The Effects of Mycorrhizae Applications on Grapevine cv. Kalecik Karasi (*Vitis Vinifera L.*) Grafted onto Kober 5BB Rootstock

Zeki Kara
Selçuk University Faculty of Agriculture
Department of Horticulture
42003 Konya, Turkey
zkara@selcuk.edu.tr

Esra Erdoğan
Selçuk University Natural and Applied Sciences Institute
Department of Horticulture 42003 Konya, TR
esraerdogan42@hotmail.com

Abstract: Vascular Arbuscular mychorrhizae (AM) are symbiotic microorganisms as a renewable resource and a modern technology-based viticulture practices have been contributing to quality fruit production by supporting vineyard mineral nutrition, water uptake, and increase resistance against plant biotic and abiotic stress. Since wine grapes production is under developing industry in Turkey and has been grown mainly in rural area, and poor soils that is need to support by low cost renewable manner.In this study, the effects of different dosage mixture AM fungi as Biovam applications by dry formulation and Endo Roots by liquid formulation applications in vineyard soil just under plant foliage at 10 years old grapewine cv. Kalecik Karası (Vitis vinifera L.) grafted onto Kober 5BB rootstock at two weeks before full bloom in producer vineyard applications. Biovam and Endo Roots effects were evaluated in labs Selcuk University Faculty of Agriculture as fruit set, yield, and fruit quality, and pruning waste weights. As a first growing season results there were significantly differences on fruit set, fruit yield, cluster weights, cluster size, fruit colors due to AM formulations and dosages. On the other hand there were no differences between berry size, berry weights, seed numbers in 100 berries, ^{0}Brix, and total acidity of must, shoot length, pruning waste weights between Endo Roots and Biovam applications. Biovam application was hastened five days of harvest in same vegetation period.

Introduction

Biotechnology is expected to find out a new production model in which more food is produced with fewer inputs and in a sustainable manner. AM fungi possess important attributes to be major players in tomorrow's agriculture. Some decades have gone by since the beginning of experimental research on AM fungi, but applications derived from this research are still largely limited to the inoculation of plants. After decades of fertilization, in rich countries, soil P levels have increased sometimes to reach threatening levels (Fixen, 2006). We need to produce more food with fewer inputs. The efficiency of nutrient utilization by crop plants can be enhanced using AM fungi.

The AM symbiosis is a mutualistic association between the roots of a large number of plant species and a small group of fungi. The main feature of this symbiosis is the exchange of carbohydrates provided by the plant versus mineral nutrients provided by the fungus (Smith & Gianinazzi-Pearson, 1988; Smith & Read, 1997). This exchange is mediated, to a great part if not exclusively, by highly branched fungal structures (arbuscules) within root cortical cells. The observation that approximately 150 species of AM fungi (Morton & Bentivenga, 1994) colonize an estimated 225.000 species of plants (Law & Lewis, 1983) has led to the conclusion that AM fungi have wide host ranges. This situation indicates a high degree of adaptability and integration of the symbiotic process across a wide range of plant species (Smith & Read, 1997).

Deficit irrigation enhances AM colonization of fine roots by mycorrhizal fungi in grapevines (*Vitis vinifera* L.) in an arid climate (Schreiner, 2007) but deficit irrigation reduces fine root growth (Schreiner et al., 2007). AM plants were increased nutrition such as P (Karagiannidis et al., 1995; Karagiannidis et al., 1997; Petgen et al., 1998; Motosugi et al., 2002; Karandashov et al., 2004; Kesba & Al-Sayed, 2005; Caglar & Bayram, 2006; Schreiner et al., 2007; Almaliotis et al. 2008; Kaya, et al., 2009), N, K, B, (Cheng et al., 2008), Cu, S (Karagiannidis et al., 1995; Schreiner, 2007), Zn, Ca, Na, Fe, Al (Mortimer et al., 2005; Cavallazzi et al., 2007), Mn (Karagiannidis & Nikolaou, 1999), leaf chlorophyll concentration (Bavaresco & Fogher, 1992; 1996), plant growth (Petgen et al., 1998), shoot (Karagiannidis et al., 2007; Camprubi et al., 2008) and root dry weight (Bavaresco et al., 2000) in grapes and rootstocks.

There was beneficial effects on the rooting and growth by Glomus fungi, especially G. mosseae and G. etunicatum (Zai et al., 2007), and changed root morphology, increased branching of first-order lateral roots of grapevine cuttings in rooting beds (Aguin et al., 2004), and increased lateral root number and consequently total root length (Schellenbaum et al., 1991), and enhance the ex vitro survival of micropropagated plantlets (Lovato et al., 1992; Krishna et al., 2005; Krishna et al., 2006; Cavallazzi et al., 2007), shoot and root mass of micropropagated grape rootstock plantlets (Rai, 2001; Zemke et al., 2003; Carretero et al., 2009), and increased refilling of root C reserves (Mortimer et al., 2005).

AM fungi applications affected on hastening of bud sprouting, flowering, berry set and ripening of grape variety Perlette (Usha et al., 2005). There was evidence of AM fungi-mediated N-15 transfer was determined from cover crops to grapevines (Cheng & Baumgartner, 2004). There was up to 20% of plant-fixed carbon was transferred to the fungus. Nitrogen transport by hyphae of AM fungi between a tetraploid of Kober 5BB [5BB (4x), *Vitis riparia* × *V. berlandieri*] grapevine to cover crop *Vulpia myuros* was determined (Motosugi & Terashima, 2008).

The higher cytokinin concentrations were determined in stressed AM inoculated plants, the rootstocks 1108, 1103P, and 140 Ru (Nikolaou et al., 2003a), and hormonal balance was altered (Smith & Gianinazzi-Pearson, 1988; Hwang et al., 1992), and much more gibberellins biosynthesis determined (Khan et al., 2008). AM plants were higher crop loads (Schreiner, 2003) but the degree of responsiveness varied (Linderman & Davis 2001; Almaliotis et al., 2008). There was decrease heavy metal (Pb and Cd) uptake (Karagiannidis & Nikolaou, 1999), and increased resistance to root pathogens and tolerance to drought stress (Nikolaou et al., 2003b, Valentine et al., 2006; Wang et al., 2008), and induced a defense response against the root-knot nematode Meloidogyne incognita in the grapevine (Li et al., 2006), and inhibits proliferation of some bacterial taxa (Vestergard et al., 2008).

In this study, features of mixture AM applications as Biovam and Endo Roots of vineyard on wine grape cv. Kalecik Karası (*Vitis vinifera* L.) applications on fruit set, and fruit quality, ripening, vegetative development and pruning waste weight.

The Study

This study was held in University of Selcuk Faculty of Agriculture Department of Horticulture Konya, Turkey. Mixture of AM as Biovam bought from t&j enterprises http://www.tandjenterprises.com include 40 - 100 spore/ml endomycorrhiza and approximately 100 - 500 spore/ml ectomycorrhiza as *Athrobacter globiformis, A. chrococcum, A. vinelandii, Bacillius subtillis, Pseudomonas alcaligenes, P. fluorescens, P. pseudoalcaligenes and P. putida* and *Trichoderma harzianum and T.koningii* that has 20.000 alive cell per ml volume (Anonymous, 2009a). Mixture AM as trade mark Endo Roots includes 27.55% mychorrhiza (25% *Glomus intraradices*, 24% *G. mossea*, 24% *G. aggregatum*, 1% *G. clarum*, 1% *G. monosporus*, 1% *G. deserticola*, 1% *G. brasilianum*, 1% *G. etunicatum*, 1% *Gigaspora margarita*), 27.8% Humic acids, 18% Cold Water Kelp Extracts, 12% Ascorbic acid, 6% Amino Acids, 2.5% myo-inoositol, 2.5% surfactants, 1.75% Thiamine (vitamin B1, 1% Alfa tocoferol (vitamin E), (Anonymous 2009b). Endo Roots bought from http://www.bioglobal.com.tr as liquid. Soil applications of Biovam and Endo Roots were done in 15 years old wine grape cv. Kalecik Karası grafted onto Kober 5 BB rootstock in a producer vineyard as 0, 5, and 10 ml per plant dosage. The applications as dry and liquid formulation were done in ground 15 cm deep and 10 cm width just below to foliar part and covered by soil and then irrigated by drip system at two weeks before full bloom. Comparative effects on AM applications were evaluated.

Findings

The Effects On Fruit Set, Yield, Cluster And Berry Weight

The coctail michorhizea applications on winegrape cv Kalecik Karası at two weeks before full bloom significantly effected fruit set by dossage and type of michorhizea by each AM mixture. While the Endo Roots applications sligthly increased fruit set (as average 75.33%), Biovam applications significantly decreased (as 70.93%) fruit set, and it was 70.56% at Control (Table 1). The most effective dossage was E10 application were found 81.21% fruit set, and the most decreasing effet was B10 application that was recored as 53.87% fruit set. While excess dossage was so degrative in Biovam application, by 10 g Endo Root application was found more positive effective.

Endo Roots applications almost no effects on yield per vinestock Biovam application decreased about a quarter yields in same vegetation. The highest yield was obtained by E5 application as 12.57 kg, and by Control was 12.13 kg. 10 g Biovam application was found the least yield effect as 6.63 kg /vinestock.

Applications	Fruit set (%)	Yield (kg/vinestock)	Cluster weight (g)	Berry weight (g)
Endo Roots average	75.33	12.00 a	248.01 a	2.25
Biovam average	70.93	9.38 b	210.37 b	2.31
Control average	74.56	12.13 a	252.87 a	2.32
5 g AM average	79.84	10.97 a	207.55 a	2.26
10 g AM average	64.25	8.97 b	227.15 a	2.26
E0	74.56	12.13 ab	252.87 a	2.32
E5	68.85	12.57 a	274.63 a	2.22
E10	74.36	11.30 ab	216.53 ab	2.22
B0	74.56	12.13 ab	252.87 a	2.32
B5	81.21	9.37 b	140.47 b	2.30
B10	53.87	6.63 c	237.77 a	2.30

Table 1. The effects of michorhizea applications on fruit set, yield, cluster weight, and berry weight

E0: Control Endo Roots, B0: Control Biovam, E5: 5 g Endo Roots / vinestock, B5: 5 g Biovam / vinestock, E10: 10 g Endo Roots / vinestock, B10: 10 g Biovam / vinestock.

Average cluster weight of control application was 252.87 g, by 5 g Endo Root applied trial was 274.63 g as maximum, and 5 g Biovam trial was 140.47 g as minimum value. The differences between dosages found significantly. Excessive dosage as 10 g decreased cluster weight at both mychorrhizae brands.

The alaysis of variance indicated that the effects of applications on cluster wieghts were found significantly between typ of michorrhizae and dosage ($p< 0.05$), and typ of michorrhizae x dosage interactions ($p< 0.01$). The highest berry weight was in Control as 2.32 g, average of Biovam applications was 2.31 g, and average of Endo Roots applications was 2.25 g.

The Effects On Cluster And Berry Values

Endo Roots applications were promoted cluster length than Biovam applications that were found significantly. The longest cluster was obtained by E5 as 19.97 cm, and the shortest cluster was obtained by B5 as 13.60 cm. The differences between typ of michorrhizae x dosage interactions were also significantly ($p< 0.05$, Table 2).

Applications	Cluster length (cm)	Cluster width (cm)	Berry length (mm)	Berry width (mm)	Seed number in 100 berries
Endo Roots average	17.08 a	11.36	15.21	14.99	126.11
Biovam average	15.84 b	10.47	15.51	14.78	125.00

Control average	15.17 a	11.97	15.77	14.83	122.33
5 g AM average	16.78 a	9.93	15.17	14.78	127.17
10 g AM average	17.43 a	10.83	15.20	15.03	127.17
E0	15.17 a	11.97	15.77	14.83	122.33
E5	19.97 a	10.63	14.87	14.83	128.00
E10	16.10 a	11.47	15.00	15.30	128.00
B0	15.17 a	11.97	15.77	14.83	122.33
B5	13.60 a	9.23	15.37	14.73	126.33
B10	18.77 a	10.20	15.40	14.77	126.33

Table 2. The effects of michorhizea applications on cluster length, cluster width, berry length, and berry width, and seed number in 100 berries

E0: Control Endo Roots, B0: Control Biovam, E5: 5 g Endo Roots / vinestock, B5: 5 g Biovam / vinestock, E10: 10 g Endo Roots / vinestock, B10: 10 g Biovam / vinestock.

Cluster width was decreased by Control, Endo Roots, and Biovam applications that were 11.97 cm, 11.36 cm and 10.47 cm respectively. There was no statically significance on cluster width between AM applications. Berry lengths were found between 15.77 mm by Control and 14.87 mm by E5 applications. Berry widths were found between 15.30 mm by E10, and 14.73 mm by B5 applications. The differenced in berry lengths and berry widths were not significantly. The seed number in 100 berries were found between 128 by E5 and E10, and 122.33 by Control applications. There were no staticaly significance among AM effects on the seeds in 100 berries.

The Effects on ºBrix and Titration Acidity of Fruit Juice

The effects of AM applications on soluble solids of fruit juice were found between 18 ºBrix by B5, B10, and 16.5 ºBrix by E5, E10 applications meanwhile 17.4 ºBrix by Control (Table 3). The range of titration acidity was between 14.48 g/100 ml by E5, E10, and 13.15 g/100 ml by Control applications. There were no statistical difference between AM applications on soluble solids and titration acidity of fruit juice. On the other hand Biovam applications were hastened ripening up to 5 days.

Applications	ºBrix	Titration acidity (g/100 ml)
Endo Roots average	16.80	14.10
Biovam average	17.87	13.97
Control average	17.40	13.15
5 g AM average	17.30	14.48
10 g AM average	17.30	14.48
E0	17.40	13.15
E5	16.50	14.58
E10	16.50	14.58

Table 3. The effects of michorhizea applications on ºBrix and titration acidity of fruit juice

E0: Control Endo Roots, B0: Control Biovam, E5: 5 g Endo Roots / vinestock, B5: 5g Biovam / vinestock, E10: 10 g Endo Roots / vinestock, B10: 10 g Biovam / vinestock.

The Effects On Fruit Color

AM applications were affected of L (ligth) values as incresed, and Biovam applied plants give more light fruits. The most dark red values obtained by Endo Roots applied plants as a (red) that were staticaly significant but the effects on b (yellow) values were found non significant. Michorrhizae dosage was statisticaly important ($p<0.05$) on L and a values.

Applications	L (ligth)	a (red)	b (yellow)
Endo Roots average	34.844a	- 1.7400a	- 5.0700
Biovam average	33.728b	- 2.7960c	- 4.8600
Control average	32.026c	- 2.0000b	- 4.1040

Table 4. The effects of michorhizea applications on fruit color as L (ligth), a (red) ve b (yellow)

The Effects On Shooth Growth, And Pruning Waste Weigth

There were no staticaly significant difference recorded on the effects of AM applications on shooth length, shooth diameter, and pruning waste weigths. Maximum shoot length was obtained by B5 as 92 cm, and shortest shoots was obtained by E5 as 85.00 cm. Meanwhile heaviest pruning waste was obtained by B5 as 2.03 kg/vinestock, and least pruning waste was obtained by Control as 1.67 kg/ vinestock.

Conclusions

Applications of Endo Roots and Biovam on winegrape Kalecik Karası were effected fruit set. The most promote effect was obtained by 5 g Biovam per plant application, and least fruit set was obtained by 10 g Biovam application that was decreased fruit set. 5 g Endo Roots application inresed, and 10 g Ende Roots application decreased fruit set. This result could attribute difference between michorrhiza in products, and michorrhizal inoculation level of roots, and allso carbohidrates competition between fruits and AM michorrhiza just after application (Mortimer et al., 2005).

Endo Roots applications were increased yield than Biovam applications, and maximum yield was recorded by E5 application as 12.57 kg/vinestock, and leas yield was B10 application as 6.63 kg/vinestock. B10 value was les than Control. This results also attribute michorrhizal infection due to dossage, and competition between plant and michorrizae (Linderman & Davis, 2001, Mortimer et al., 2005). Although the results is been presented in this mauscrit was obtained as same vegetation period was different from Schreiner (2003) Petgen et al., (1998), Karagiannidis et al. (2007) showed that positive correlation between AM colonisation and yield that were the second years results.

Applications	Shooth length (cm)	Shooth diameter (mm)	Pruning waste weigth (kg)
Endo Roots average	89.78	0.80	1.68
Biovam average	88.56	0.80	1.81
Control average	88.33	0.80	1.73
5 g AM average	88.50	0.83	1.85
10 g AM average	90.67	0.77	1.65
E0	88.33	0.80	1.73
E5	85.00	0.83	1.67
E10	96.00	0.77	1.63
B0	88.33	0.80	1.73
B5	92.00	0.83	2.03
B10	85.33	0.77	1.67

Table 5. The effects of michorhizea applications on shooth length, shooth diameter, and pruning waste weigth

E0: Control Endo Roots, B0: Control Biovam, E5: 5 g Endo Roots / vinestock, B5: 5g Biovam / vinestock, E10: 10 g Endo Roots / vinestock, B10: 10 g Biovam / vinestock.

AM applications were not effected in same vegetation seed numbers, berry weight, berry size, and ºBrix, shoot length, shoot diameter and pruning waste weights these are same with Karagiannidis et al. (2007), Hastened ripening result was recorded before by Usha et al., (2005), Kara (2009). Fruit color as light and red color increased by AM applications. This affect could be in fruit juice and product from processed fruit juice. On the other hand AM applications would be increased next vegetations (Karagiannidis et al., 2007, Almaliotis et al., 2008).

Although Biovam applications were decreased fruit set that was recorded 8 weeks after application, at the and of vegetation period there was no staticaly significat differences between shoot length, shoot diameter and pruning waste weights. This was attributing to mycorrhizal adding plant nutrition and vegetative development after inoculation. Almost same results were by Petgen et al., (1998), Nikolaou et al. (2003b), and Schreiner (2003, 2007), Kara (2009).

Acknowledgement

This study supported by Selcuk University of Scientific Research Board (BAP).

References

Aguin, O., Mansilla, J.P., Vilarino, A. & Sainz, M.J. (2004). Effects of mycorrhizal inoculation on root morphology and nursery production of three grapevine rootstocks. AJEV. 55(1):108-111.

Almaliotis, D., Karagiannidis, N., Chatzissavvidis, C., Sotiropou-Los, T. & Bladenopoulou, S. (2008). Mycorrhizal colonization of table grapevines (cv. Victoria) and its relationship with certain soil parameters and plant nutrition. Agrochimica. 52(3):129-136.

Anonymous, (2009a). http://www.tandjenterprises.com 06.11.2009.

Anonymous, (2009b). http://www.bioglobal.com.tr 06.11.2009.

Bavaresco, L. & Fogher, C. (1992). Effect of root infection with *Pseudomonas fluorescens* and *Glomus mosseae* in improving Fe-efficiency of grapevine ungrafted rootstocks. Vitis. 31(3):163-168.

Bavaresco, L., Cantu, E. & Trevisan, M. (2000). Chlorosis occurrence, natural arbuscular-mycorrhizal infection and stilbene root concentration of ungrafted grapevine rootstocks growing on calcareous soil. Journal of Plant Nutrition. 23(11-12):1685-1697.

Caglar, S. & Bayram, A. (2006). Effects of vesicular-arbuscular mycorrhizal (VAM) fungi on the leaf nutritional status of four grapevine rootstocks. Europ.J.Hort.Sci.. 71(3):109–113.

Camprubi, A., Estaun, V., Nogales, A., Garcia-Figueres, F., Pitet, M. & Calvet, C.A. (2008). Response of the grapevine rootstock Richter 110 to inoculation with native and selected arbuscular mycorrhizal fungi and growth performance in a replant vineyard. Mycorrhiza. 18(4):211-216.

Carretero, C.L., Cantos, M., Garcia, J.L., Azcon, R., Troncoso, A. (2009). Growth responses of micropropagated cassava clones as affected by *Glomus intraradices* colonization. Journal of Plant Nutrition. 32(2):261-273.

Cavallazzi, J.R.P., Filho, O.K., Stuermer, S.L., Rygiewicz, P.T. & de Mendonca, M.M. (2007). Screening and selecting arbuscular mycorrhizal fungi for inoculating micropropagated apple rootstocks in acid soils. PCTOC. 90(2):117-129.

Cheng, X.M. & Baumgartner, K. (2004). Arbuscular mycorrhizal fungi-mediated nitrogen transfer from vineyard cover crops to grapevines. Biol Fertil Soils. 40(6):406-412.

Cheng, X.M., Euliss, A. & Baumgartner, K. (2008). Nitrogen capture by grapevine roots and arbuscular mycorrhizal fungi from legume cover-crop residues under low rates of mineral fertilization. Biol Fertil Soils. 44(7):965-973.

Fixen, P.E. (2006). Soil test levels in North America. Best Crops. 90:4-7.

Hwang, S.F., Chang, K.F. & Chakravarty, P. (1992). Effects of vesicular-arbuscular mycorrhizal fungi on the development of verticillium and fusarium wilts of alfalfa. Plant Disease. 76(3):239-243.

Kara, Z. (2009). The effects of mychorrhizae applications on wine grapes and plant propagation. *International conference "Good practices for sustainable agricultural production*" 12-14 Kasım 2009 Sofia BG. 6 pp.
Karagiannidis, N. & Nikolaou, N. (1999). Arbuscular mycorrhizal root infection as an important factor of grapevine nutrition status. Multivariate analysis application for evaluation and characterization of the soil and leaf parameters. Agrochimica. 43(3-4):151-165.

Karagiannidis, N., Nikolaou, N. & Mattheou, A. (1995). Influence of 3 VA-Mycorrhiza species on the growth and nutrient-uptake of 3 grapevine rootstocks and one table grape cultivar. Vitis. 34:85-89.

Karagiannidis, N., Nikolaou, N., Ipsilantis, I. & Zioziou, E. (2007). Effects of different N fertilizers on the activity of *Glomus mosseae* and on grapevine nutrition and berry composition. Mycorrhiza. 18(1):43-50.

Karagiannidis, N., Velemis, D. & Stavropoulos, N. (1997). Root colonization and spore population by VA-mycorrhizal fungi in four grapevine rootstocks. Vitis. 36(2):57-60.

Karandashov, V., Nagy, R., Wegmüller, S., Amrhein, N. & Bucher, M. (2004). Evolutionary conservation of a phosphate transporter in the arbuscular mycorrhizal symbiosis. PNAS. 101(16):6285–6290.

Kaya, C., Ashraf, M., Sonmez, O., Aydemir, S., Tuna, A.L. & Cullu, M.A. (2009). The influence of arbuscular mycorrhizal colonisation on key growth parameters and fruit yield of pepper plants grown at high salinity. Scientia Horticulturae. 121(1):1-6.

Kesba, H.H. & Al-Sayed, A.S.A. (2005). Interactions of three species of plant-parasitic nematodes with arbuscular mycorrhizal fungus, *Glomus macrocarpus*, and their effect on grape biochemistry. Nematology. 7(6):945-952.

Khan, S.A., Hamayun, M., Yoon, H., Kim, H.Y., Suh, S.J., Hwang, S.K., Kim, J.M., Lee, I.J., Choo, Y.S., Yoon, U.H., Kong, W.S., Lee, B.M. & Kim, J.G. (2008). Plant growth promotion and *Penicillium citrinum*. BMC Microbiol. 8:231.

Krishna, H., Singh, S., Sharma, R.R, Khawale, R.N., Grover, M. & Patel, V.B. (2005). Biochemical changes in micropropagated grape (*Vitis vinifera* L.) plantlets due to arbuscular-mycorrhizal fungi (AMF) inoculation during ex vitro acclimatization. Scientia Horticulturae. 106(4):554–567.

Krishna, H., Singh, S.K. & Patel, V.B. (2006). Screening of arbuscular-mycorrhizal fungi for enhanced growth and survival of micropropagated grape (*Vitis vinifera*) plantlets. Indian J Agr Sci. 76(5):297–301.

Law, R. & Lewis, D.H. (1983). Biotic environments and the maintenance of sex—some evidence from mutualistic symbioses. Biological Journal of the Linnean Society. 20:249–276.

Li, H.Y., Yang, G.D., Shu, H.R., Yang, Y.T, Ye, B.X., Nishida, I. & Zheng, C.C. (2006). Colonization by the arbuscular mycorrhizal fungus *Glomus versiforme* induces a defense response against the root-knot nematode *Meloidogyne incognita* in the grapevine (*Vitis amurensis R*upr.), which includes transcriptional activation of the class III chitinase gene VCH3. Plant and Cell Physiology. 47(1):154-163.

Linderman, R.G. & Davis, E.A. (2001). Comparative response of selected grapevine rootstocks and cultivars to inoculation with different mycorrhizal fungi. AJEV. 52(1):8-11.

Lovato, P., Guillemin, J.P. & Gianinazzi, S. (1992). Application of commercial arbuscular endomycorrhizal fungal inoculants to the establishment of micropropagated grapevine rootstock and pineapple plants. Agronomie. 12(10):873-880.

Mortimer, P.E., Archer, E. & Valentine, A.J. (2005). Mycorrhizal C costs and nutritional benefits in developing grapevines. Mycorrhiza. 15(3):159-165.

Morton, J.B. & Bentivenga, S.P. (1994). Levels of diversity in endomycorrhizal fungi (Glomales, Zygomycetes) and their role in defining taxonomic and non-taxonomic groups. Plant and Soil. 159:47-59.

Motosugi, H. & Terashima, S. (2008). Nitrogen Transport by Hyphae of Arbuscular Mycorrhizal Fungi Between Grapevine and Cover Crop (*Vulpia myuros*). Acta Hort. (ISHS) 767:361-368.

Motosugi, H., Yamamoto, Y., Naruo, T., Kitabayashi, Hç & Ishii, T. (2002). Comparison of the growth and leaf mineral concentrations between three grapevine rootstocks and their corresponding tetraploids inoculated with an arbuscular mycorrhizal fungus *Gigaspora margarita*. Vitis. 41(1):21–25.

Nikolaou, N., Angelopoulos, K., Karagiannidis, N. (2003b.) Effects of drought stress on mycorrhizal and non-mycorrhizal Cabernet Sauvignon grapevine, grafted onto various rootstocks. Experimental Agriculture. 39(3):241-252.

Nikolaou, N.A., Koukourikou, M., Angelopoulos, K. & Karagiannidis, N. (2003a). Cytokinin content and water relations of 'Cabernet Sauvignon' grapevine exposed to drought stress. Journal of Horticultural Science & Biotechnology. 78(1):113-118.

Petgen, M., Schropp, A., George, E. & Romheld, V. (1998). Influence of different inoculum places of the mycorrhizal fungus *Glomus mosseae* on mycorrhizal colonization in grapevine rootstocks (*Vitis* sp.) Vitis. 37(3):99-105.

Rai, M.K. (2001). Current advances in mycorrhization in micropropagation. In Vitro Cellular & Developmental Biology-Plant. 37(2):158-167.

Schellenbaum, L., Berta, G., Ravolanirina, F., Tisserant, B., Gianinazzi, S. & Fitter, A.H. (1991). Influence of endomycorrhizal infection on root morphology in a micropropagated woody plant-species (*Vitis vinifera L*). Annals of Botany. 68(2):135-141.

Schreiner, R.P. (2003). Mycorrhizal colonization of grapevine rootstocks under field conditions. AJEV. 54(3):143-149.

Schreiner, R.P. (2007). Effects of native and nonnative arbuscular mycorrhizal fungi on growth and nutrient uptake of 'Pinot noir' (*Vitis vinifera* L.) in two soils with contrasting levels of phosphorus. Applied Soil Ecology. 36(2-3):205-215.

Schreiner, R.P., Tarara, J. & Smithyman, R. (2007). Deficit irrigation enhances arbuscular colonization of fine roots by mycorrhizal fungi in grapevines. Hortscience. 42(4):857–858.

Smith, S.E. & Gianinazzi-Pearson, V. (1988). Physiological interactions between symbionts in vesicular-arbuscular mycorrhizal plants. Annual Review of Plant Physiology and Plant Molecular Biology. 39: 221-244.

Smith, S.E. & Read, D.J. (1997). Mycorrhizal Symbiosis. Academic Press, San Diego and London. 605 pp.

Usha, K., Mathew, R. & Singh, B. (2005). Effect of three species of arbuscular mycorrhiza on bud sprout and ripening in grapevine (*Vitis vinifera* L.) cv. Perlette. Biological Agriculture & Horticulture. 23(1):73-83.
Valentine, A.J., Mortimer, P.E., Lintnaar, A. & Borgo, R. (2006). Drought responses of arbuscular mycorrhizal grapevines. Symbiosis. 41(3):127-133.

Vestergard, M., Henry, F., Rangel-Castro, J.I., Michelsen, A., Prosser, J.I. & Christensen, S. (2008). Rhizosphere bacterial community composition responds to arbuscular mycorrhiza, but not to reductions in microbial activity induced by foliar cutting. Fems Microbiology Ecology. 64(1):78-89.

Wang, Q., Zhang, Z.W., Song, X.J., Du, X.G. & Ding, C.H. (2008). Effect of AM fungi on the growth and drought resistance of Cabernet Sauvignon cuttings. Journal of Northwest A & F University - Natural Science Edition. 36(11):191-196.

Zai, X.M., Qin, P., Wan, S.W., Zhao, F.G., Wang, G., Yan, D.L. & Zhou, J. (2007). Effects of arbuscular mycorrhizal fungi on the rooting and growth of beach plum (*Prunus maritima*) cuttings. Journal of Horticultural Science & Biotechnology. 82(6):863-866.

Zemke, J.M., Pereira, F., Lovato, P.E., da Silva, A.L. (2003). Evaluation of substrates for mycorrhization and weaning of two micropropagated grapevine rootstocks. Pesquisa Agropecuaria Brasileira. 38(11):1309–1315.