The Frequency of Vesicular-Arbuscular Mycorrhizae in the Roots of *Camellia japonica* L. from Different Sites in New Zealand.[1]

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ABSTRACT: The development of short roots and the frequency of vesicular-arbuscular mycorrhizae in *Camellia japonica* L. were investigated in different localities in New Zealand. Mycorrhizal short roots were best developed at a depth of 5 to 15 cm. The average number of root hairs per centimeter of root length ranged from 80 to 120. The highest frequency of vesicular-arbuscular mycorrhizae was found in the short roots with diameters of 1.4 to 2.0 mm. Typical vesicular-arbuscular mycorrhizae were found in the short roots of *Camellia japonica* L. Spores of *Endogone* occurred in the rhizosphere of mycorrhizal roots.

THE CHARACTERISTICS of vesicular-arbuscular mycorrhizae have been extensively described by Kelley (1950), Boullard (1956), Mosse (1963), and Harley (1969). There have been no detailed studies on mycorrhizae in *Camellia japonica*, although some research has been carried out on vesicular-arbuscular mycorrhizae in *Thea chinensis* in tea plantations in Ceylon (*fide* Kelley 1950). Webster (1953), who studied mycorrhizae in *Thea chinensis*, reported that the symbiont fungus was *Rhizophagus theae*. He described tea plants with older and thicker roots without root hairs and with very poor development of vasicular-arbuscular mycorrhizae. Vorontsev (1959), investigating mycorrhizae in tea plantations in Georgia, pointed out the striking shortage of root hairs in tea plants as compared with apple trees.

There is evidence (Baylis 1959, Morrison 1956, Mosse 1957, Gerdemann 1964, and Gray and Gerdemann 1969) of the positive influence of ectomycorrhizal symbiosis on the host plant. Vesicular-arbuscular mycorrhizae can increase plant growth and can help to supply nutrients to the host plant. Herein lies the main justification for studies on mycorrhizae.

MATERIALS AND METHODS

Root samples of *Camellia japonica* were taken from depths 0 to 5 cm; 5 to 15 cm; and 15 to 25 cm from different places in the immediate vicinity of 20 shrubs under investigation. Ten 50 cm^3 soil samples were collected with a steel testing tube. The roots were taken from trees and shrubs growing in the following localities in New Zealand: Lincoln College, Canterbury; The Botanical Gardens and Woodley Park, both in Christchurch; and a private garden in Christchurch (five shrubs from each site).

The shrubs under investigation were from 10 to 60 years old, growing at an altitude of about 50 m above sea level. Samples were taken during the flowering season, in September. The shrubs were free of diseases. The silt-loam, well-drained soil was well supplied with nutrients and humus. The pH of the soil from different sites varied from 5.4 to 6.2.

The soil was removed from the surface of the roots under running water. All roots were measured, observed under a stereoscopic microscope, and arranged in order of thickness (300, 500, 700, 1,000, 1,200, 1,400, 1,600, 2,000, 2,500, and 3,000 μ). A sample

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of 10 short roots of about 1 cm length was taken from each series, and hand sections were made.

Ten slides were made from each series, with 100 sections to the slide. The hyphae were stained with cotton blue in lactophenol. Peuss's formula (Peuss 1958) was used to evaluate the frequency of vesicular-arbuscular mycorrhizae.

RESULTS AND DISCUSSION

In the root system of *Camellia japonica* I observed two types of young, short roots. The roots of the first type were ocher in color, not extensively branched, and knotty and irregular (Fig. 1*a*, *c*). The roots of the second type were light ocher in color, more extensively branched, and smooth (Fig. 1*b*). The youngest and thinnest roots were usually white and 0.4 to 1.2 mm in diameter. The number of short roots was directly proportional to their depth (Table 1). In the surface layer of the soil, conditions were apparently unfavorable for the growth of roots and the development of mycorrhizae, perhaps because there were relatively rapid changes in temperature, moisture, and concentrations of CO_2 over short periods of time. The reduced number of short roots and the poorer development of mycorrhizae in the surface soil layer on the sites in the Christchurch Botanical Gardens, Lincoln College, and Woodley Park, apparently was caused partly by mechanical cultivation and by unfavorable microclimatic conditions for the growth of short roots in the surface soil layer. The optimal conditions for the growth of short roots and development of mycorrhizal associations occurred at depths from 5 to 15 cm (Table 1).

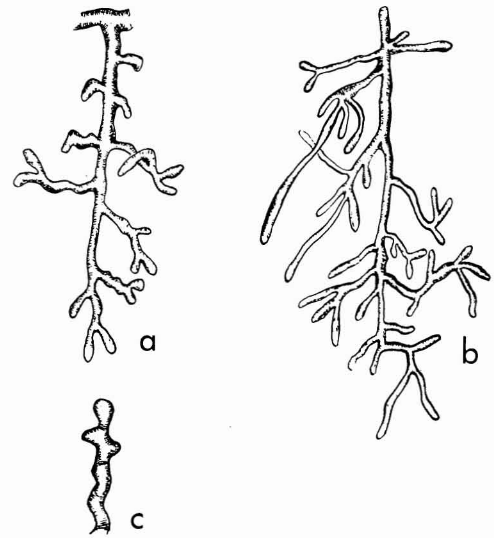

FIG. 1. *Camellia japonica* L. *a*, fine roots of knotty shape and ocher color, 1 × 3; *b*, smooth and richly branched fine roots of light ocher color, 1 × 3; *c*, detail of knotty root, 1 × 4.

TABLE 1

AVERAGE NUMBER OF ROOTS OF *Camellia japonica* L. AND FREQUENCY OF VESICULAR-ARBUSCULAR MYCORRHIZAE

SITE	DEPTH (CM)	TOTAL NO. OF ROOTS	NO. OF SHORT ROOTS	AVERAGE FREQUENCY OF MYCORRHIZA (%)
Private Garden,	0– 5	170	156	11
Christchurch;	5–15	483	422	27
pH 6.2	15–25	428	274	13
Woodham Park,	0– 5	115	52	9
Christchurch;	5–15	215	162	18
pH 5.9	15–25	208	131	6
Botanical Gardens,	0– 5	90	79	8
Christchurch;	5–15	223	197	18
pH 5.4	15–25	301	213	10
Park in Lincoln	0– 5	47	36	28
College; pH 5.8	5–15	187	169	51
	15–25	212	137	24

NOTE: 50 cc of soil samples; number = 60.

The most abundant development of vesicular-arbuscular mycorrhizae occurred at a depth of 5 to 15 cm in shrubs over 50 years old in the park of Lincoln College. This fact apparently is explained by the relatively large quantity of humus in the soil when compared with amounts in the other sites.

Root hairs were comparatively rare, and there were no significant differences in the number of root hairs in shrubs of different ages and on different sites. The number of root hairs varied from 80 to 120 (over a root length of 1 cm), and this figure correlated with the diameter of the roots (Fig. 2). The highest number of root hairs per 1 cm of root occurred in roots 1.5 to 2.0 mm in diameter.

A special single cell layer was developed under epidermal cells. Knotty-shaped roots had exodermal cells which were more suberized than those of the smooth roots. The parenchymatic cells had built up 8 to 12 layers of cortex. The walls of the endodermis cells were slightly suberized. The vascular cylinder contained two groups of xylem and phloem. There were rhombohedral calcium oxalate crystals in the cells.

Typical vasicular-arbuscular mycorrhizae developed in both the knotty and smooth roots. Nonseptate hyphae occurred frequently on the surface of the roots and penetrated into the root tissue (Fig. 3), whereas septate hyphae were found only on the surface of roots. The hyphae penetrated roots directly through epidermal cells. Mycorrhizal infections do not spread internally from parent roots to fine roots, since every new rootlet is reinvaded from the soil. I observed the formation of apressoria at the points of entry. The dimorphic nature of the external mycelium was soon in the rhizoplane, and was of the same type as that described by Mejstřík (1965). There was no hyphal penetration of the endodermis or of the vascular tissue (Fig. 4). The hyphae were 2.4 to 4.4 μ in diameter, and they

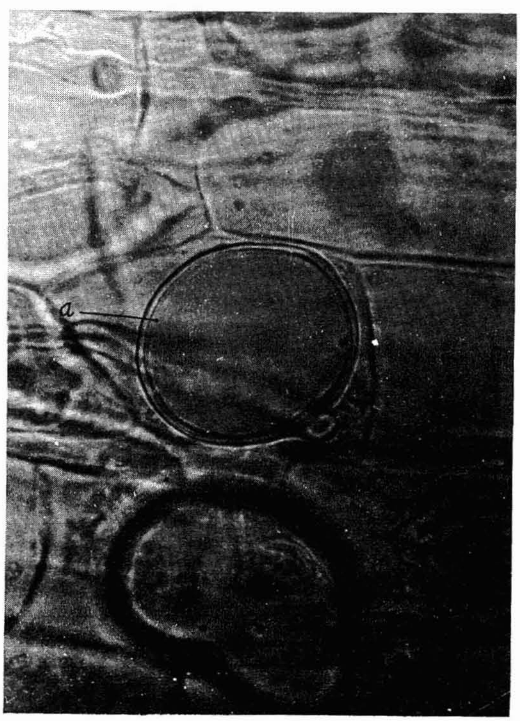

FIG. 2. *Camellia japonica* L. Vesicule in cells of cortex. *a*, vesicule. × 1,000.

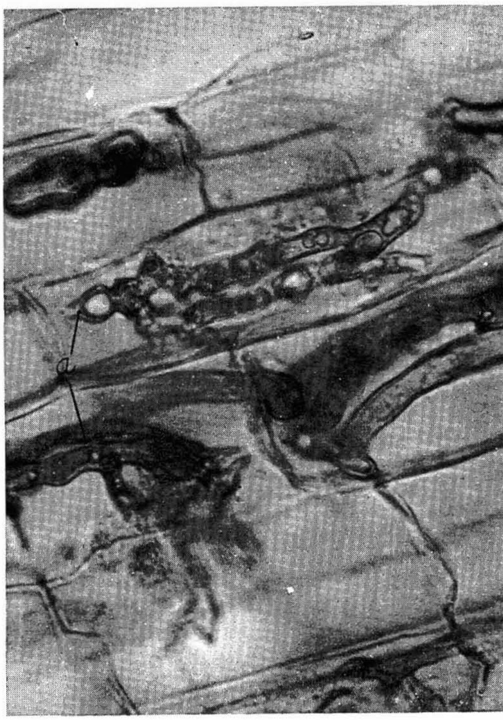

FIG. 3. *Camellia japonica* L. Vesicular-arbuscular mycorrhiza in the root tissue, hyphae in parenchymatic cells of cortex. *a*, hyphae. × 1,000.

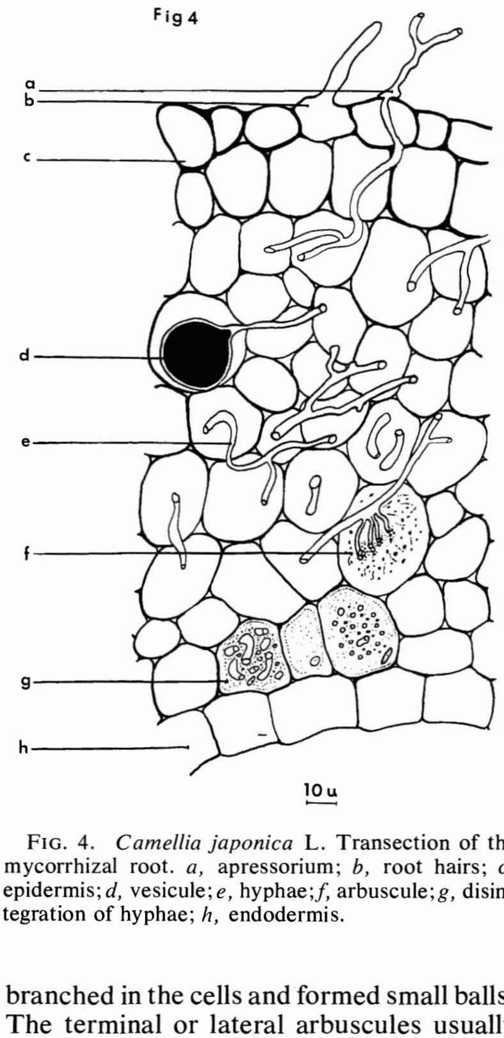

FIG. 4. *Camellia japonica* L. Transection of the mycorrhizal root. *a*, apressorium; *b*, root hairs; *c*, epidermis; *d*, vesicule; *e*, hyphae; *f*, arbuscule; *g*, disintegration of hyphae; *h*, endodermis.

branched in the cells and formed small balls. The terminal or lateral arbuscules usually were produced in the central cell layers of the cortex. An enlarged nucleus with a prominent nucleolus was usually attached to the center of the arbuscule. Vesiculae were often intercellular and usually multinuclear, having connections with their parent hyphae (Fig. 5). The disintegration (digestion?) of hyphae was observed, especially in older parts of the root tissue. There were no morphological differences between mycorrhizal and nonmycorrhizal roots. The vesicular-arbuscular mycorrhizae were caused probably by species of *Endogone*. Typical chlamydospores of *Endogone* were commonly found in the rhizospheres of mycorrhizal roots.

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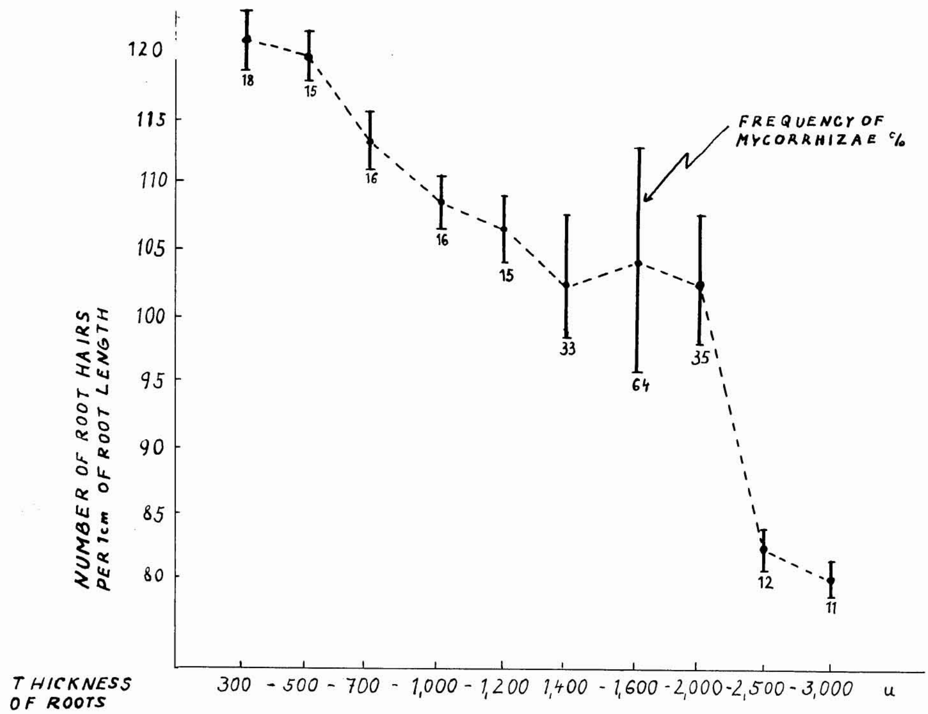

FIG. 5. *Camellia japonica* L. Mycorrhizal frequency, number of root hairs per 1 cm of root length, and thickness of roots.