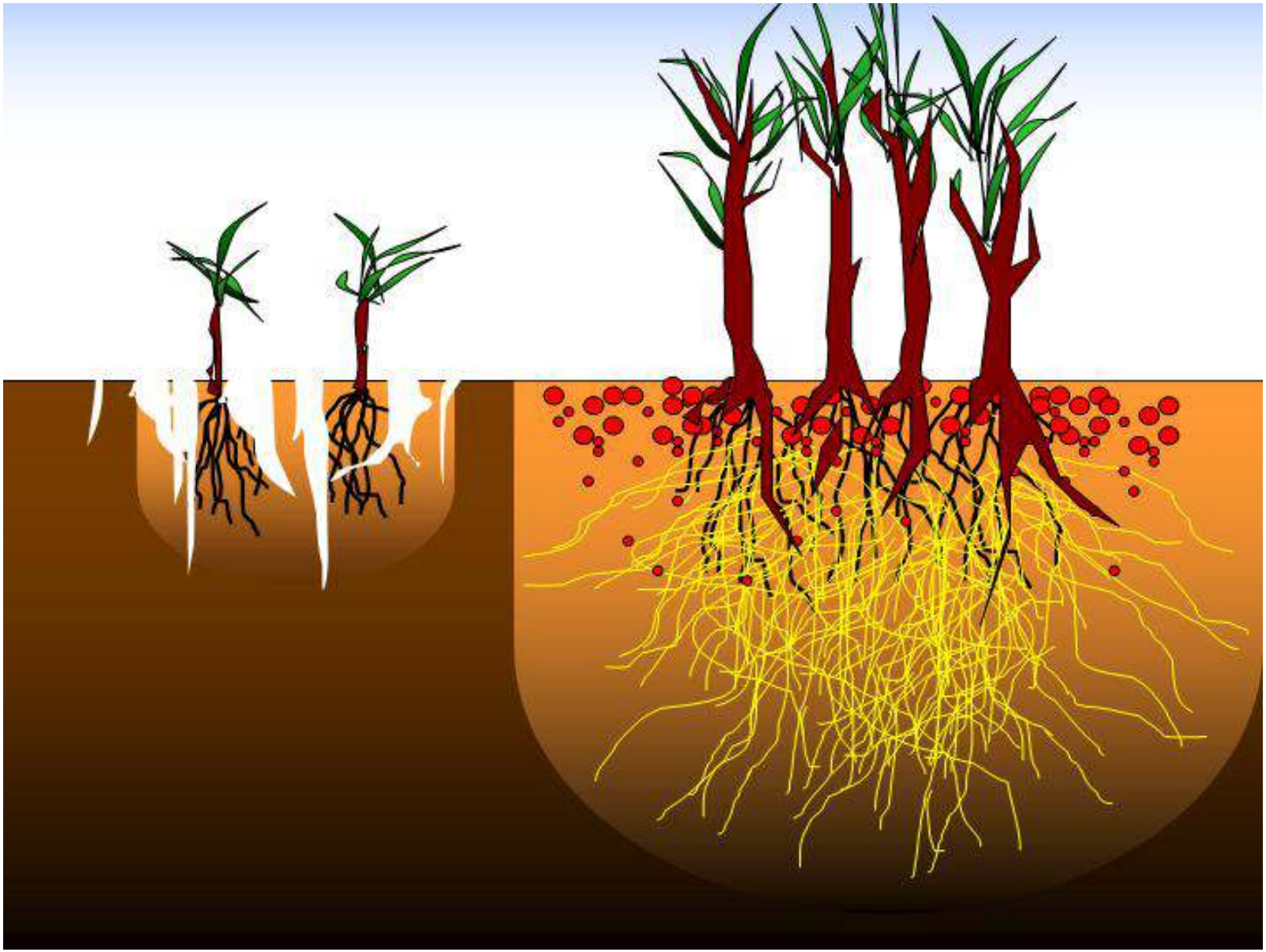


Radice di cipolla micorrizzata da *Gigaspora margarita*



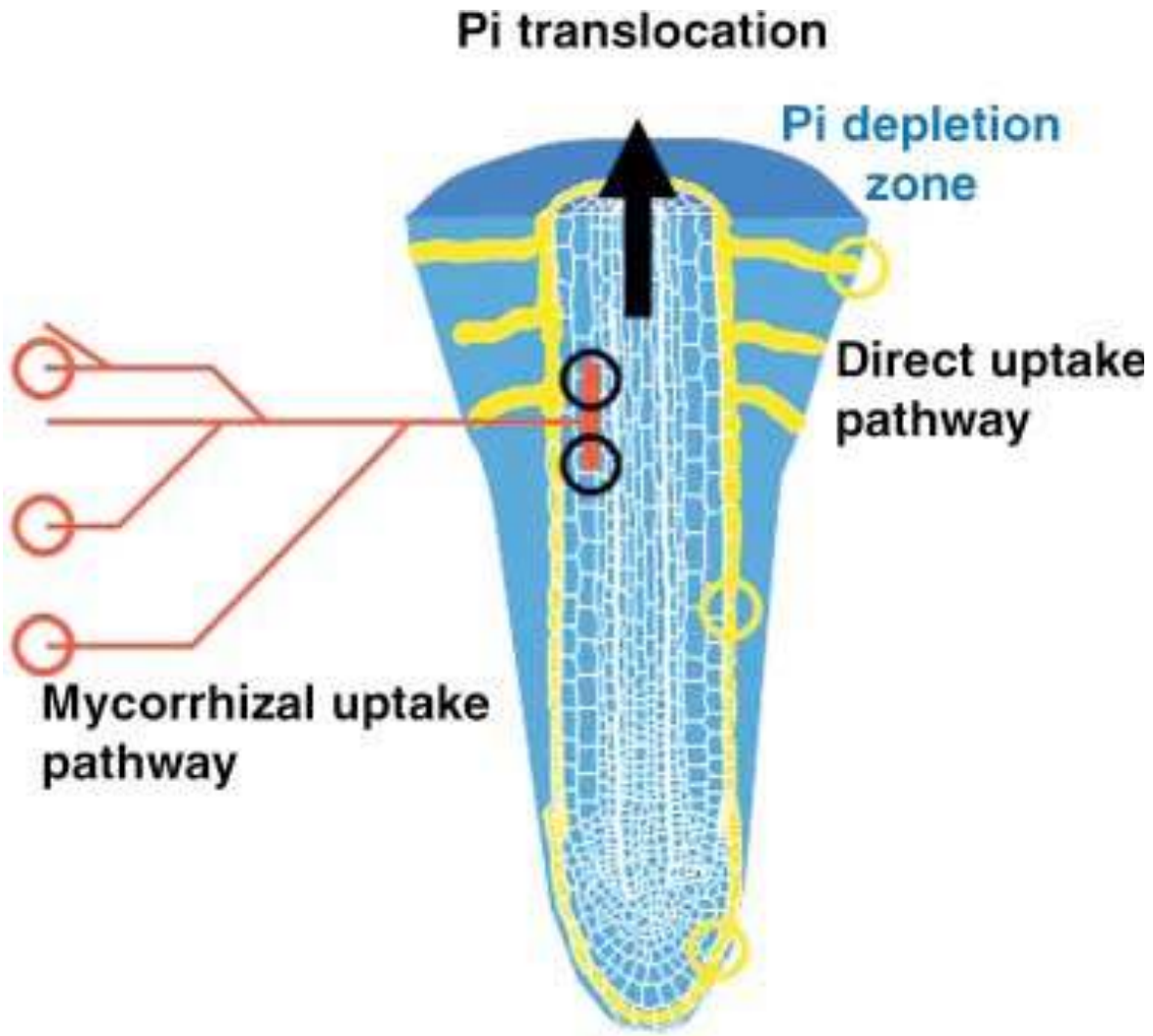
Il fungo utilizza il **glucosio** prodotto dalle piante in quanto non sanno utilizzare carboidrati complessi presenti nell’humus

Le (endo)Micorrize



EFFETTI MICORRIZA

- **Aumento della superficie di assorbimento**, da 100 a 1000 volte *(Gil,1995);*
- **Maggiore efficienza nell'assorbimento di elementi poco mobili come P** (Smith e Read, 1997), **microelementi Zn, Fe, Cu** (Azcón *et al.,* 2003; Lehmann and Rillig, 2015) e **di K** (Koide, 1991b);
- **Maggiore efficienza nell'assorbimento di N inorganico** (Ames et al.,1983; Johansen et al., 1992, 1993, 1994; Hawkins e George, 1999) e di **aminoacidi** *(Hawkins et al., 2000; Chalot et al., 2006);*
- **Migliore resistenza a stress idrico e stress salino** (Al-Karaki et al., 1998; Al-Karaki, 2006);
- **Migliore resistenza a stress biotici** (Gianinazzi et al., 2010)
- **Elicitazione metabolismo secondario** (Sbrana et al, 2014; Avio et al., 2018)



Acquisizione ed asportazione di fosforo (Pi) in pianta micorrizzata

SISTEMI AGRICOLI INTENSIVI

eccessivo impiego di fungicidi e geodisinfestanti

eccessivo impiego di concimi minerali

abbandono di alcune pratiche agricole (rotazione e sovescio)

Lavorazioni del terreno

Riduzione contenuto di sostanza organica del suolo

Riduzione la biodiversità microbica del suolo

Inoculazione dei suoli con FMA

Migliore sfruttamento delle risorse idriche e nutritive del suolo
minore impiego fertilizzanti e acqua irrigua

Migliore resistenza a stress biotici e abiotici
minore impiego fitofarmaci

Migliore qualità nutrizionale dei prodotti

Specie FMA autoctone ed introdotte

(competizione/antagonismo tra le spp. selezionate e/o con le spp. autoctone)

Specie vegetale

(*Brassicaceae* e *Chenopodiaceae* non ospiti, durata coltura)

Funzionalità specie-specifica della simbiosi

Tipo di terreno/substrato

(pH, contenuto di elementi nutritivi, contenuto di S.O.)

Gestione della coltura

(concimazione, trattamenti chimici al suolo)

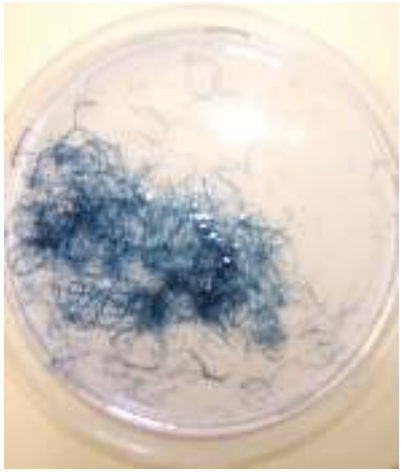
Effetto dei fungicidi su FMA

No Inhibitory Effect	Inhibitory Effect⊗
Carbamate (Ferbam, Fermate)	*Aliette (Fosetyl-Al)*
Carbendazim (Bavistan)	Benomyl (Benlate, Tersan-1991)
Chloroneb (Tersan, Demosan)	Captan (Orthocide)
Chlorothalonil (Bravo, Daconil-2787, Exotherm)	Copper Oxychloride Sulfate (CDCS)
Difolatan (Sulfonimide, Difosan, Captafol)	Formalin (Formaldehyde)
Mancozeb (Dithane M-45, Manzate; Fore)	*Metalaxyl = Mefenoxam (Subdue, Ridomil)*
Manate (Dithane M-22, Maneb)	PCNB (Terrachlor, Tri-PCNB)
Rovral (Chipco-26019)	Phaltan (Folpet; Thiophal)
Thiabendazole (Mertect)	Terrazole (Truban, ETMT)
Thiram (Tersan 75, Arasan)	Tilt (CGA-65250, Banner, Propiconizol)
Topsin-M (Easout, Fungo, Duosan)	Thiophanate Methyl (Cleary 3336)
Triforine (Funginex)	Triadimefon (Bayleton)
	Vitavax (Carboxin, DCMO)
	Azoxystrobin (Abound, Dynasty, Heritage, Protégé, Quadris, Quilt, Soyard, Uniform)
	Kresoxim-methy (Cygnus, Sovran)

*Alcune ricerche hanno evidenziato che alcuni fungicidi possono stimolare i FMA
⊗NOTE: l'effetto è evidenziato quando il p.a. è applicato al suolo e non sulla pianta

- **Frequenza di micorrizzazione del sistema radicale (F)**

(numero di frammenti micorrizzati/numero totale di frammenti)*100;



- **Intensità di micorrizzazione del sistema radicale (M)**

(95n5+70n4+30n3+5n2+n1)/(numero totale frammenti), dove n5, n4, n3, n2, n1 sono il numero di frammenti attribuiti alle classi di frequenza della infezione (0, 1, 2, 3, 4, 5)

- **Intensità arbuscolare nel sistema radicale (A)** = a*(M/100)

a_1= abbondanza di arbuscoli nella parte micorrizzata dei frammenti radicali)

software: MYCOCALC (http://www.dijon.inra.fr/mychintec/Mycocalc-prg/download.html)

1. Produzione vivaistica piantine

Specie: pomodoro da industria
Substrato: torba sterilizzata (121 °C per 20 minuti)

TRATTAMENTI

INTRA: prodotto commerciale a base di *Glomus intraradices (½ dose di etichetta);*

MIX: prodotto commerciale a base di diverse specie del genere *Glomus* (*G. intraradices; G. mosseae; G. caledonium; G. viscosum; G. coronatum*) *(½ dose di etichetta)*

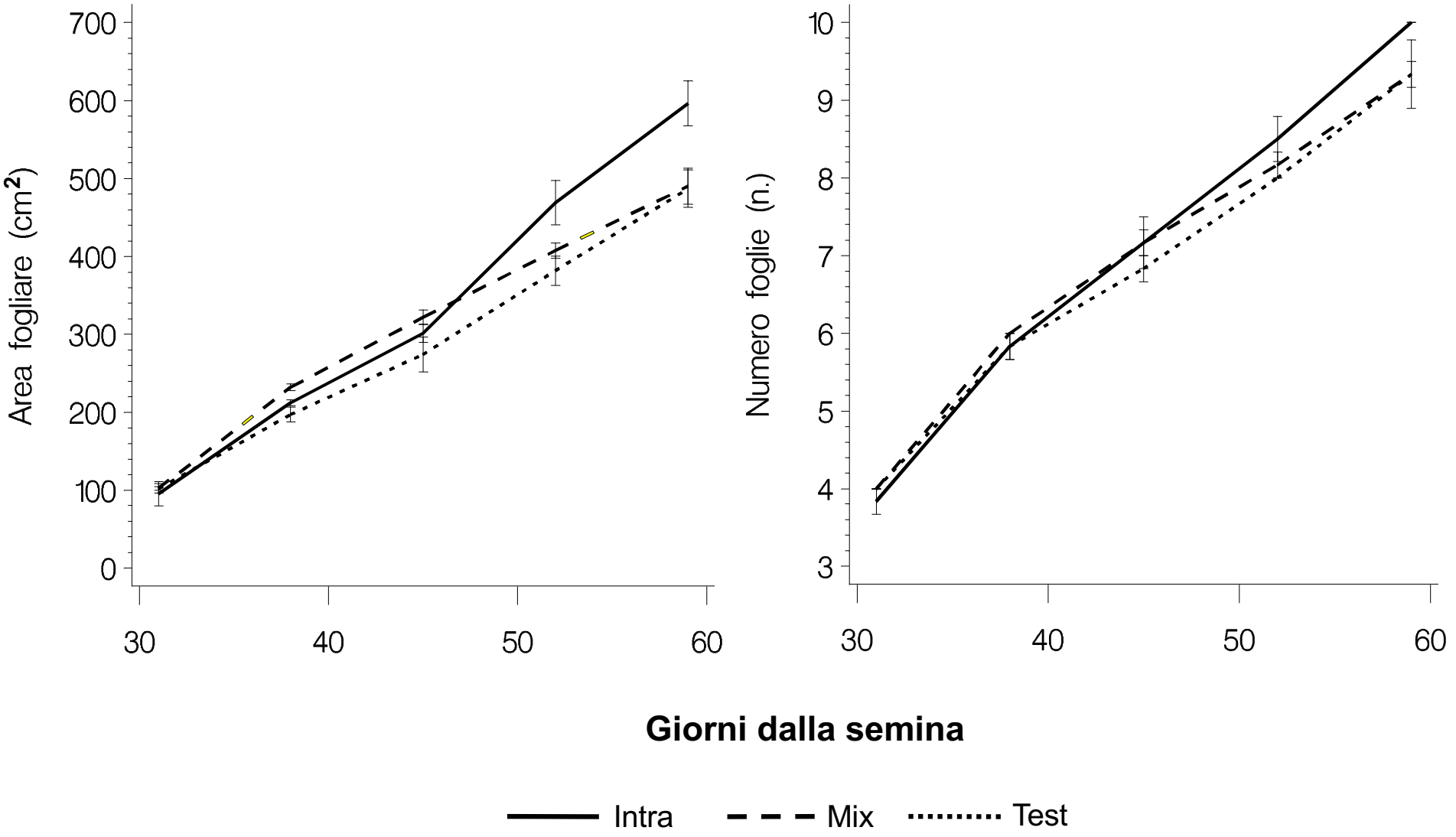
Test: controllo non micorrizzato

Frequenza di micorizzazione

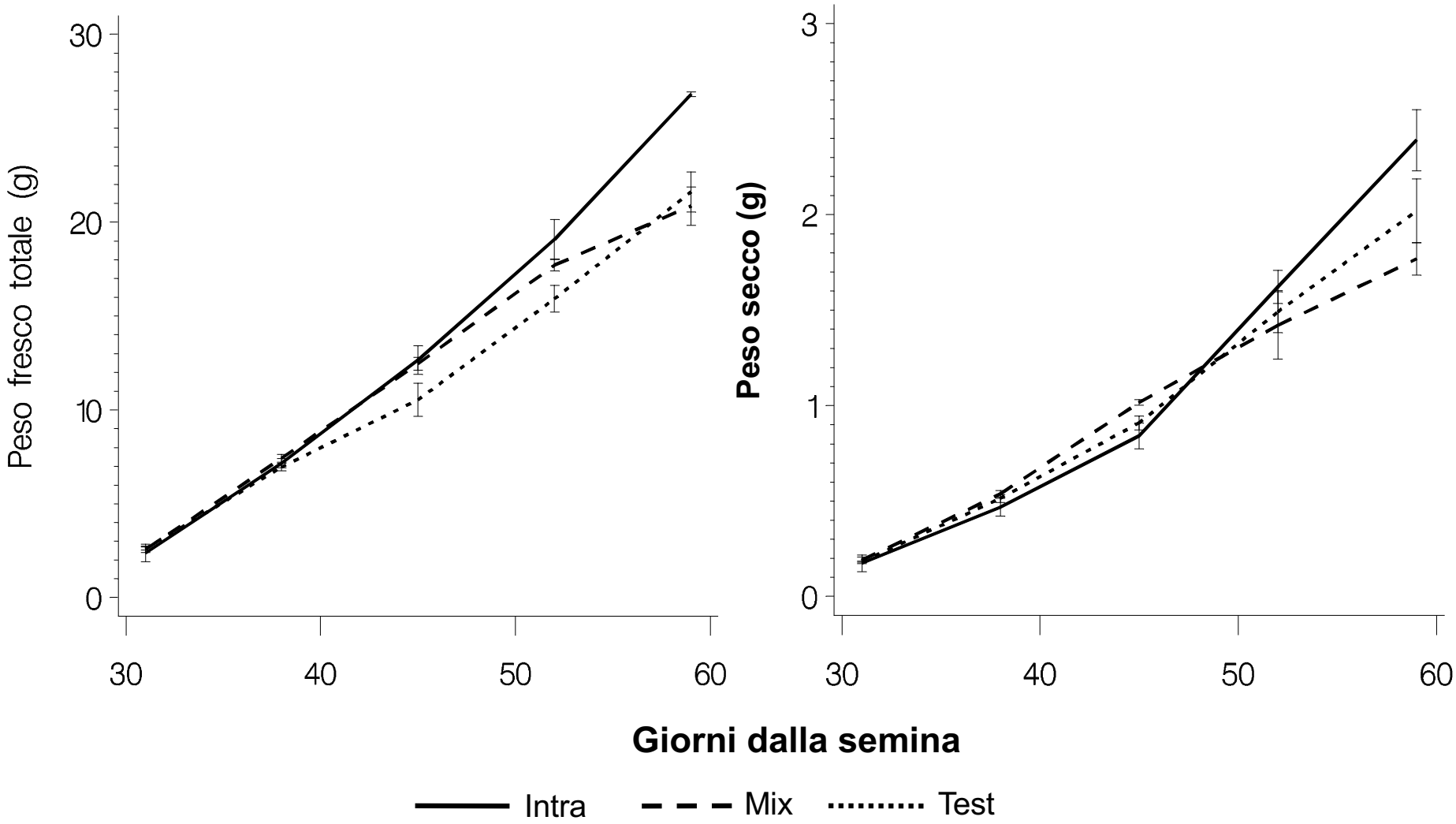
INTRA: 75%

MIX <10%

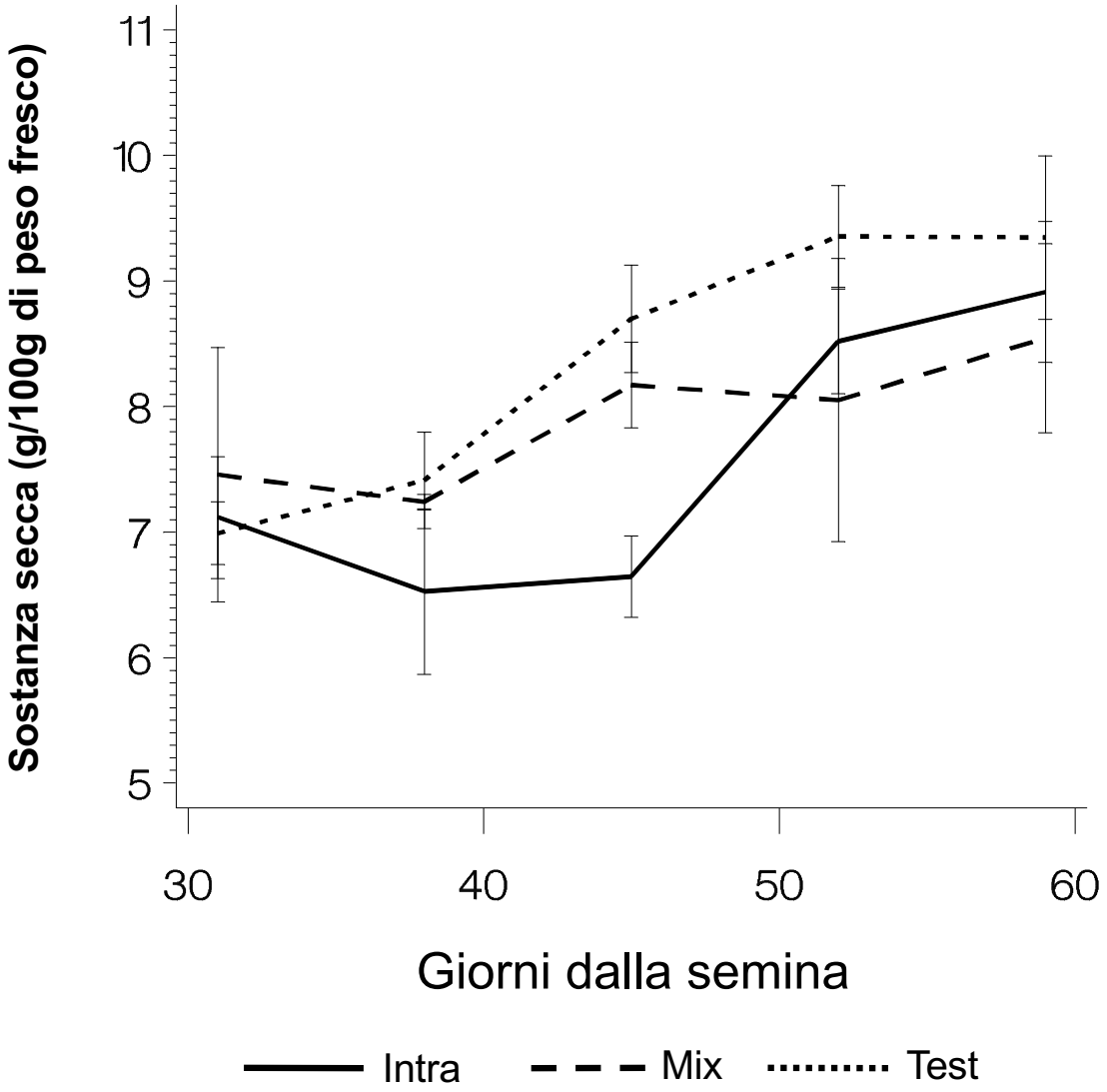
Test: assente



Effetto dell'inoculo micorrizico su area fogliare e numero di foglie



Effetto dell'inoculo micorrizico su peso fresco e secco della parte aerea



Effetto dell’inoculo micorrizico sulla percentuale di sostanza secca della parte aerea

1. Produzione vivaistica piantine

Specie: pomodoro da industria

DUE TIPI DI SUBSTRATO

Torba (T)
povera di nutrienti e di microorganismi del suolo

+ concime organico Lysodin 24 1 $g \cdot L^{-1}$

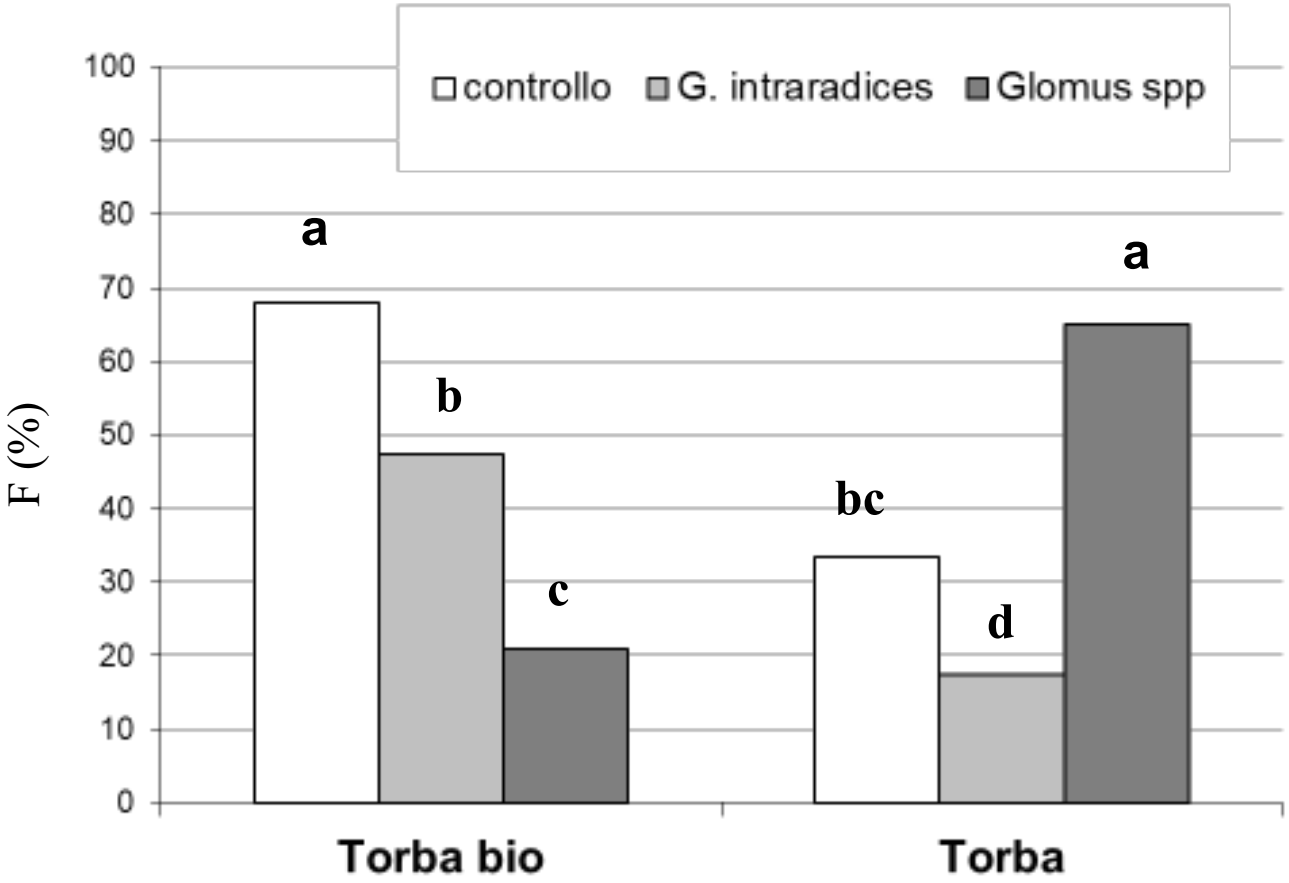
Torba Bio (Tbio)
arricchito in nutrienti di origine organica e di microrganismi del suolo

DUE INOCULI MICORRIZICI

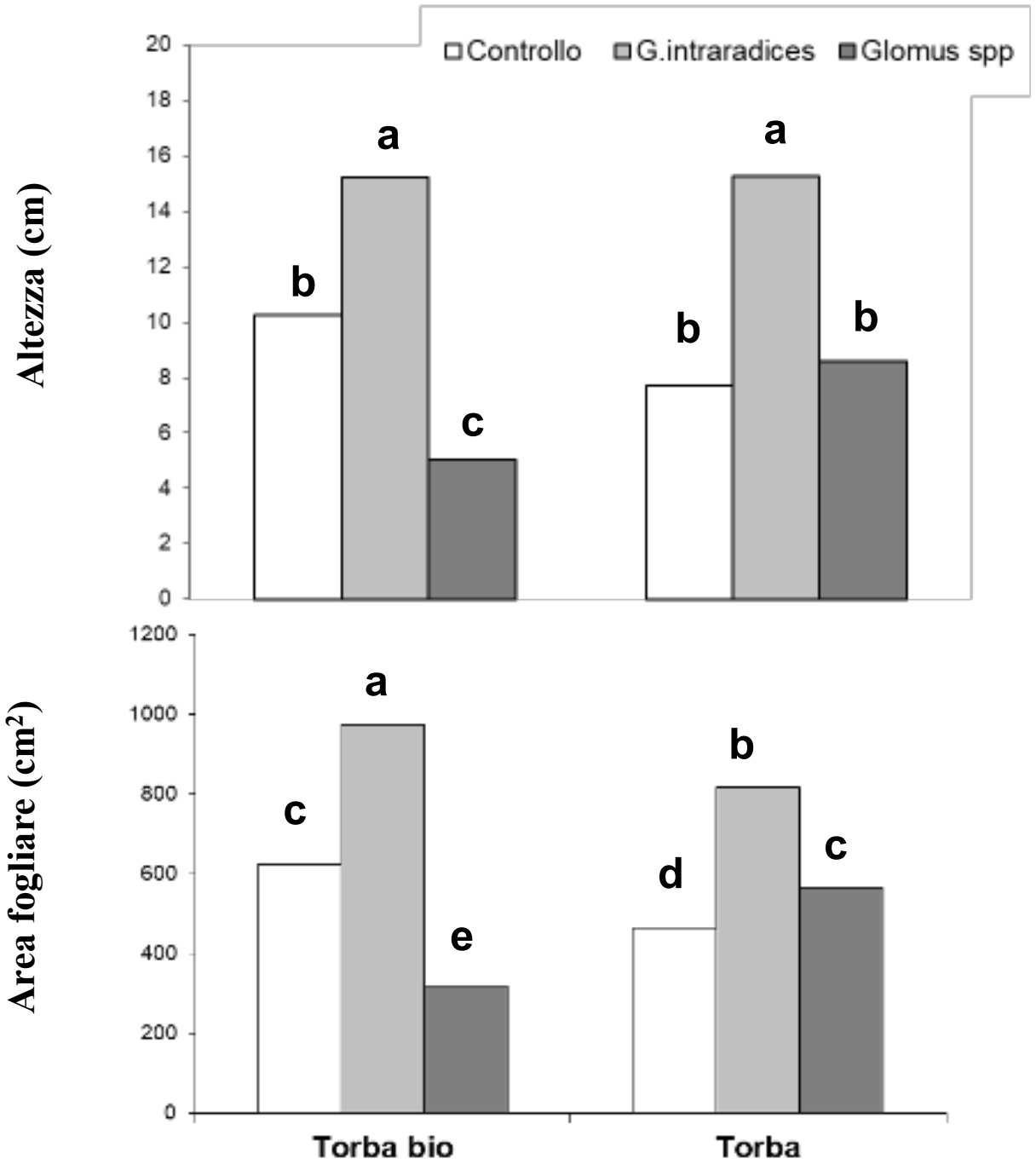
INOCULO A
(*Glomus intraradices*)

INOCULO B
(Specie diverse di *Glomus)*

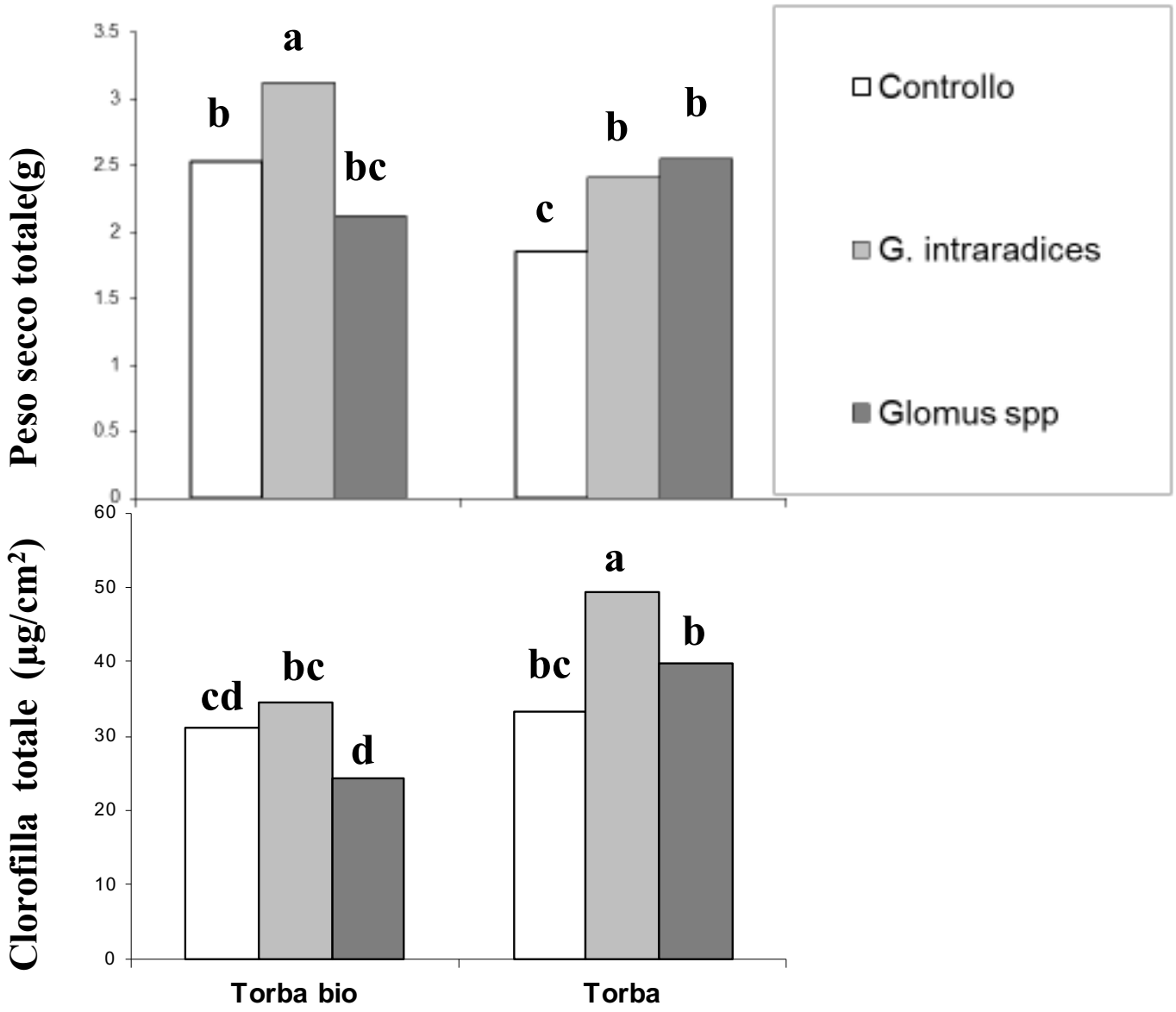
Controllo T +Controllo Tbio



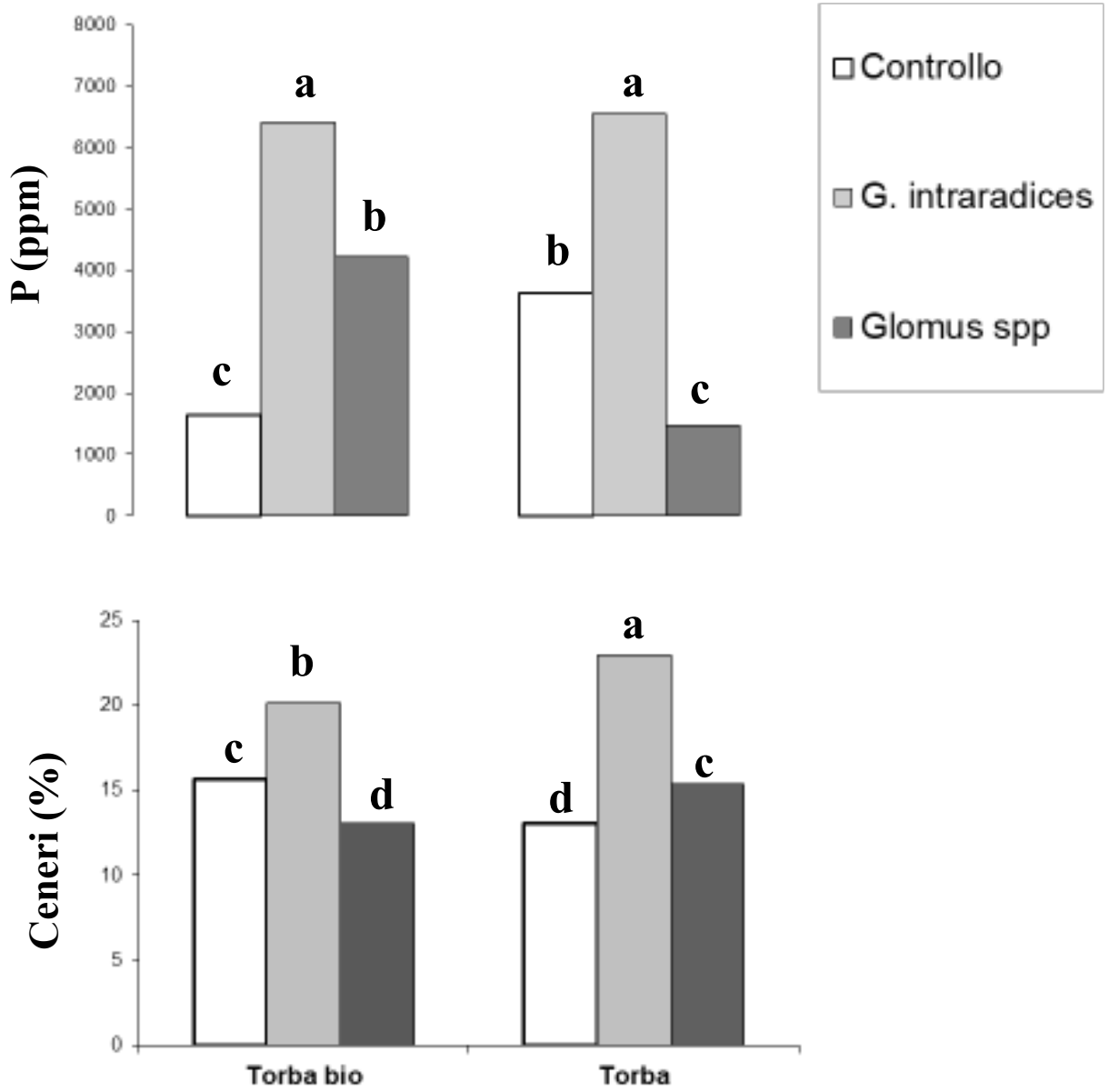
Frequenza di micorizzazione in radici di piantine di pomodoro



Effetto dei substrati e dell'applicazione di i. m. su altezza ed area fogliare di piantine di pomodoro



Effetto dei substrati e dell'applicazione di i.m. sul peso secco totale e sul contenuto di clorofilla totale di piantine di pomodoro



Effetto dei substrati e dell'applicazione di micorrize sulla concentrazione (ppm) di P in foglie e sul contenuto percentuale di ceneri in piantine di pomodoro

2. Produzione vaseria fiorita

frontiers in Plant Science

ORIGINAL RESEARCH

Influence of biochar, mycorrhizal inoculation, and fertilizer rate on growth and flowering of *Pelargonium* (*Pelargonium zonale* L.) plants

Giulia Conversa, Anna Bonasia, Corrado Lazzizera and Antonio Elia*

Department of the Science of Agriculture, Food and Environment, University of Foggia, Foggia, Italy

Geranio (cv Pinnacle Dark Red)
Glomus intraradices + Glomus mosseae
25 spore-ife-radici per g p.c.
Dose: 8 kg/m^3 di substrato
Aggiunto al substrato al trapianto

TABLE 3 | Mycorriza colonization frequency (F) and intensity (M), and arbuscule abundance (A) of *Pelargonium* plants inoculated (MICO+) or not ($MICO_0$) with arbuscular mycorrhizal fungi (AMF) and grown for 74 d in substrate amended with different rates of biochar (BC_0, BC_{30}, BC_{70}), and fertilized with different rates of fertilizer ($FERT_1$, $FERT_2$).

Treatments	Mycorrhization parameter		
	F (%)	M (%)	A (%)
Biochar rate (BC)[1]			
BC_0	15.0[a]	0.48	0
BC_{30}	13.0[a]	1.31	0
BC_{70}	5.7[b]	1.12	0
Fertilization rate (F)[2]			
$FERT_1$	13.3	1.42	0
$FERT_2$	9.7	0.51	0
AMF inoculation (I)			
MICO+	14.6[a]	1.71[a]	0
$MICO_0$	8.2[b]	0.14[b]	0
Significance[3]			
Biochar rate	*	NS	NS
Fertilization rate	NS	NS	NS
AMF inoculation	*	**	NS
BC*I	NS	NS	NS
BC*F	NS	NS	NS
I*F	NS	NS	NS
BC*I*F	NS	NS	NS

[1]*BC_0, BC_{30}, and BC_{70}: 100:0, 70:30, and 30:70 (v:v) peat:biochar substrate mixtures, respectively.*

[2]*$FERT_1$ and $FERT_2$: fertilized with 140 and 210 mg L^{-1} of Nitrophoska® Gold®, respectively.*

[3]*NS, *, and ** not significant or significant at $P \leq 0.05$ and $P \leq 0.01$, respectively.*

[a–b]*Means in columns followed by the same letters are not significantly different according to LSD test ($P = 0.05$).*

Means in columns without letters are not significantly different according to the LSD test ($P = 0.05$).

Pelargonium plant growth as affected by media mixture, arbuscular mycorrhizal funghi (AMF) inoculation and nitrogen fertilization at 28 and 74 day after transplant (dat).

Treatments	Dry weight (g/plant)									
	28 dat					74 dat				
	Total	Leaf	Stem	Truss	Root	Total	Leaf	Stem	Truss	Root
Biochar rate (B)										
B_0	2.8a	1.7a	0.37a	0.33a	0.42a	6.5b	2.0a	1.1a	2.4b	1.1a
B_{30}	2.9a	1.9a	0.36a	0.25a	0.38a	7.8a	2.4a	1.2a	3.3a	1.0a
B_{70}	1.8b	1.1b	0.22b	0.26a	0.29b	4.4c	1.3b	0.6b	1.8c	0.6b
Fertilizer rate (F)										
F_1	2.4a	1.4b	0.32	0.28a	0.41a	5.5b	1.6b	0.8b	2.1b	0.9a
F_2	2.7a	1.7a	0.31	0.28a	0.32b	7.0a	2.2a	1.1a	2.9a	0.9a
AMF inoculation (I)										
MICO+	2.6a	1.6a	0.32	0.29a	0.36a	6.8a	2.1a	1.0a	2.7a	0.93a
MICO-	2.5a	1.5a	0.31	0.27a	0.36a	5.7b	1.7b	0.9b	2.2b	0.84a
Significance[(1)]										
B	***	***	***	NS	*	**	*	***	***	**
N	NS	*	NS	NS	*	***	***	**	***	NS
I	NS	NS	NS	NS	NS	*	*	*	**	NS
B*F	*	***	NS	NS	NS	**	*	NS	**	NS
B*I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F*I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B*F*I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[(1)] NS, *, **, and *** not significant or significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively.
[a-b] Means in columns not sharing the same letters are significantly different according to LSD test ($P = 0.05$).

Pelargonium flowering traits as affected by media mixture, arbuscular mycorrhizal funghi (AMF) inoculation and nitrogen fertilization at 74 day after transplant

Treatments	Truss			Flower	F. buds
	Fresh weight	Dry weight			
	g/plant		(n.)		
Biochar rate (B)					
B_0	11.4 b	2.4 b	3.9 b	27.3 b	1.9
B_{30}	17.4 a	3.3 a	5.0 a	43.6 a	3.4
B_{70}	9.7 b	1.8 c	3.4 b	23.1 b	2.3
Fertilizer rate (F)					
N_1	14.5 a	2.7 a	4.3 a	36.5 a	2.9
N_2	11.2 b	1.2 b	4.0 a	26.1 b	2.2
AMF inoculation (I)					
MICO-	10.4 b	2.2 b	3.8 b	24.9 b	2.1 b
MICO+	15.3 a	2.7 a	4.5 a	37.8 a	3.0 a
Significance†					
Biochar rate (B)	***	***	*	**	Ns
Fertilizer rate (F)	**	**	Ns	**	Ns
AMF inoculation (I)	***	***	*	**	Ns
B*F	Ns	Ns	Ns	Ns	Ns
B*I	**	**	Ns	*	Ns
F*I	Ns	Ns	Ns	Ns	Ns
B*I*F	Ns	Ns	Ns	Ns	Ns

(1) NS, *, **, and *** not significant or significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively.
a-b Means in columns not sharing the same letters are significantly different according to LSD test ($P = 0.05$).

TABLE 5 | Physiological indices, nitrogen (N), phosphorus (P), potassium (K), and chlorophyll (CHL) concentrations of *Pelargonium* leaves in plants inoculated (MICO+) or not ($MICO_0$) with arbuscular mycorrhizal fungi (AMF) and grown for 28 (only electrolyte leakage) and 74 d in substrate amended with different rates of biochar (BC_0, BC_{30}, BC_{70}), and fertilized with different rates of fertilizer ($FERT_1$, $FERT_2$).

Treatments	EL (%)		RWC (%)	CHLa	CHLb	CHLtot	N	P	K
				(g kg^{-1} DW)			(µg mg^{-1}DW)		
	Sampling time (DAT)								
	28	74							
Biochar rate (BC)[1]									
BC_0	0.9[b]	7.3	88[b]	0.32	0.13	0.46	12.3[b]	3.7[a]	1.8[c]
BC_{30}	0.9[b]	7.2	89[ab]	0.34	0.14	0.49	14.4[b]	3.4[b]	2.6[b]
BC_{70}	1.8[a]	6.7	90[a]	0.31	0.14	0.45	17.1[a]	1.9[c]	3.9[a]
Fertilizer rate (F)[2]									
$FERT_1$	1.0	6.4	89	0.31	0.13[b]	0.45[b]	12.2[b]	2.7[b]	2.6
$FERT_2$	1.3	7.8	89	0.33	0.14[a]	0.49[a]	16.3[a]	3.4[a]	2.9
AMF inoculation (I)									
MICO+	1.3	6.1[b]	90[a]	0.34	0.16[a]	0.49[a]	14.3[a]	3.2[a]	2.9[a]
$MICO_0$	1.0	8.3[a]	88[b]	0.33	0.13[b]	0.45[b]	14.2[a]	2.8[b]	2.5[b]
Significance[3]									
Biochar rate (BC)	*	NS	*	NS	NS	NS	**	**	*
Fertilizer rate	NS	NS	NS	NS	*	*	**	***	NS
AMF inoculation (I)	NS	**	*	NS	**	**	NS	*	*
BC*F	*	NS	NS	***	***	***	*	NS	NS
BC*I	NS	NS	NS	NS	NS	NS	NS	NS	NS
F*I	NS	NS	NS	NS	**	**	NS	NS	NS
BC*F*I	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] *BC_0, BC_{30}, and BC_{70}: 100:0, 70:30, and 30:70 (v:v) peat:biochar ratio, respectively.*

[2] *$FERT_1$ and $FERT_2$: fertilized with 140 and 210 mg L^{-1} of Nitrophoska® Gold®, respectively.*

[3] *NS, *, **, and *** not significant or significant at $P \leq 0.05$, $P \leq 0.01$, and $P \leq 0.001$respectively.*

[a–b–c] *Means in columns followed by the same letters are not significantly different according to the LSD test ($P = 0.05$). Means in columns without letters are not significantly different according to the LSD test ($P = 0.05$).*

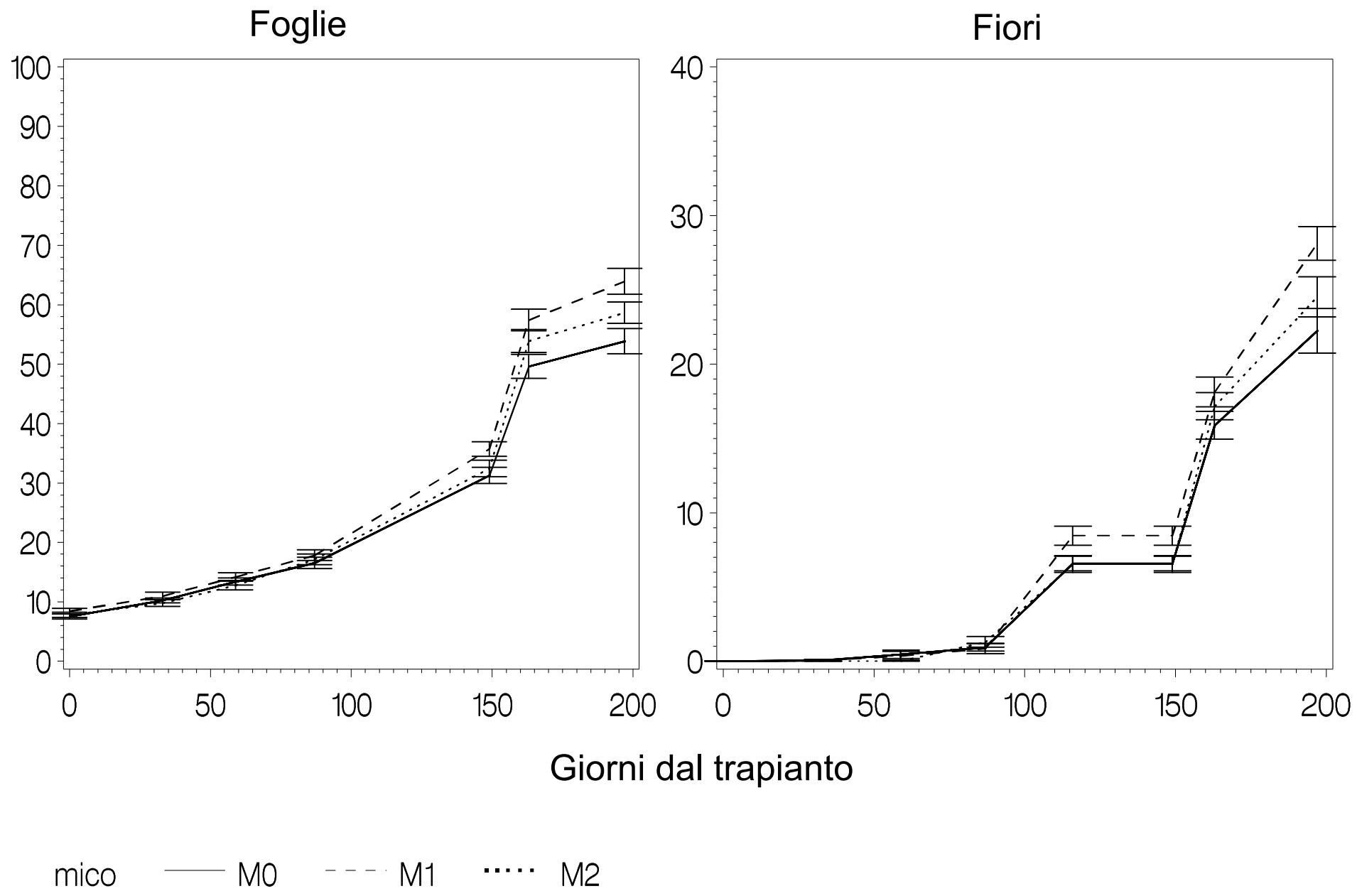
2. Produzione vaseria fiorita

Ciclamino (*Cyclamen persicum* L.)
var. Halios Ecarlate vif compact

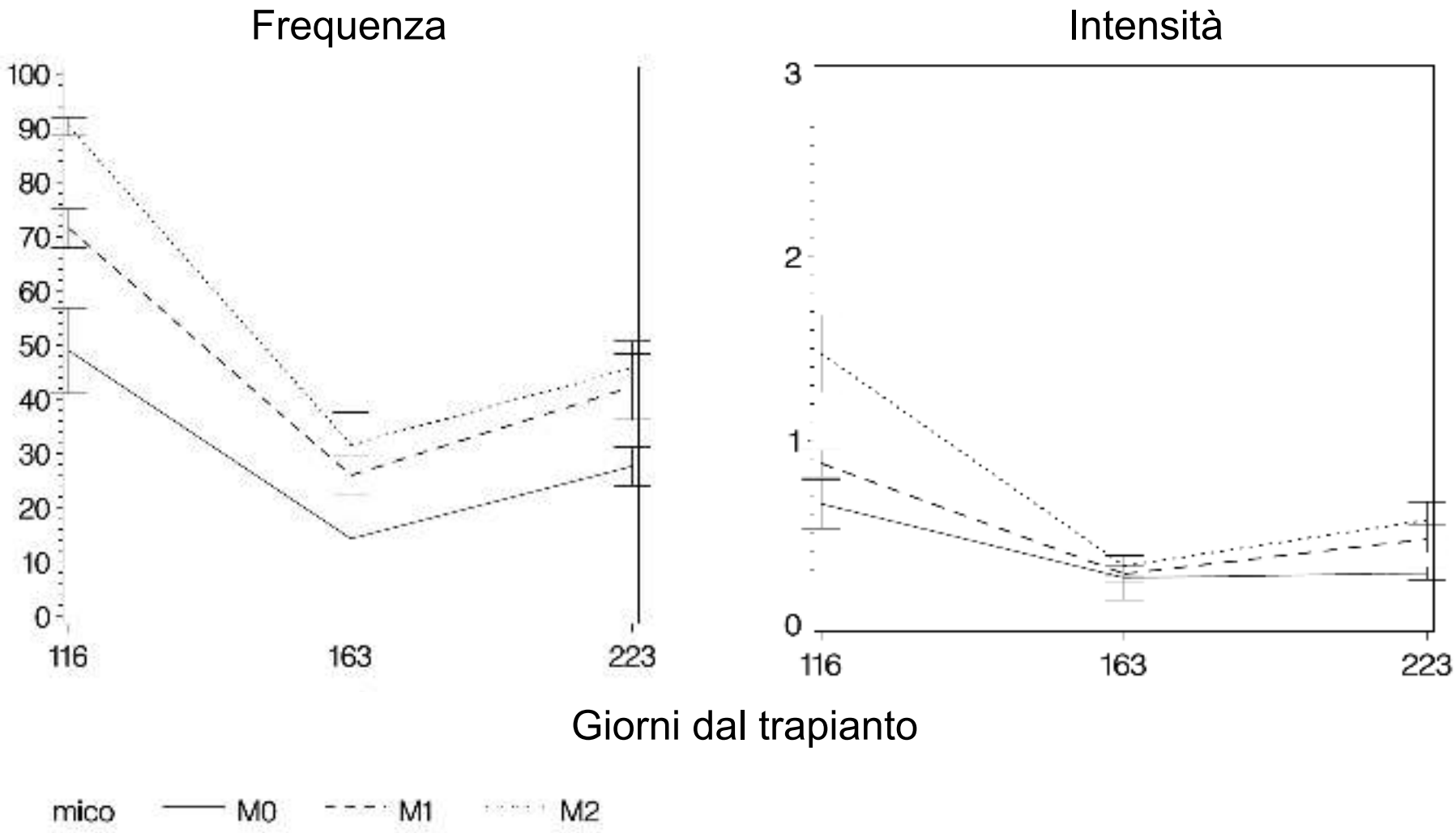
Glomus intraradices + Glomus mosseae
25 spore-ife-radici per g p.c.

Dosi:
- 8 kg/m^3 di substrato (M_1)
- 12 kg/m^3 di substrato (M_2)

Aggiunto al substrato (torba:perlite) al trapianto


Foglie
Fiori
100
90
80
70
60
50
40
30
20
10
0
40
30
20
10
0
0
50
100
150
200
Giorni dal trapianto
mico
M0
M1
M2

Colonizzazione radicale di ciclamino



Biol Fertil Soils (2013) 49:691–703
DOI 10.1007/s00374-012-0757-3

3. Produzione pieno campo

ORIGINAL PAPER

Yield and phosphorus uptake of a processing tomato crop grown at different phosphorus levels in a calcareous soil as affected by mycorrhizal inoculation under field conditions

G. Conversa · C. Lazzizera · A. Bonasia · A. Elia

Trattamenti:

Livelli di fosforo:
- 0 kg·ha^{-1} (P_0)
- 60 kg·ha^{-1}(P_{60})
-120kg·ha^{-1} (P_{120})

Inoculazione:
- si (M) (G. intraradices)
- no (nM)

Livelli di N e K:
N: 250 (100) kg·ha^{-1}
K: 400 (200) kg·ha^{-1}

Schema sperimentale: Split-plot
con 3 ripetizioni
fattore principale: livelli di fosforo
fattore secondario: inoculazione micorrizica

Unità sperimentale:
4 file binate (circa 30 m^2) - 2005
6 file binate (31,5 m^2) - 2006

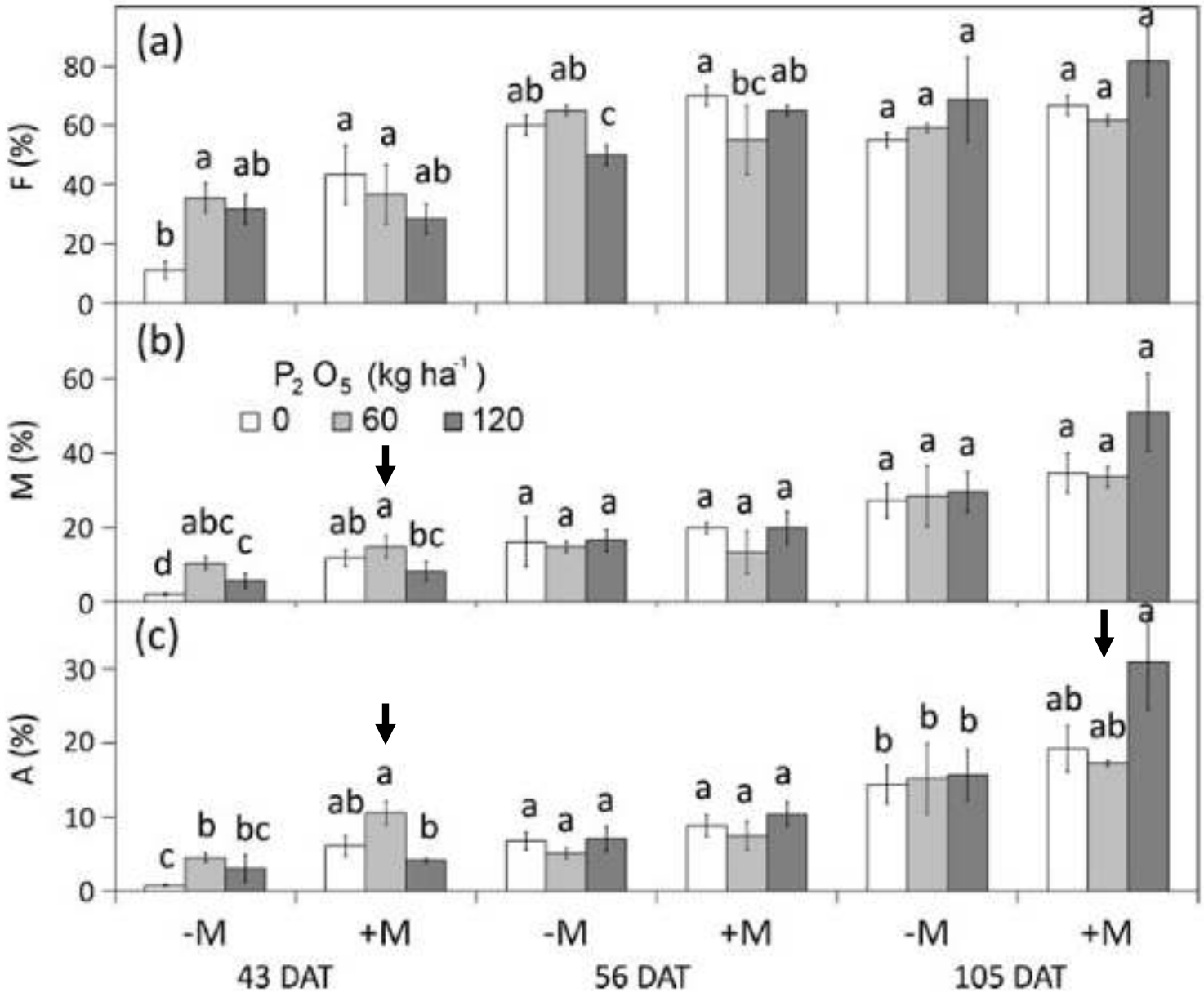


Fig. 2 Effect of P fertilization and inoculation with G. intraradices on frequency (a), intensity (b) of root colonization and on arbuscule abundance (c) at 43, 56 and 105 DAT in the 2006 processing tomato field trial.

Error bars indicate ± SE of mean. +M with G. intraradices inoculum, −M without inoculum. Within the same sampling date, different letters indicate significant differences at P=0.05 according to the LSD test

Table 2 Tomato plant growth measurements during crop cycle as affected by inoculation with *Glomus intraradices* and P fertilization in 2006 (experiment 2) field trial

Treatments	DAT 43			DAT 71			DAT 91			DAT 105		
	Shoot	Fruit		Shoot	Fruit		Shoot	Fruit		Shoot	Fruit	IEg
	DW (g)	DW (g)	(n.)	DW (g)	DW (g)	(n.)	DW (g)	DW (g)	(n.)	DW (g)		(%)
Inoculation (I)												
+M	82.2 a	1.1 a	3.2 a	195 a	296 a	75 a	190 a	349 a	87 a	201 a	442 a	–
−M	69.6 b	0.6 b	2.3 a	185 a	250 a	74 a	192 a	350 a	77 b	171 b	383 b	–
P_2O_5 (kg ha^{-1}) (P)												
0	56.3 b	0.3 b	1.8 b	190 a	244 b	75 a	182 a	355 a	78 a	183 a	403 a	12.9 a
60	81.7 a	1.0 a	3.3 a	194 a	291 a	76 a	205 a	359 a	89 a	179 a	404 a	15.5 a
120	89.7 a	1.2 a	3.2 a	186 a	285 a	72 a	186 a	335 a	80 a	196 a	429 a	18.7 a
Significance[a]												
I	*	*	ns	ns	ns	ns	ns	ns	*	*	**	–
P	*	*	*	ns	*	ns	ns	ns	ns	ns	ns	ns
I×P	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	–

Means followed by similar letters within a column do not differ, according to LSD test at $P=0.05$

+M with introduced AMF, −M without introduced AMF

[a] ns, * and ** , not significant or significant at $P\leq0.05$ and $P\leq0.01$, respectively

DAT: giorni dopo il trapianto

Table 3 Marketable fruits in tomato plants affected by inoculation with *G. intraradices* and P fertilization in 2005 (experiment 1) and 2006 (experiment 2) field trials

Treatments	Experiment 1					Experiment 2				
	Total yield		Marketable yield		IEy	Total yield		Marketable yield		IE_y
	Fruit				(%)	Fruit				(%)
	(n.)	(g/plant)	(n.)	(g/plant)		(n.)	(g/plant)	(n.)	(g/plant)	
Inoculation (I)	↓	↓	↓	↓		↓	↓	↓	↓	
+M	67 a	4,705 a	61 a	3,867 a	–	103 a	4,863 a	65 a	3,950 a	–
−M	61 b	3,681 b	54 b	3,556 b	–	92 b	4,323 b	60 b	3,651 b	–
P_2O_5 (kg ha^{-1}) (P)										
0	63 a	4,121 a	54 a	3,630 a	21.5 b	98 a	4,569 a	62 a	3,792 a	4.8 b
60	67 a	4,001 a	60 a	3,852 a	34.6 a	98 a	4,477 a	61 a	3,703 a	17.5 a
120	60 a	4,214 a	58 a	3,651 a	29.1 a	96 a	4,720 a	65 a	3,905 a	15.2 a
Significance[a]										
I	*	**	*	**	–	*	**	*	*	–
P	ns	ns	ns	ns	*	ns	ns	ns	ns	*
I×P	ns	ns	ns	ns	–	ns	ns	ns	ns	–

Means followed by the same letter within a column do not differ, according to LSD test at $P=0.05$

+M with introduced AMF, −M without introduced AMF

[a] ns, * and **, not significant or significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

Table 4 Reproductive traits of tomato plants as affected by inoculation with *Glomus intraradices* and P fertilization at 71 DAT in 2006 (experiment 2) field trial

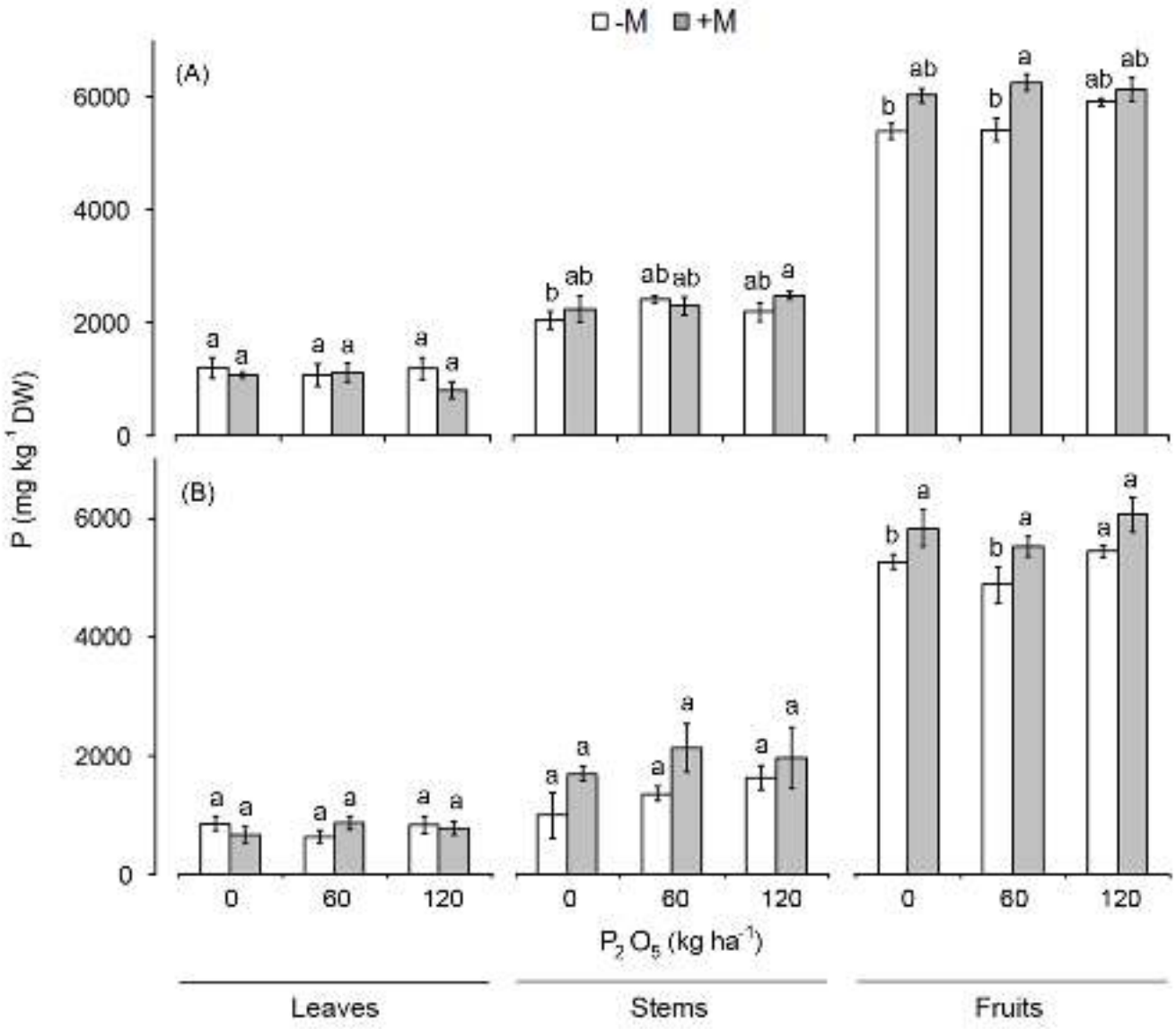
Treatments	Trusses	Total flowers	Flowers per truss	Proportion of total flowers borne on truss[a]		
				Large	Medium	Small
	(n./plant)	(n.)		(%)		
Inoculation (I)						
+M	53 a	244 a	4.4 a	6.7 a	91 a	3.0 b
−M	55 a	229 b	4.3 b	4.9 b	91 a	4.2 a
P_2O_5 (kg ha^{-1}) (P)						
0	52 a	225 a	4.4 a	4.4 b	92 a	3.5 a
60	57 a	245 a	4.3 a	6.3 a	90 a	3.7 a
120	55 a	238 a	4.3 a	6.5 a	90 a	3.7 a
Significance[b]						
I	ns	*	*	*	ns	**
P	ns	ns	ns	*	ns	ns
I×P	ns	ns	ns	ns	ns	ns

[a] Truss class size: large, 15–8 flowers per truss; medium, 7–4 flowers per truss; small, 1–3 flowers per truss

Means followed by the same letter within a column do not differ, according to LSD test at $P=0.05$

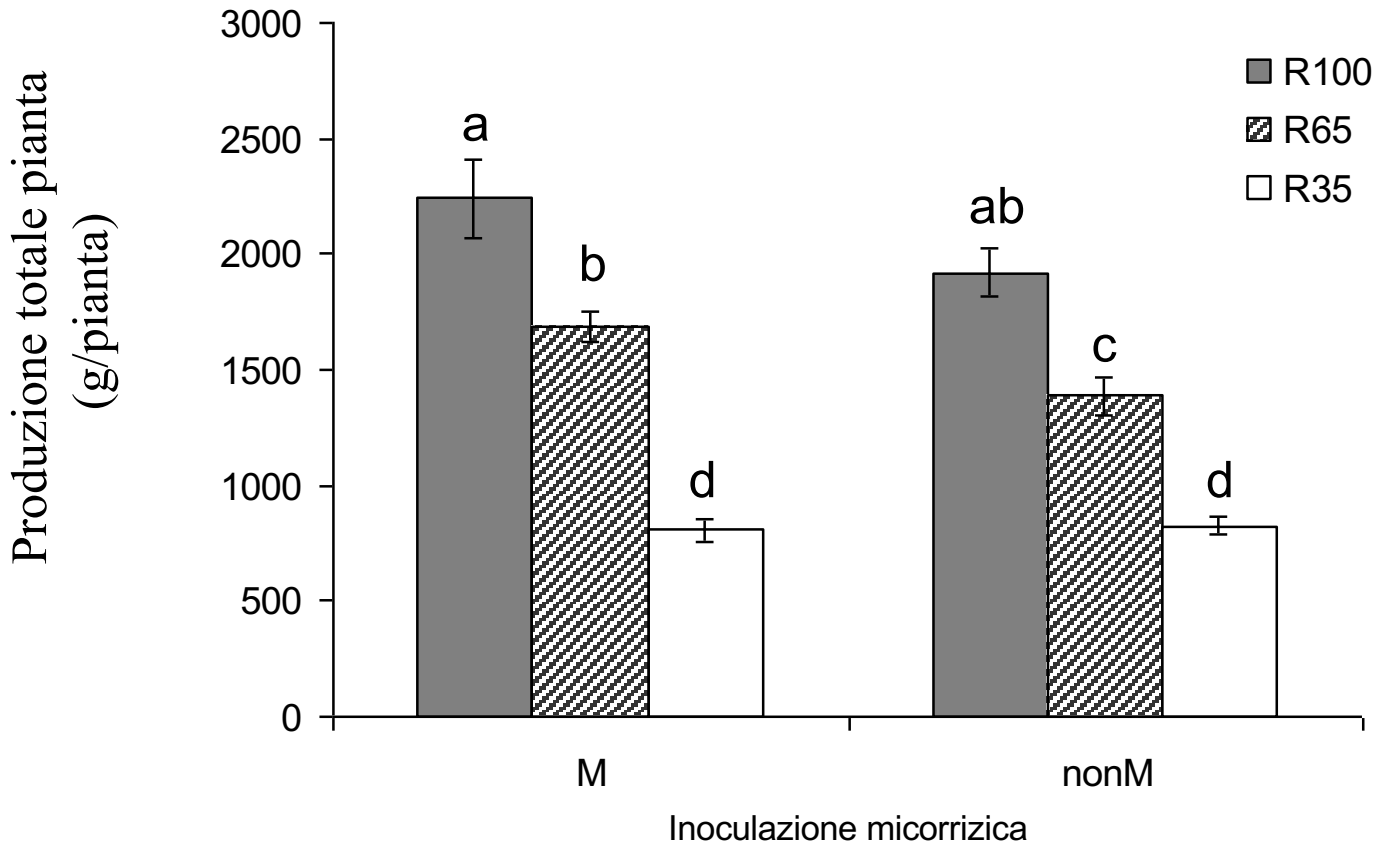
+M with introduced AMF, −M without introduced AMF

[b] ns, * and **, not significant or significant at $P\leq0.05$ and $P\leq0.01$, respectively



Effect of phosphorous fertilization and soil inoculation with *G. intraradices* on phosphorous (P) concentration in the different processing tomato plant parts in the 2005 (A) and 2006 (B) experiments. Error bars indicate ± S.E. of mean. +M: with *G. intraradices* inoculum, –M: without inoculum. Bars with different letters are significantly different at $P < 0.05$ according to Duncan's multiple range test.

3. Produzione pieno campo



Influenza del regime irriguo e dell'inoculazione del terreno con funghi AM sulla produzione di pomodoro da industria.

3. Produzione pieno campo

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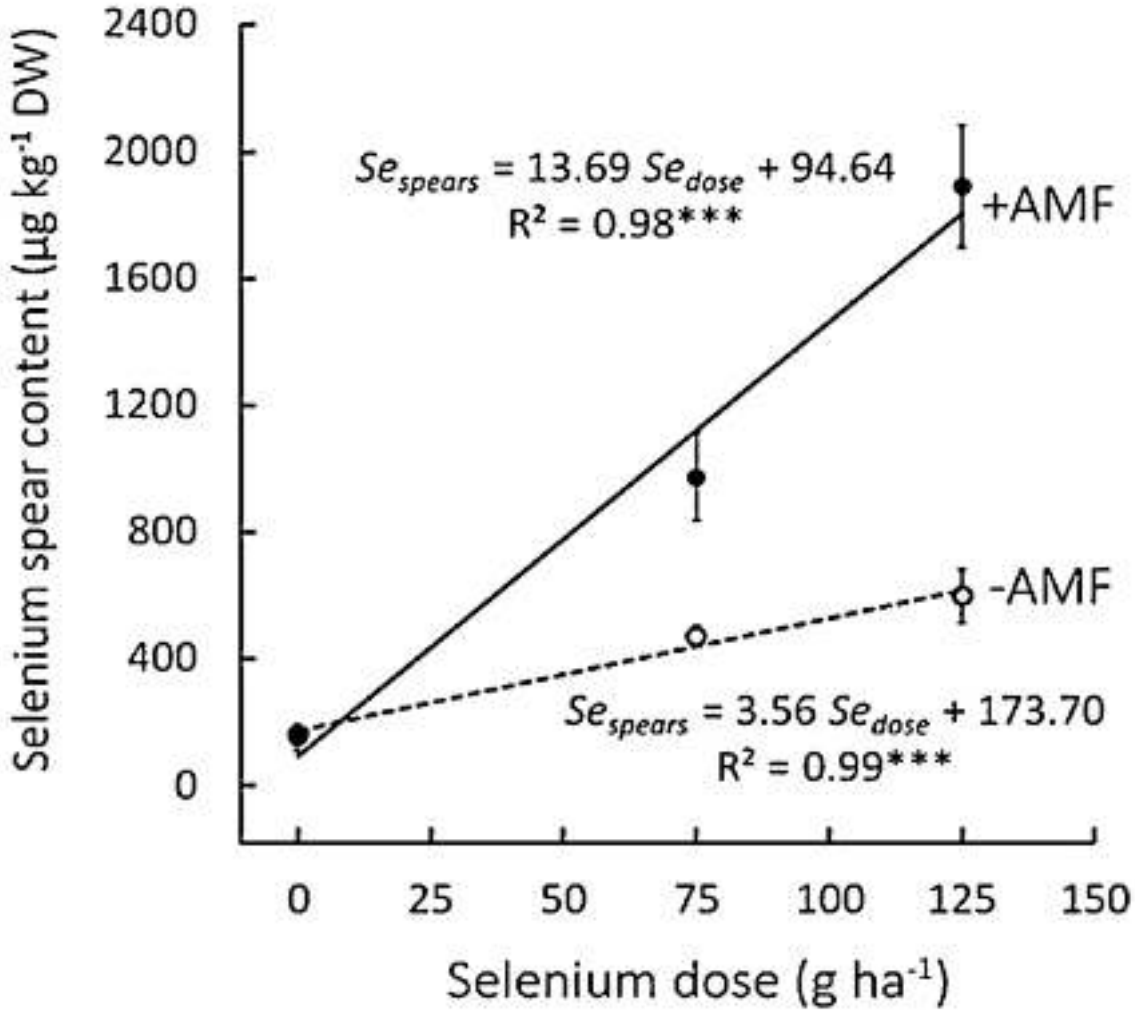
Selenium fern application and arbuscular mycorrhizal fungi soil inoculation enhance Se content and antioxidant properties of green asparagus (*Asparagus officinalis* L.) spears

Giulia Conversa[a,*], Corrado Lazzizera[a], Antonio Eugenio Chiaravalle[b], Oto Miedico[b], Anna Bonasia[a], Paolo La Rotonda[a], Antonio Elia[a]

Table 5
Total and marketable yield of asparagus crop (cv. Grande), mean fresh weight and dry biomass, total selenium and phenol concentrations and antioxidant activity of spears affected by different doses of selenium (Se), applied on fern as sodium selenate solution, and by the inoculation of soil with arbuscular mycorrhizal fungi (AMF) (B1trial).

Treatments	Crop yield		Spears					
	Total (Mg ha^{-1})	Marketable	Mean fresh weight (g)	Dry mass (g kg^{-1} FW)	Selenium (μg kg^{-1} DW)	(μg 100 g^{-1} FW)	Total phenols (mg GAE kg^{-1} DW	Antioxidant capacity (μmol TE g^{-1} DW)
Se dose (g ha^{-1})								
0	6.9 ± 0.5	4.8 ± 0.4	18.1 ± 0.6	88.5 ± 2.8	157 ± 24	1.3 ± 0.2	8420 ± 245	63.6 ± 2.9
75	7.2 ± 0.4	4.6 ± 0.4	17.4 ± 0.3	89.0 ± 1.8	808 ± 137	7.0 ± 1.1	8860 ± 14[illegible]	65.8 ± 2.1
125	7.1 ± 0.5	4.5 ± 0.4	17.3 ± 0.7	88.9 ± 2.4	1246 ± 26[illegible]	10.4 ± 2.1	9113 ± [illegible]24	67.2 ± 2.4
AMF inocul. (AMF)								
+AMF	6.8 ± 0.4a[1]	4.6 ± 0.4a	17.0 ± 0.5a	84.4 ± 1.2b	1007 ± 226a	8.5 ± 1.9a	9113 ± 190a	73.7 ± 1.7a
-AMF	7.3 ± 0.4a	4.6 ± 0.3a	18.1 ± 0.5a	93.9 ± 1.2a	359 ± 75b	3.3 ± 0.69b	8484 ± 142b	57.0 ± 1.0b
Year								
2011	8.7 ± 0.3a	6.2 ± 0.3a	18.5 ± 0.5a	88.3 ± 1.9a	783 ± 249a	6.7 ± 2.1a	8788 ± 149a	65.8 ± 2.1a
2012	5.4 ± 0.3b	3.0 ± 0.2b	16.6 ± 0.6a	90.1 ± 1.8a	687 ± 166a	6.1 ± 1.4a	8825 ± 217a	65.5 ± 1.9a
Significance[2]								
Se	ns	ns	ns	ns	***	***	*	*
Se_{Lin}	ns	ns	ns	ns	***	***	*	*
Se_{Qua}	ns	ns	ns	ns	ns	ns	ns	ns
AMF	ns	ns	ns	***	***	***	**	***
Year	*	*	ns	ns	ns	ns	ns	ns
Se*AMF	ns	ns	ns	ns	***	**	ns	*
Se_{Lin}*AMF	ns	ns	ns	ns	ns	ns	ns	*
Se_{Qua}*AMF	ns	ns	ns	ns	ns	ns	ns	ns
Se *Year	ns	ns	ns	ns	ns	ns	ns	ns
Se_{Lin}*Year	ns	ns	ns	ns	ns	ns	ns	ns
Se_{Qua}*Year	ns	ns	ns	ns	ns	ns	ns	ns
AMF *Year	ns	ns	ns	ns	ns	ns	ns	ns
Se*AMF*Year	ns	ns	ns	ns	ns	ns	ns	ns

[1] Means in columns not sharing the same letters are significantly different according to LSD test ($P = 0.05$).



Selenium content in cv. Grande spears as affected by different doses of selenium sprayed on two consecutive years (2010 and 2011) as sodium selenate solution on the fern of plants grown in soil inoculated (+AMF) and not inoculated (-AMF) with arbuscular mycorrhizal fungi (AMF). Vertical bars indicate ±SE of mean (n=16) of the observed values. Regression straight lines indicate the linear regression between Se rates and soil AMF inoculation significant at $P \leq 0.001$.

3. Produzione pieno campo

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Heavy metal contents in green spears of asparagus (*Asparagus officinalis* L.) grown in Southern Italy: Variability among farms, genotypes and effect of soil mycorrhizal inoculation

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Table 7
Effect of mycorrhizal application on trace elements concentration (mg kg^{-1} FW) in 'Grande' asparagus spears (Farm B).

Mycorrhizal treatment	Essential elements								
	Co	Cu	Fe	Mo	Mn	Ni	Se	V	Zn
AMF+	0.018 ± 0.001	1.00 ± 0.03	27.7 ± 1.3	0.036 ± 0.002	2.34 ± 0.06	0.237 ± 0.011	0.013 ± 0.002	0.096 ± 0.004	4.92 ± 0.17
AMF-	0.010 ± 0.001	0.56 ± 0.03	21.0 ± 1.4	0.034 ± 0.003	1.22 ± 0.05	0.108 ± 0.003	0.015 ± 0.001	0.038 ± 0.004	3.45 ± 0.16
Significance[1]	***	***	**	ns	***	***	ns	***	***

Mycorrhizal treatment	Non-essential elements						
	As	Cd	Cr	Hg	Pb	Sn	U
AMF+	0.0137 ± 0.0009	0.0012 ± 0.0001	0.112 ± 0.012	n.d.	0.039 ± 0.001	0.0033 ± 0.0002	0.0033 ± 0.0002
AMF-	0.0036 ± 0.0005	0.0016 ± 0.0001	0.053 ± 0.006	n.d.	0.019 ± 0.002	0.0015 ± 0.0002	0.0015 ± 0.0002
Significance[1]	***	*	***	–	***	***	***

[1] ns, *, **, and ***, not significant or significant at $P \leq 0.05$, $P \leq 0.01$, or $P \leq 0.001$, respectively.

CONCLUSIONI

- ❑ Principali effetti biostimolanti della inoculazione FMA, piante in contenitore e su terreno
  - aumento del numero di fiori/frutti
  - aumento della produzione
  - aumento della crescita (in contenitore)
  - migliore stato fisiologico
  - aumento della concentrazione di macro e micronutrienti

    metalli pesanti ed allergeni ?!

- ❑ Effetti positivi evidenti non prima di 60-100 giorni

- ❑ Composizione e dosi di inoculo

- ❑ Non sempre esiste una relazione univoca tra livello colonizzazione radicale in piante inoculate e risposta della pianta

- ❑ FMA autoctoni meno efficaci rispetto a quelli

Grazie per l'attenzione