HortScience 17(4):655–656. 1982.

Effect of the Ectomycorrhizal Fungus *Pisolithus tinctorius* and Auxin Rooting Formulations on Growth of 'Cortland' Apple Trees[1]

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Additional index words. Malus domestica, indolebutyric acid, naphthaleneacetic acid, naphthaleneacetamide

Abstract. **'Cortland'/Malling (M) 7 apple trees (*Malus domestica* Bork.) which were treated at planting time with commercial root promoters, containing either naphthaleneacetamide (NAAm) + naphthaleneacetic acid (NAA), indolebutyric acid (IBA) + fertilizer, or the ectomycorrhizal fungus *Pisolithus tinctorius*, increased terminal growth. *P. tinctorius* was superior to either rooting compound for increasing total growth, and only *P. tinctorius* increased root weight. Colonization of the root system by *P. tinctorius* was not observed, although the roots of *P. tinctorius*-treated trees appeared to have more endomycorrhizae. The growth increase was not due to increased nutrient uptake.**

Growth of newly planted fruit and nut trees is frequently poor for the first 1 or 2 years (6, 10). Looney and McIntosh (6) reported increased root production of 'Bartlett' pear trees when indolebutyric acid (IBA) was applied either in toothpicks or by dusting cut ends of roots. However, no treatment increased shoot growth the year of planting. Increased root growth of pecan (10) was achieved when IBA was applied in lanolin paste prior to planting or via IBA-impregnated toothpicks placed in holes drilled in the roots. Many forest trees require mycorrhizal fungi to grow and survive (11). Mycorrhizae are potentially useful for stimulating growth and increasing production of a number of horticultural crops (7).

The experiment was intended to determine if either commercially available auxin preparations designed to stimulate rooting or the ectomycorrhizal fungus *P. tinctorius* could increase root development and enhance growth of newly planted apple trees.

One-year old 'Cortland'/Malling (M) 7 apple trees were purchased from a local nursery. A 30-cm-diameter hole about 30-cm-deep was dug for each tree in a Ridgebury sandy loam at the Horticultural Research Center in Belchertown, Mass. One group of 7 check trees was planted, leaving 5 cm of rootstock above the soil line. Two groups of trees were treated and planted with manufacturer-recommended rates of 2 commercial auxin rooting formulations. The NAAm + NAA products (Transplantone) contained 0.018% NAAm and 0.002% NAA (Union Carbide, Ambler, PA). The IBA + NPK product (UP-START) contained 0.003% IBA and 5N–6.4P–4.2K, (Chevron Chemical Company, San Francisco, Calif.). One liter of solution containing 3.4 mg/liter NAA and 30.6 mg/liter NAAm was placed around the roots of each NAAm + NAA-treated tree. The IBA- and N-P-K treated trees received 1900 ml of solution containing 1100, 1419, and 913 mg/liter of N-P-K, respectively, and 0.7 mg/liter IBA. The ectomycorrhizal fungus *P. tinctorius*[4] contained in 750 ml of vermiculite, was mixed with 3750 ml of soil. This soil mixture was placed around the roots of 7 apple trees, and the remainder of the planting hole was filled with the parent soil. A 5th group of trees was treated with *P. tinctorius* and IBA + N-P-K, and a 6th group of trees was treated with *P. tinctorius* and NAAm + NAA. Each treatment was replicated 7 times in a randomized block design. During the growing season each tree received two 25-g fertilizer applications containing 10N–4.3P–8.3K.

Ninty-five days after treatment, 5 leaves were harvested from each midshoot of the tree's central leader. These were dried at 70°C, ground, and then analyzed for N using the microKjeldahl method and for P, K, Ca, Mg, Fe, Cu, Zn, Mo, Co, Cu, and Al by atomic absorption spectrophotometry. After leaf drop in the fall, all trees were lifted. All current season shoots were measured, cut, and weighed. The roots were removed and weighed. A sample of the fibrous roots was prepared according to Phillips and Hayman (9) for microscopic examination of endomycorrhizal colonization. Infection by ectomycorrhizae was evaluated by root surface examination.

Terminal growth and the weight of current season's growth was stimulated by *P. tinctorius* and both root stimulator treatments, alone or when applied in combination (Table 1). Only the NAAm + NAA treatment failed to increase growth of the terminal and lateral shoots combined (total growth). Root weight was increased only with the *P. tinctorius* treatment. The limited significance of effects by the root stimulators was partially due to high variability among samples. Looney and McIntosh (6) reported a consistent stimulatory effect of IBA on root development of 'Bartlett' pear trees, but there was no resultant increase in shoot growth.

IBA + N-P-K was more effective than NAAm + NAA for increasing the weight of 1-year-old wood, and *P. tinctorius* was superior to both for increasing total growth of 1-year-old wood and root weight. A direct comparison between the NAA–NAAm combination and IBA could not be made, because the recommended use rate did not result in equimolar amounts being used. Promotive effects of root stimulators and the *P. tinctorius* may be additive, since total growth from the combined treatments was greater than when each was used alone.

No treatments changed P, Cu, Zn, and Ca from the check levels, and only *P. tinctorius* and IBA + N-P-K increased leaf N. (data not

Table 1. The effect of the ectomycorrhizal fungus *Pisolithus tinctorius*, IBA + NPK, and NAAm + NAA on growth and root development of 1-year-old 'Cortland'/M 7A apple trees (refer to text for treatment formulations).

Treatment	Terminal growth (cm)	Total growth (cm)	1-yr-wood wt (g)	Root wt (g)	Total tree wt (g)
Check	25.0c[z]	86.9e	10.4d	105.7c	291c
NAAm + NAA[y]	31.9b	114.4de	15.2c	124.4bc	328bc
IBA + NPK[x]	32.5ab	131.0cd	20.5b	123.1bc	348b
Pisolithus tinctorius	34.9ab	162.0ab	23.9b	161.0a	419a
P. tinctorius + NAAm + NAA	32.7ab	152.6bc	23.8b	142.6ab	355b
P. tinctorius + IBA + NPK	37.4a	184.7a	31.8a	156.6ab	412a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[y]Transplantone.
[x]UP-START.

[1]Received for publication Oct. 7, 1981. Paper No. 2061, Massachusetts Agricultural Experiment Station, University of Massachusetts at Amherst. This research was supported in part by Experiment Station Project No. 376.

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shown). The *P. tinctorius* treatment alone or when combined with the root stimulators resulted in increased levels of K and decreased levels of B and Mg in leaf samples. NAAm + NAA alone increased Mg slightly and had no additive effects when combined with *P. tinctorius*. IBA + NPK alone increased K and Mn and decreased B while further increasing the K level when combined with *P. tinctorius*.

Leaves of untreated trees contained near-normal levels of all elements except K (13). No leaf scorch characteristics of K deficiency were observed. Oberly and Boynton (8) suggested that unless visual symptoms occur, added K may not increase growth. However, the possibility that increased growth could result in increased K uptake cannot be dismissed. Enhanced growth due to mycorrhiza is often attributed to increased uptake of less mobile elements such as P(2), Zn(1), or Cu(3). Levels of these elements were uninfluenced by the *P. tinctorius*. Therefore, increased growth from *P. tinctorius* most likely cannot be explained on the basis of increased nutrient uptake.

Trees that received *P. tinctorius* had many leaves with yellowish-white margins. This was most pronounced on older leaves. This symptom was dissimilar to commonly accepted foliar nutrient deficiency or toxicity symptoms and leaf analyses confirmed that this could not be explained on the basis of nutrient content of leaves.

Observations of roots failed to confirm colonization of the roots with *P. tinctorius*. However, it was observed that *P. tinctorius*-treated trees appeared to have more endomycorrhizae infection than untreated trees. Growth stimulation appeared to occur in the absence of infection with *P. tinctorius*. Levisohn (4) demonstrated that ecomycorrhiza can stimulate growth of several tree species in the absence of colonization. Slankis (12) cited several examples where fungal filtrates stimulated the growth of trees and aseptically grown root cultures. *P. tinctorius* and several other ectomycorrhizae increased the percent rooting and root volume of bearberry and huckleberry without colonization (5). Mycorrhizae are known to produce the growth promoting plant hormones, auxins, gibberellins, and cytokinins, that can be liberated in the growing media (12). We suggest that the increased growth of 'Cortland' apple trees may be due to growth stimulation from hormones produced by the *P. tinctorius* or the endomycorrhizae in *P. tinctorius*-treated trees.

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HortScience 17(4):656–658. 1982.

Effect of CGA-15281, an Ethylene-generating Material, on Maturity of 'Delicious' Apple[1]

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Additional index words. Malus domestica, (2-chloroethyl)phosphonic acid, (2-chloroethyl) methylbis (phenylmethoxy) silane, butanedioic acid mono-(2, 2-dimethylhydrazide)

Abstract. **Application of (2-chloroethyl)methylbis (phenylmethoxy) silane (CGA-15281) in combination with butanedioic acid mono-2-2-dimethylhydrazide (daminozide) and naphthaleneacetic acid (NAA) increased fruit color of 'Delicious' apple (*Malus domestica* Bork.) in 1980 within 5 days after treatment at concentrations of 250 and 500 ppm, but was not significantly better than untreated controls at harvest. Fruit firmness was reduced within 10 days by the application of 500 ppm CGA in the absence of daminozide. In 1981, application of CGA at various rates from 250 to 1000 ppm did not significantly alter percent soluble solids, starch index, surface color or fruit firmness in comparison to a 500-ppm ethephon treatment. Fruit ethylene levels of all CGA treated fruit were higher 2 hours after treatment in comparison to ethephon at 500 ppm. Ethylene levels of 1000 ppm CGA treatment remained higher than ethephon treatment until 24 hours after treatment.**

The activity of CGA-15281, a potential peach-thinning compound (1, 2, 3), is dependent upon ethylene release. Potential also exists for its use on other fruit crops as a ripening and/or abscission-inducing agent in a similar fashion as ethephon, another ethylene-generating product. The purpose of this study was to examine the influences of CGA-15281 on maturity indices and red color development of 'Delicious' apples.

Fruit measurements. In 1980 and 1981, a 3-apple sample from each tree was collected immediately prior to the application of CGA and at 5-day intervals thereafter. Samples were analyzed for fruit firmness (FF) using an Effegi fruit firmness tester with 4 readings per fruit. The percent red color was evaluated visually by the same person over the course of each year's study. The number of dropped fruit below each tree was counted 10 days after treatment with CGA. Starch Index (4) based on a visual rating of 1 (all starch) to 10 (no starch) in the cortex of the fruit was determined on samples collected in 1981.

1980. Treatments were applied to 6-year-old 'Miller Sturdeespur Red Delicious'/Malling-Merton 106 as whole trees in a randomized complete block with 6 treatments and 6 replications. The treatments are presented in Table 1. Daminozide was applied on June 27 and CGA + NAA on August 18. Tri-

[1]Received for publication Oct. 29, 1981.

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