VA菌根菌がウンシュウミカンの樹体生長,水ストレス耐性,ならびに果実発育・品質に及ぼす影響

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Effects of Vesicular-Arbuscular Mycorrhizal Fungi on Satsuma Mandarin Tree Growth and Water Stress Tolerance and on Fruit Development and Quality

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Summary

The effects of vesicular-arbuscular mycorrhizal (VAM) fungi were studied at low concentrations of applied phosphorus (P) on satsuma mandarin (*Citrus unshiu* Marc. cv. Okitsu wase) trees which were grafted on trifoliate orange (*Poncirus trifoliata* Raf.) rootstock. The VAM fungi used were *Glomus ambisporum* Smith and Schenck, *Glomus fasciculatum* (Thaxter) Gerdemann and Trappe emend. Walker and Koske, *Glomus mosseae* (Nicolson and Gerdemann) German and Trappe, and *Gigaspora ramisporophora* Spain.

The trees that were inoculated with the VAM fungi grew larger and had better fruit quality as compared with non VAM control trees. The fruit of former were larger, had higher sugar contents in the juice, and better peel color in both 1992 and 1993 than did the latter. In the non VAM control trees, there was a significant difference between seasons in fruit size and quality. This difference is attributed to the low rainfall in 1992 resulting in high sugar content while fruit development was retarded. In 1993, however, heavy precipitation from June to November produced large fruit, but with lower sugar content.

After water shortage treatment of 10 days, the water stress tolerance of satsuma mandarin trees was improved by the inoculation of a VAM fungus (*Gigaspora ramisporophora*).

Introduction

VAM endophytes are obligate biotrophic fungi forming symbiotic relationships with the roots of many plants (Al-Raddad, 1987; An et al., 1993). Many studies have been conducted utilizing VAM fungi in the search for different beneficial symbiotic relationships with fruit trees. Ishii et al. (1989, 1993) and Ishii and Kadoya (1994) reported on their beneficial effects on soil managements such as use of charcoal and sod culture system using Bahia grass (*Paspalum notatum* Flügge.). It has been known that efficient absorption of phosphorous (P) fertilizer may affect not only the growth but also water stress tolerance of citrus trees (Levy et al., 1983). Nelsen and Safir (1982) reported that the ability of mycorrhizal hyphae to maintain P delivery to the root at low soil moisture was the basis for improved drought tolerance. Even though the importance of the role of VAM fungi in water stress tolerance is widely recognized, we have no knowledge of the symbiotic relationship between VAM fungi and citrus fruit quality.

There are many reports that VAM fungi stimulate citrus growth by promoting P absorption. Yuda et al. (1981) stated that P fertilization to satsuma mandarin trees might improve fruit quality by reducing organic acid content in the juice resulting in an increase of Brix/acid ratio if the P fertilizers were efficiently absorbed into the trees. Yakushiji et al. (1992) reported that sugar accumulation in the juice of satsuma mandarin fruits was influenced by the osmoregulation of the juice sac at low water potentials.

However, that the VAM fungi improve citrus fruit quality is still unexplored. This experiment was conducted to determine the beneficial effects

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of VAM fungi on tree growth, water stress tolerance, and fruit size and quality of satsuma mandarin trees at low P fertilization.

Materials and Methods

The experiment was carried out with two-year-old satsuma mandarin trees on trifoliate orange rootstocks which had been transplanted in 45-liter capacity pots on April 14, 1990, and was carried out in a randomized block design with 5 replications. Before transplanting, all the roots of test trees were dipped in Iprodione solution (50 g/50 liter of water) for a few minutes to eliminate undesirable spores/organisms. On May 12, 1990, different isolates of spores from *Glomus ambisporum, Glomus fasciculatum, Glomus mosseae* and *Gigaspora ramisporophora* which were obtained from citrus growing area of Ehime prefecture, Japan were cultured in pots with Bahia grasses for two years. The cultures of spores, mycelia and infected root fragments consisting of 700 *Glomus* sp. spores and 100 *Gigaspora ramisporophora* spores were mixed with perlite-vermiculite (1:1, v/v) and added to the pots. The process was repeated on May 19, 1992, except that the inocula consisted of 800 *Glomus* sp. spores and 200 *Gigaspora ramisporophora* spores. The control plants without inoculation were drenched with 2 g Iprodione/2 liter of water pot. Fruits were thinned to one fruit per 20～25 leaves on June 7, 1992 and June 10, 1993. Trees were grown under natural conditions and irrigated irregularly.

Each inoculated and non-inoculated tree received 2 g of N, 0.5 g of P, and 2 g of K in 1990, 6.45 g of N, 5.5 g of P, 5.15 g of K in 1991, 2 g of N, 1 g of P and 1.3 g of K in 1992 and 6 g of N, 2 g of P, and 6 g of K in 1993. Ammonium phosphate was the sole source of P. Other nutrients were applied as a mixture of $CaCO_3$ and $MgSO_4$ (10 g·tree^{-1}·year^{-1}) and a micronutrient's solution (10 ml·tree^{-1}·year^{-1}), containing mainly 0.001 % Mn and 0.005 % B, was applied in the early spring. The concentration of other micronutrients such as Fe, Cl, Zn, Co, Cu, and Mo were below 0.001 %.

Experiment 1

(A) Tree growth and leaf P concentration

Tree growth was measured in December in 1992 and 1993. In mid-October, leaf area was determined with a personal computer equipped with an image processor (Epson GT-20). For the determination of leaf P content, the leaves collected were oven-dried (80 °C for 48 hr.) and ground to pass through a 20 mesh sieve. The ground tissue samples were ashed at 550 °C overnight and the residues dissolved in 2.4 N HCl. The concentration of leaf P was measured colorimetrically by the Denigés method (1921).

(B) Fruit development and quality

The fruits were harvested on November 24, 1992, and November 17, 1993, and their size and weight recorded. A group of four trees from each VAM species and 20 fruits from each group were randomly chosen and analyzed for peel color (Minolta CR-200 color meter), sugar and acid contents in the juice with a Refractometer (Atago N1) and the total titratable acidity with 0.1 N NaOH.

Experiment 2

Water Stress

On September 5, 1992, a water stress experiment was carried out with 4 pots inoculated with *Gigaspora ramisporophora* and 4 control pots. Each pot was covered with a polyethylene sheet (1.5 m long, 1.5 m wide) tied around the base of the stem to keep the soil mix dry and the trees exposed to natural water stress for 5 and 10 days. When the soil moisture potential, pF, reached 3.0 after short duration of water stress, foliar irrigation was given in the morning for 5 consecutive days. Water stress damage was measured by counting the number of abscised leaves·day^{-1}·tree^{-1} and by observing the tree's performance on the 5th and 10th day. The roots were washed, stained according to the method of Phillips and Hayman (1970), and observed under light microscope to rate the degree of root infection by VAM fungi. The percentage of VAM infection was calculated by the following equation:

$$\% \text{ of VAM infection} = (\text{Root length infected}/\text{Root length observed}) \times 100$$

Results

Experiment 1

(A) Tree growth and leaf P concentration

Table 1 shows the effects of 4 different kinds of VAM fungi on tree growth and leaf P concentrations in 1992 and 1993. No significant difference between VAM fungi-inoculated and non inoculated treatment on tree height was existed, but leaf area and tree canopy area of non VAM trees were severely decreased. Leaf P concentration in control trees was consistently lower than that VAM trees.

(B) Fruit development and quality

In 1992 when rainfall was low (Fig. 1), fruit development was severely depressed and resulted in a higher Brix value and higher Brix/acid ratio in the fruit juice. In the non VAM plot, the fruit response to the water stress was especially conspicuous. In 1993 when the rainfall was high from June to November, there was no significant different on fruit size and shape index between VAM and non VAM trees. Brix value and the Brix/acid ratio significantly increased and acid content decreased in all VAM fungi-inoculated trees more so than in the control; the average fruit production per tree and the a/b value of peel color in all VAM trees were higher than those in non VAM trees (Table 2).

Experiment 2

When the relationship between VAM development and water stress was examined, a leaf wilting symptom was barely visible in the VAM and

Table 1. Effects of VAM fungi-inoculation on tree growth and leaf P concentration of satsuma mandarin trees in 1992 and 1993.

Treatment	Leaf area (cm^2)	Tree height (cm)	Tree canopy area (m^2)	Leaf P concentration (%)
1992				
Non VAM	10.3±1.1[z]	78.7±1.6	0.15±0.01	0.123±0.002
Gigaspora ramisporophora	19.0±1.5	77.5±5.5	0.27±0.02	0.142±0.004
Glomus ambisporum	13.2±1.0	83.5±1.7	0.30±0.01	0.145±0.001
Glomus fasciculatum	15.3±1.1	87.3±4.8	0.21±0.02	0.138±0.003
Glomus mosseae	17.6±0.8	80.5±3.5	0.29±0.01	0.151±0.001
1993				
Non VAM	9.8±1.3	82.0±0.6	0.20±0.01	0.151±0.007
Gigaspora ramisporophora	24.3±2.7	82.6±3.0	0.32±0.02	0.168±0.007
Glomus ambisporum	21.2±0.5	85.1±2.0	0.36±0.03	0.181±0.009
Glomus fasciculatum	20.6±1.5	81.8±2.7	0.29±0.02	0.172±0.003
Glomus mosseae	18.5±1.4	84.6±2.2	0.30±0.02	0.174±0.010

[z] Mean±standard error (SE), n=4.

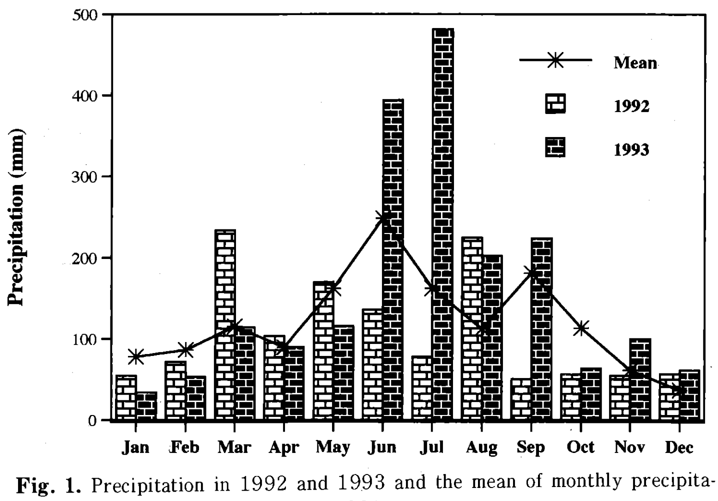

Fig. 1. Precipitation in 1992 and 1993 and the mean of monthly precipitation over five years (1987 to 1991).

Table 2. Effects of VAM fungi-inoculation on fruit development and quality of satsuma mandarin in 1992 and 1993.

Treatment	Average fruit production per tree (kg)	Average fruit wt. (g)	Shape index of fruit	Sugar (Brix)	Acid (%)	Brix/acid ratio	Peel color	
							L	a/b
1992								
Non VAM	0.42a[z]	52.3a	125a	13.2a	1.02a	12.9a	67.6a	0.43a
Gigaspora ramisporophora	1.59b	110.6b	128a	11.7b	1.06a	11.0b	62.6b	0.57b
Glomus ambisporum	1.39b	116.2b	126a	12.5ab	1.14a	11.0b	62.5b	0.58b
Glomus fasciculatum	1.34b	107.0b	129a	11.4b	0.99a	11.5b	62.6b	0.57b
Glomus mosseae	1.16b	126.7b	128a	11.5b	1.07a	10.7b	63.7b	0.53b
1993								
Non VAM	0.44a	111.4a	121a	9.4a	1.23a	7.6a	65.3a	0.37a
Gigaspora ramisporophora	1.87bc	135.9a	131a	11.2b	1.07b	10.5b	67.8b	0.47b
Glomus ambisporum	1.98c	116.4a	127a	10.6b	1.15ab	9.2b	65.3a	0.46b
Glomus fasciculatum	1.18b	119.3a	127a	10.6b	1.02b	10.4b	65.4a	0.46b
Glomus mosseae	1.59bc	124.9a	130a	10.5b	1.06b	9.9b	66.1a	0.47b

z Duncan's multiple range test at 5% level, n=20.

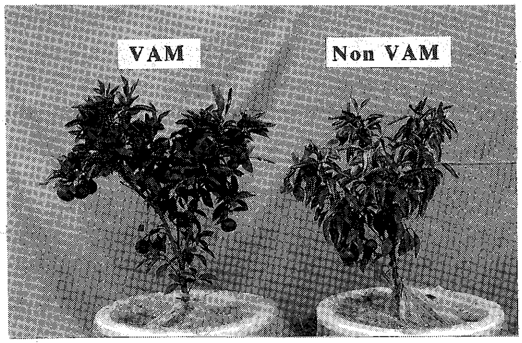

Fig. 2. Comparison of fruiting and size of satsuma mandarin trees with and without VAM inoculation after 10 days of water stress.

Table 3. Effect of VAM fungi-inoculation on water stress of satsuma mandarin trees.

Treatment	VAM infection[y] (%)	Water stress damage[z]	
		5 days	10 days
Non VAM	0	1.0±0.0[x]	4.3±0.5
Gigaspora ramisporophora	38.2±0.1	1.0±0.0	1.1±0.1

z Water stress damage was measured by tree performance and the number of leaf defoliation (Damage index: 1=Normal, 2=Slight, 3=Medium, 4=Severe, 5=Death).
y % of VAM infection= (Root length infected/Root length observed)×100.
x Mean±SE, n=4.

non VAM trees until 5th day of water stress. However, the degree of wilting and defoliation increased with increasing the soil pF value; most of the non VAM trees died within 10 days after covering the pots (Fig. 2), whereas the symptoms of water stress in VAM trees were hardly noticeable (Table 3).

Discussion

It has been well-documented that the inoculation of VAM fungi stimulates the growth of citrus seedlings in the presence of less P (Allen and Boosalis, 1983; Graham et al., 1987; Levy et al., 1983; Nemec, 1978). Citrus species are all VAM-dependent, but differ in their degree of dependency (Krikun and Levy, 1980; Menge et al., 1978). On trifoliate orange seedlings, the most commonly used rootstocks in Japanese citrus industry, Ishii and Kadoya (1989) and Tang et al. (1982) reported that VAM-inoculated seedling grew more vigorous that did the non VAM seedlings. Similarly, our research indicates that although a wide variation of root infection among and within different species of VAM fungi occurred, the growth of fruit-bearing satsuma mandarin trees on trifoliate orange rootstocks was stimulated by inoculation with 4 different species of VAM fungi in the presence of low P concentration (Table 1).

Yuda et al. (1981) reported that P fertilization to satsuma mandarin might improve fruit quality by significantly reducing organic acid content in the juice thereby resulting in an increased Brix/acid ratio, provided P was efficiently absorbed by the roots. Others found that P fertilization does not improve fruit quality (Ichiki et al., 1974; Okada and Hisada, 1971; Wada et al., 1971). Wada et al. (1971) reported that fruit quality or tree vigor did not suffer from the lack of P fertilization for many years. However, the above researchers made no mention of the percent infection of mycorrhizal fungi on citrus roots. Phosphorus is not readily available to the trees even when large quantities are applied if the soil is acidic (Yuda et al., 1981), also high concentrations of P in the soil is known to inhibit VAM development. It is well known that VAM fungi are ubiquitous, and that the fungi enhance uptake of mineral nutrition, particularly P nutrition, and stimulate growth of host plants under low P conditions.

It has not yet been reported that VAM fungi-infected citrus trees produce better quality fruits than do non-infected trees. Fruit size and peel colors are desirable criteria, but the Brix/acid ratio of the juice is equally important. Because high citrus fruit quality is demanded by consumers, much effort has been given to improve quality. In our experiment VAM fungi-inoculated satsuma mandarin trees promoted vigorous tree growth and higher leaf P concentration than did non-inoculated trees. Higher P concentration in VAM trees may have contributed to the increase of Brix value and Brix/acid ratio by reducing the organic acid content in the juice, thus improving fruit quality. In VAM fungi-inoculated trees, sugar content ranged from 11 to 13 Brix, the average fruit production was three to five times more, and a/b value of peel color was higher compared to the same criterion in non VAM. Further, there was no significant difference in fruit quality and development between 1992 and 1993 on VAM trees. In contrast, there was a significant difference in fruit quality and size between seasons on non VAM trees. Due to the limited rainfall over five years prior to 1992, the Brix value increased to 13.2 whereas the fruit development was retarded that season. In 1993, however, heavy precipitation from June to November (144 % more than in 1992) caused sufficient water supply to the trees and lowered the Brix value of non-infected trees. Yakushiji et al. (1992) reported that higher sugar accumulation in the fruit juice of satsuma mandarin trees which are grown under a low (more negative) water potential is attributed to internal osmoregulation in the trees.

It is reported that VAM fungi-infected trees can increase the uptake of nutrients into the plants (Cooper, 1984), reduce the susceptibility of plant to certain pathogens (Dehne, 1982), alter the water relations and photosynthetic capacity of plants (Brown and Bethlenfalvay, 1988; Nelsen and Safir, 1982), and increase reproduction (Koide et al., 1988). These beneficial effects of the VAM trees could result in the annual production of high quality citrus fruits.

The infection by mycorrhizal fungi increased P nutrition of plants and the enhanced water conductivity was attributed at least in part to increased surface area for water uptake provided by the mycorrhizal hyphae (Allen et al., 1981; Hardie and Leyton, 1981). The hyphae may also bridge the gap that occurs as the soil dries and separates from the root (Graham et al., 1987). In our experiment with (*Gigaspora ramisporophora*) VAM fungus-inoculated trees, root fresh weight of VAM trees was about three times greater than that of non VAM trees. Because of greater root volume after the infection, the hydraulic conductivity of VAM trees affects the total fresh weight of the trees by maintaining a high level of photosynthetic activity and transpiration rate under adverse climatic conditions (Shrestha, 1994). The higher rates of water uptake and transpiration a) help to decrease the leaf temperature that provides favorable conditions for photosynthesis and b) prevent wilting and defoliation.

In Japanese citrus cultivation, trees grown in a plastic green house are forced to grow by controlling soil moisture. Mulching cultivation using a plastic sheet on the soil surface is the other popular method practiced in the field to create water stress. Controlling available moisture in the soil and fertilization are very important practices in producing high quality fruit because limiting moisture supply during the ripening period retards growth but increases sugar content in the juice. Although fruits with higher sugar content can be sold at a higher price, trees are weakened if water stress is prolonged; it is also very difficult to decide when to water-stress the tree. Severe water stress can upset the flowering pattern of trees and sometimes lead to death. Our experiment indicates that VAM fungi contribute substantially to the production of high quality fruits and the survival under and after water stress while supplying adequate P to the root.

Shrestha (1994) reported the presence of VAM spores in every orchard in the Ehime citrus growing area, and that the percentage of VAM infection was high in every vigorous tree grown under plastic green houses or in the open fields. In particular, the higher percentage of VAM infection was observed in the high quality fruit-producing orchards which we attribute to increased uptake of P and enhanced photosynthetic activity.

Literature Cited

Allen, M. F., W. K. Smith, T. S. Morre, Jr. and M. Christensen. 1981. Comparative water relations and photosynthesis of mycorrhizal and nonmycorrhizal *Bouteloua gracilis* (H.B.K.) Lag ex Steud. New Phytol. 87 : 677-685.

Allen, M. F. and M. C. Boosalis. 1983. Effects of two species of VA mycorrhizal fungi on drought tolerance of winter wheat. New Phytol. 93 : 61-76.

Al-Raddad, A. 1987. Effect of three vesicular-arbuscular mycorrhizal isolates on growth of tomato, eggplant and pepper in a field soil. Dirasat 14 : 161-168.

An, Z., T. Shen. and H. Wang. 1993. Mycorrhizal fungi in relation to growth and mineral nutrition of apple seedlings. Scientia Hortic. 54 : 275-285.

Brown, M. S. and G. J. Bethlenfalvay. 1988. The *Glycine-Glomus-Rhizobium* symbiosis. VII. Photosynthetic nutrient-use efficiency in nodulated, mycorrhizal soybeans. Plan Physiol. 86 : 1292-1297.

Cooper, K. M. 1984. Physiology of VA mycorrhizal associations. p. 155-186. In: C. L. Powell and D. J. Bagyaraj (eds.). VA mycorrhiza. CRC Press, Boca Raton, Florida.

Dehne, H. W. 1982. Interaction between vesicular-arbuscular mycorrhizal fungi and plant pathogens. Phytopathol. 72 : 1115-1119.

Denigés, M. G. 1921. Détermination quantitative des plus faibles quantités de phosphates dans less produits biologiques par la méthode céruléomolybdigue. Compt. rend. Soc. biol. 84 : 875-877.

Graham, J. H., J. P. Syvertsen and M. L. Smith, Jr. 1987. Water relation of mycorrhizal and phosphorus-fertilized non-mycorrhizal citrus under drought stress. New Phytol. 105 : 411-419.

Hardie, K. and L. Leyton. 1981. The influence of vesicular-arbuscular mycorrhiza on growth and water relations of red clover. 1. In phosphate deficient soil. New Phytol. 89 : 599-608.

Ichiki, K., Y. Yamashita and S. Hayashida. 1974. Study on the growth, yield and quality of mandarin orange influenced by the rates of N and P applied when grown in various soils. Materials from 'Kankitsu Kenkyu Kaigi' -Citrus Research Congress co-ordin, by Fruit Res. Sta. Minist. Agri. Forest. 2 : 127-128. (In Japanese).

Ishii, T. and K. Kadoya. 1989. Effect of VA mycorrhizal on citrus growth and carbohydrate contents. J. Japan. Soc. Hort. Sci. 58 (Suppl. 1): 30-31. (In Japanese).

Ishii, T., K. Tatsumi and K. Kadoya. 1989. VA mycorrhizal development of citrus trees as affected by soil managements. J. Japan. Soc. Hort. Sci. 58 (suppl. 1): 32-33. (In Japanese).

Ishii, T., J. Hamada, K. Ishizaki, Y. H. Shrestha and K. Kadoya. 1993. Effect of sod culture system by Bahia grass (*Paspalum notatum* Flügge.) on vesicular-arbuscular mycorrhizal development of satsuma mandarin trees. J. Japan. Soc. Hort. Sci. 62 (Suppl. 2): 98-99. (In Japanese).

Ishii, T. and K. Kadoya. 1994. Effects of charcoal as a soil conditioner on citrus growth and vesicualr-arbuscular mycorrhizal development. J. Japan. Soc. Hort. Sci. 63 : 529-535.

Krikun, J. and Y. Levy. 1980. Effect of vesicular-arbuscular mycorrhiza on citrus growth and mineral composition. Phytoparasitica 8 : 195-200.

Koide, R. T., M. Li, J. Lewis and C. Irby. 1988. Role of mycorrhizal infection in the growth and reproduction of wild vs. cultivated plants. I. Wild vs. cultivated oats. Oecologia 77 : 537-543.

Levy, Y., J. Syvertsen and S. Nemec. 1983. Effect of drought stress and vesicular-arbuscular mycorrhiza on citrus transpiration and hydraulic conductivity of roots. New Phytol. 93 : 61-66.

Menge, J. A., E. L. V. Johnson and R. G. Platt. 1978. Mycorrhizal dependency of several citrus cultivars under three nutrient regimes. New Phytol. 81 : 553-559.

Nelsen, C. A. and G. R. Safir. 1982. Increased drought tolerance of mycorrhizal onion plants caused by improved phosphorus nutrition. Planta 154 : 407-413.

Nemec, S. 1978. Response of six citrus rootstocks to three species of *Glomus*, a mycorrhizal fungus. Proc. Fla. State Hort. Soc. 91 : 10-14.

Okada, N. and H. Hisada. 1971. The effect of phosphorus fertilization levels on satsuma mandarin. Materials from 'Kankitsu Kenkyu Kaigi' -Citrus Research Congress co-ordin. by Fruit Res. Sta. Minist. Agri. Forest. 2: Report No. 136. (In Japanese).

Phillips, J. M. and D. S. Hayman. 1970. Improved procedure for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. Trans. Br. Mycol. 55 : 158-161.

Shrestha, Y. H. 1994. Effect of vesicular-arbuscular mycorrhizal fungi on tree growth, fruit development and quality, photosynthesis, transpiration and water stress of satsuma mandarin trees. M. S. Thesis. Coll. Agr., Ehime Univ., Matsuyama, Japan.

Tang, Z., Q. Zhang and S. Hou. 1982. The effect of mycorrhizal fungus on phosphate uptake by citrus in red earth. Acta Mycologica Sinica 2 : 15-17.

Wada, H., N. Akinari, A. Sadasaku and K. Kurogami. 1971. The effect of phosphorus fertilization on leaf composition yield and fruit quality of satsuma mandarin growing in the 'Izumisagan' soil. Materials from 'Kankitsu Kenkyu Kaigi' -Citrus Research Congress co-ordin. by Fruit Res. Sta. Minist. Agri. Forest. 2: Report No. 137. (In Japanese).

Yakushiji, H., H. Nonami, N. Takagi, T. Fukuyama, S. Ono and Y. Hashimoto. 1992. Enhancement of sugar accumulation and osmoregulation of satsuma mandarin trees grown at low water potentials. J. Japan. Soc. Hort. Sci. 61 (Suppl. 1): 44-45. (In Japanese).

Yuda, E., H. Kurooka and S. Nakagawa. 1981. Search for efficient phosphorous fertilization. Proc. Int. Soc. Citriculture 537-539.

VA 菌根菌がウンシュウミカンの樹体生長，水ストレス耐性，ならびに果実発育・品質に及ぼす影響

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摘　要

ウンシュウミカン（興津早生，カラタチ台）におけるVA 菌根菌の効果をリン少量施用下において調査した．供試したVA 菌根菌は，*Glomus ambisporum, Glomus fasciculatum, Glomus mosseae* および *Gigaspora ramisporophora* であった．

VA 菌根菌接種区では，対照（VA 菌根菌不在）区と比べて，樹体生長が良好となり，果実の発育や品質も良好になる傾向がみられた．特に，接種区における果汁の糖含量（ブリックス），果皮の着色および果実の大きさは，1992 年と 1993 年の年次変動が小さく，安定していた．反対に，対照区では年度による果実の発育や品質に大きな差異がみられた．すなわち，降雨量が少なかった 1992 年では果汁の糖含量が高まったが，果実の肥大は悪かった．しかし，6 月から 11 月の降雨量が多かった 1993 年では果実の肥大は良好であったが，果汁の糖含量は著しく低かった．

水欠乏条件下でVA 菌根菌の接種効果を検討したところ，調査開始 10 日目の対照樹では著しい水ストレス障害が発生し，中には枯死するものがあったのに対し，*Gigaspora ramisporophora* の接種樹では水ストレス症状がほとんど観察されなかった．