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A Pictorial Guide to Coffee Grafting

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Overview of coffee decline caused by the Kona coffee root-knot nematode

Since the early 1900s coffee growers in Kona, Hawai'i, have been experiencing a decline of their crop. In 1907, Smith and Blacow noted plant-parasitic nematodes as pests capable of causing these losses (Schmidt et al. 2001). Then in 1935, Ripperton et al. observed dieback of 'Kona Typica' coffee, a coffee decline that was later found to be caused by *Meloidogyne konaensis*, as described by Eisenback et al. in 1994. This serious disease of coffee was initially referred to by terms such as "transplanting decline," a "replant problem," "nutritional stress," and "Kona wilt."

A coffee survey conducted statewide in 2000–2001 (Hue et al. 2005) found that 33.9% (n=65) of Big Island farms were infested with coffee root-knot nematode (CRKN). Researchers concluded that poor coffee nutrition and a heavy infestation of plant-parasitic nematodes were major factors causing significant losses of yield in Hawai'i. In 2002, Nelson et al. estimated that 85% of the acreage in Kona was infested with *M. konaensis* and that the overall yield loss caused by this nematode was 60%. Growers need to be vigilant in keeping CRKN out of uninfested areas and, if affected, to slow the spread of the pest. Kawabata et al. (2018) outline procedures for sampling a farm to diagnose a nematode infestation.

Figure 1. Newly grafted coffee seedlings.

For additional and more detailed information about CRKN, cultural management of nematodes, replanting and more, see publications in the References and Literature Cited section of this publication.

Why it's important to graft coffee onto nematode-tolerant rootstock

In Hawai'i, there currently are no chemicals that can legally be used to treat for CRKN. Nematode-tolerant or -resistant rootstocks are the only effective and practical method for managing CRKN (Schmitt et al. 2001). Grafting 'Kona Typica' to these rootstock plants (Fig. 1) allows coffee to thrive in soils infested with CRKN. Without this tolerance, nematodes will overcome the tree's root system, causing the tree to exhibit symptoms of decline and overbearing. Non-tolerant trees have reduced yields, struggle to survive even with irrigation and good fertility, and are often killed by nematode infestation

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Figure 2. Visual differences in the leaves of *C. arabica* 'Typica' (left) and *C. liberica* 'Fukunaga' (right).

(Serracin et al. 1999).

There are varying levels of nematode tolerance in rootstocks. Since 2001, *Coffea liberica* var. dewevrei 'Fukunaga' (Fig. 2) has been recommended by Bittenbender et al. as a suitable rootstock. Current research is evaluating the long-term tolerance of nine rootstocks including 'Fukunaga' at the Kona Research Station in Kainaliu.

Supplies and tools for preparing rootstock and scion materials

- Rootstock seeds
- Scion seeds
- Forestry tubes
- Trays (optional: with lids)
- Sterile media (ex: vermiculite, perlite, peat mixtures)

Growing the rootstock

Nematode-tolerant rootstock seeds must be used; however, obtaining seeds of *C. liberica* 'Fukunaga' can be challenging. Some growers have their own mother trees and may be willing to sell or share seeds. New growers may need to reach out to their local Cooperative Extension agent for assistance in locating and obtaining rootstock seed or mother plants. Rootstock seedlings should be established well in advance of the scion material, usually 2–3 months before the scion seeds are planted. The following are steps in preparing rootstock plants suitable for grafting:

1. Harvest and pulp ripe 'Fukunaga' cherry.
2. Float the seeds (parchment) in water and discard all that rise to the surface.
3. Ferment for approximately 24–48 hours in room-temperature water to remove mucilage. Do not boil or chill the seeds during fermentation. A thorough fermentation is important to reduce mold and rot issues during germination. Small batches may take longer to ferment and require physical removal of mucilage.
4. Sow seeds immediately or dry them to store. Observational studies indicate that freshly harvested, pulped, and fermented (or scarified) 'Fukunaga' seeds germinate consistently.
5. Sow seeds in a porous tray with non-compacted, well-drained sterile[1] media such as 100% vermiculite. Keep the media moist but not waterlogged. Bottom heat can be used to expedite germination.
6. Once seeds are germinated, allow the cotyledons to open before replanting.
7. Replant seedlings into sterile media in forestry tubes. The planting media may consist of 60:40 peat:perlite. Discard any seedlings with J-rooting [A], split taproots [B], or pest problems, or those lacking in vigor [C] (Fig. 3).
8. Keep well watered and treat for insect and fungal pests as needed.
9. Rootstock seedlings are ready for grafting when at least three pairs of true leaves emerge.

[1]Use of sterile media is very important, as the root-knot nematode is a soil-borne pest. If you use soil from your property, or a neighbor's property, it could have populations of the nematode that could infest your scion and/or rootstock seedlings. Similarly, it is important to keep the materials off the ground, and away from areas where soil could be splashed from the ground onto the trays or forestry tubes and infest your grafting stock.

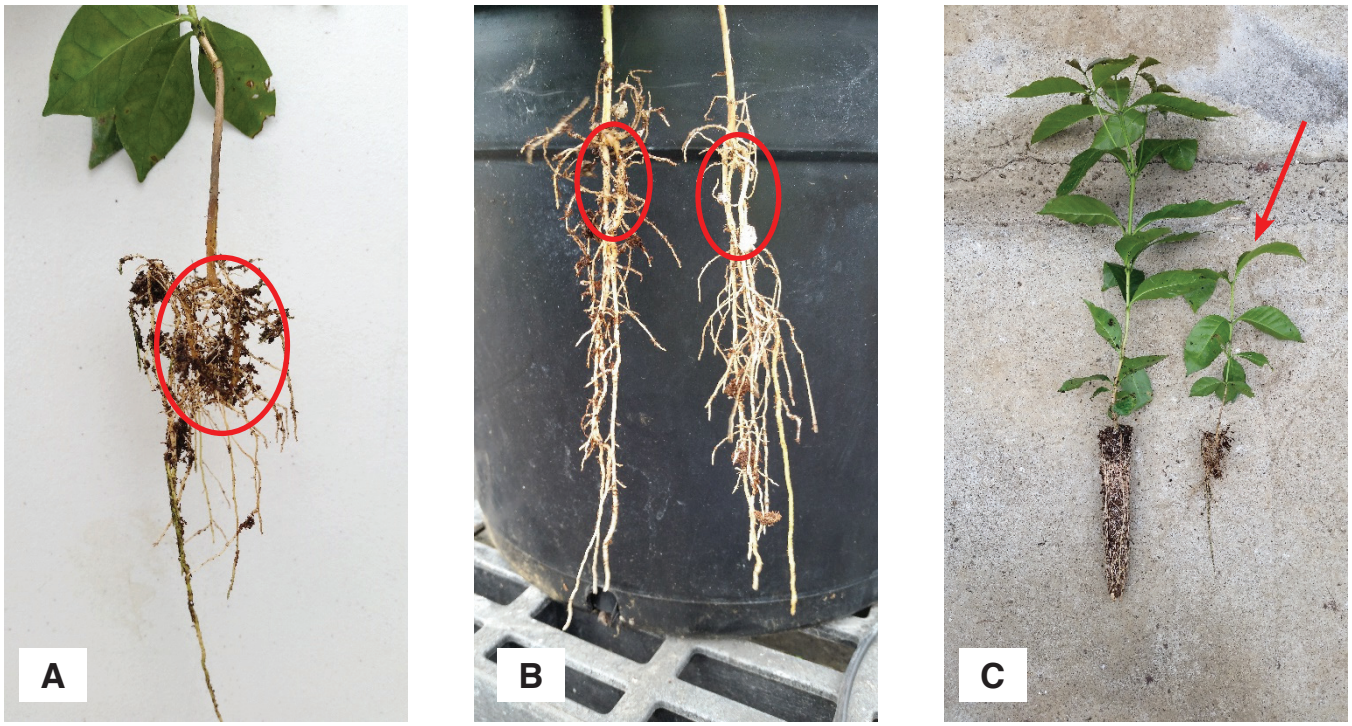

Figure 3. Defects in rootstock seedlings. A: J-root; B: split taproot; C: lacking vigor

Growing the scion

Scion seeds should be selected based on the variety of coffee that you want to produce; in most cases this will be *Coffea arabica* 'Kona Typica' cultivars. Select ripe berries from desirable trees. Seeds should be prepared similarly to the rootstock seeds (see above), with the added note that seeds can be dried and stored for future germination. This is important, as timing of rootstock seed availability may limit the timing of grafting.

Scion seeds should be planted 2–3 months after the rootstock material. Plant seeds in an open tray using sterile media (e.g., 100% vermiculite, 80:20 perlite:peat, etc.) with about a ¾" layer of media on top. Time to germination can be decreased by utilizing plastic dome coverings on the trays or bottom heat, but these are not required for germination. Grafting should ideally be done when scions are just beginning to germinate and the parchment is still covering the cotyledons. Older seedlings with the cotyledons emerged can also be used; however, the parchment-covered cotyledon stage provides a more consistently successful graft. Discard any seedlings lacking in vigor and treat or discard those with pest problems as necessary.

How to graft coffee onto a root-knot nematode-tolerant rootstock

In Hawai'i, coffee is typically grafted using a modified Reyna Method (Reyna 1966). The Reyna Method is a technique to connect the scion to the rootstock seedling by cleft graft, while the scion's cotyledons are still protected in the parchment. This publication describes this method, using photographs to illustrate the various steps.

Supplies and tools for grafting (Fig. 4):

- Germinated scion seedlings, with parchment still covering cotyledons
- *M. konaensis*-tolerant rootstock seedlings, with at least three pairs of true leaves
- Clean, sharp razor blade or similar
- Clean, sharp shears
- Isopropyl alcohol to clean and sterilize tools
- Container for alcohol

Figure 4a. Supplies and tools for grafting coffee seedlings.

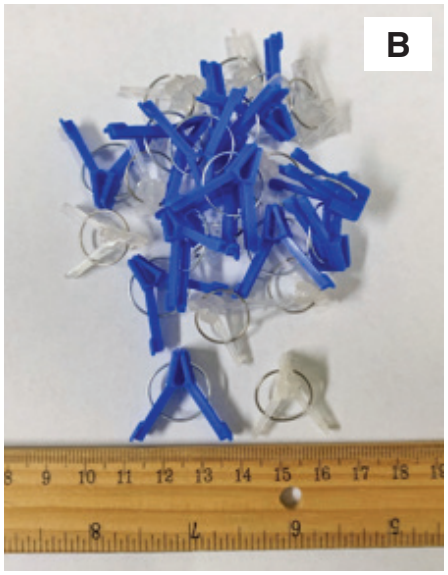

Figure 4b. Spring-loaded side grafting clips for small (≤ 4mm) stem diameters.

- Grafting clips
- Rack for holding plants
- Humidity chamber ready to receive grafted plants

Coffee-grafting procedures

Step 1:

Find a cool, shady area in which to conduct your coffee grafting. Clean your shears and razor blade with isopropyl alcohol to minimize contamination of grafts. Let air dry or wipe dry with a clean cloth. A container for the alcohol is useful for sterilizing tools between cuts.

Step 2:

Select a rootstock seedling such as 'Fukunaga' to graft onto. It should have at least three pairs of true leaves above the cotyledons (Fig. 5). For best cambial connection, select a rootstock with similar stem diameter as the scion. It is fine to have a scion diameter smaller than the rootstock stem, but it is not recommended to have a scion diameter larger than the rootstock stem. Be selective and do not use rootstocks that appear to be weak or smaller than the rest of the rootstocks established at the same time. These tend to be weak plants and should be culled.

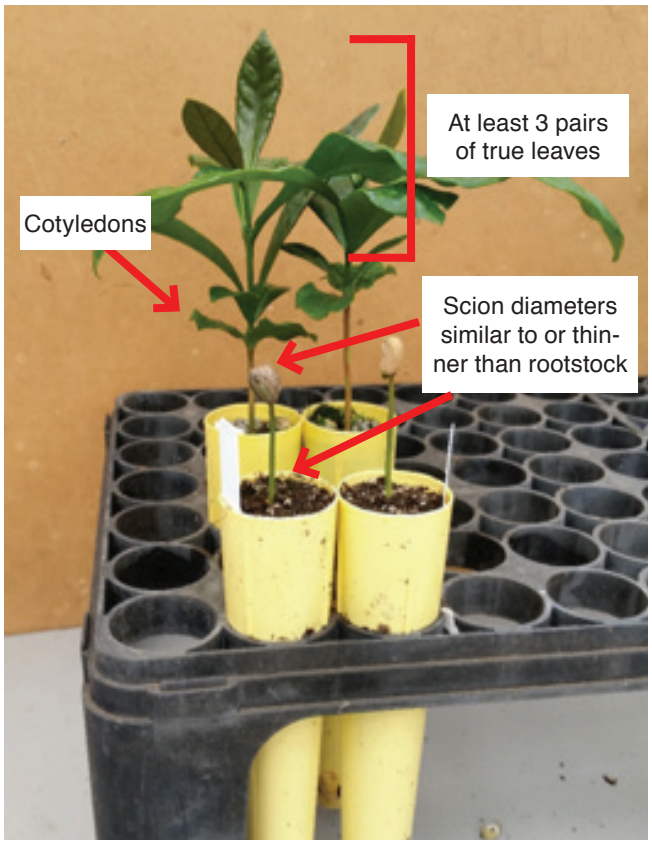

Figure 5. Coffee rootstocks (back) and scions (front) for grafting

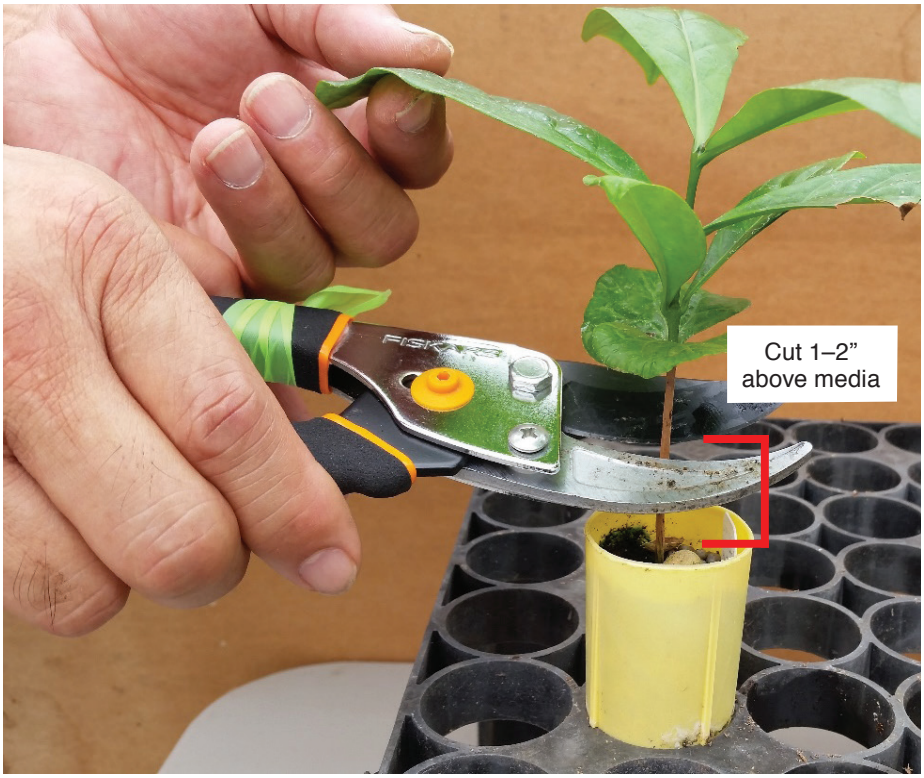

Figure 6. Recommended location for cutting rootstock.

Step 3:

Sanitize your shears with the alcohol. Using your shears, remove the top and foliage of the rootstock by cutting about 1–2 inches above the media surface but below the cotyledons (Fig. 6).

Note: Attempting to graft above the cotyledons potentially leaves nodes from which rootstock shoots can be generated. Often, the rootstock is more vigorous that the scion. Following grafting and during cambial connection, any new growth from the rootstock could hinder graft fusion. In the field, grafts made above the cotyledons could also result in repeated need to desucker rootstock verticals. If left, these verticals can outgrow and out-complete scion verticals for nutrients, water, and sunlight.

Step 4:

Select your scion (Fig. 7). The scion seedling should still have the parchment, or hull, covering the cotyledons. As with the rootstock seedlings, be selective. Do not use scions that appear weak or smaller than the other seeds established at the same time; these should be culled.

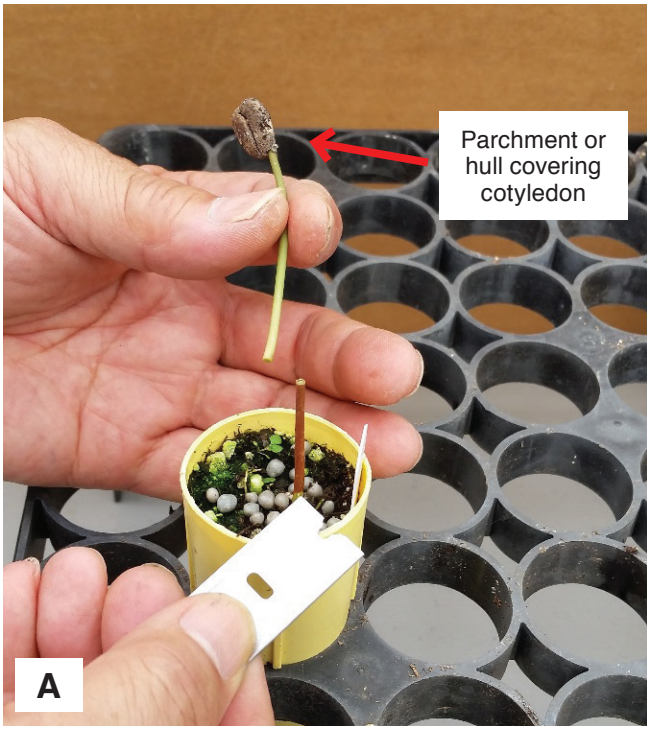

Figure 7a. Selection of scion.

Figure 7b. Scions grown in sterile potting media and perlite.

Figure 7c. Scions grown in vermiculite and perlite.

Step 5:

Sterilize the razor blade with alcohol. Using the razor blade, slice a wedge-shaped point on the stem of the scion, about 2 inches below the parchment covering (Fig. 8). The wedge portion should be about ¼–3/8 inch long.

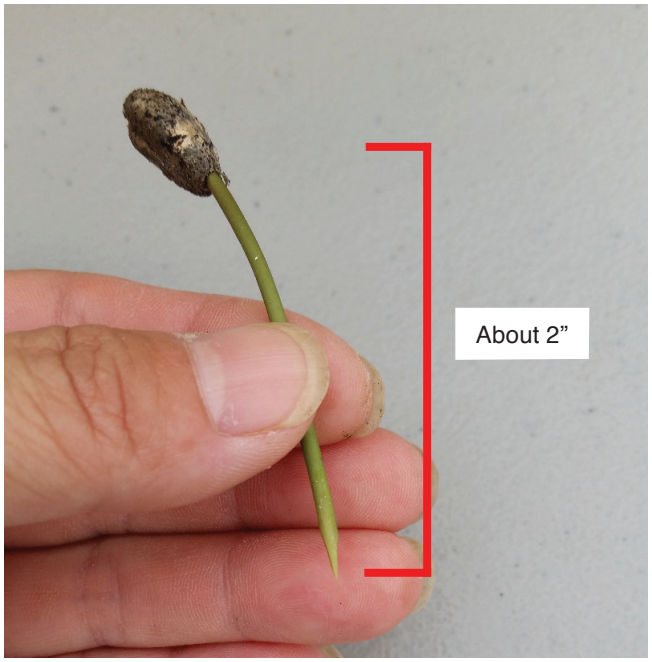

Figure 8. Coffee scion prepared for grafting.

Step 6:

Also using the razor blade, with a slow, controlled rocking motion, cut a slit about 3/8” to ½” down the center of the stem of the topped rootstock (Fig. 9). If the rootstock is wider than the scion, the slit in the rootstock can be slightly to one side, about a third of the way across the cut top, instead of halfway. The slit should be deeper than the length of the wedge on the scion.

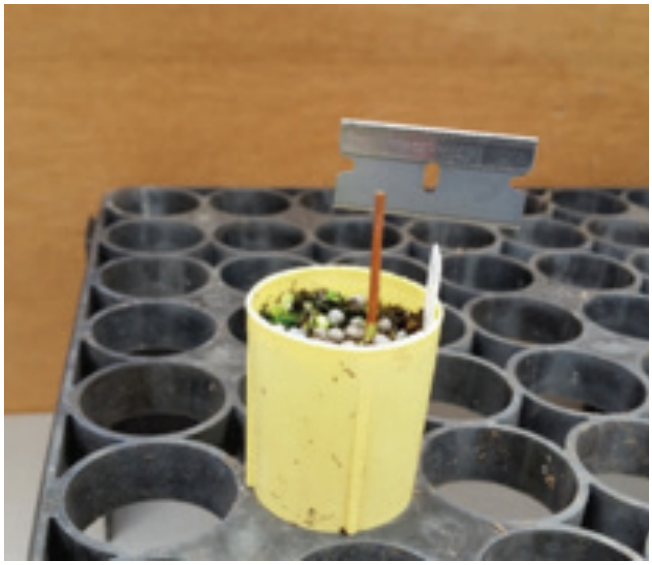

Figure 9. Preparing a cleft in the rootstock.

Step 7:

With the blade, carefully open the slit to gently slide the wedge of the scion into the opening in the rootstock stem.

Step 8:

The cambium is a layer just below the skin of the stem. It is important to match the cambium layers of both the scion and rootstock (Fig. 10). If the scion stem is smaller than the rootstock, move the scion to match at least one side of the scion with one side of the rootstock. The scion and rootstock should be touching, with no gaps.

Step 9:

Clip the stems at the joint area to secure the graft (Fig. 11). No wax or tape is needed.

Step 10:

Place grafted plants in a humidity chamber or mist box with high humidity (Fig. 12), to prevent the scion and rootstock from drying out and wilting. High humidity is crucial for graft survival. Chambers should not be in direct sunlight and should be elevated above the soil or otherwise protected from contamination by CRKN.

Note: Clean and dry out humidity chambers after successful grafts are removed. Additionally, monitor for disease and fungal pathogen presence on the plants as well as in the chamber and treat as necessary.

Figure 12a. Humidity chambers made with storage bins.

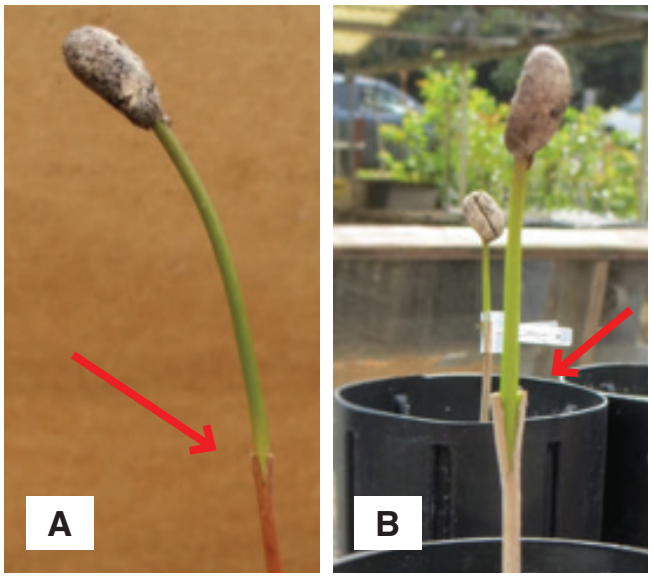

Figure 10a and 10b. If scion and rootstock are not the same diameter, one side of each needs to match.

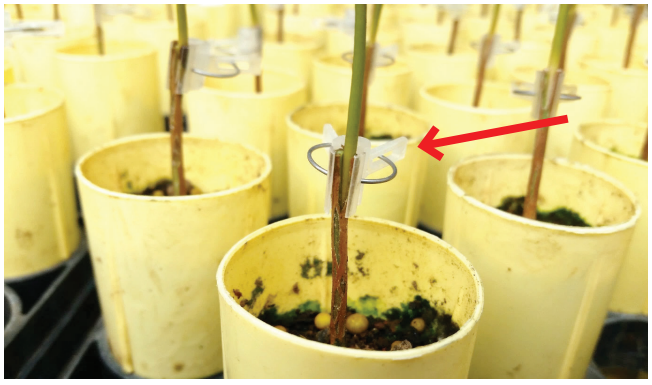

Figure 11. Clip holding coffee graft together.

Figure 12b. Elevated humidity chamber.

Step 11:

Keep newly grafted plants in the humidity chamber for at least four weeks to allow the scion and rootstock cambiums to fuse completely (Fig. 13). Once the cambial connection is made (Fig. 14), the grafted plants can be removed from the humidity chamber, repotted, and placed under shade cloth to acclimatize under stronger sunlight. Maintain soil moisture and provide grafted plants with a small amount of a general slow-release fertilizer.

Figure 13. Coffee graft that is working.

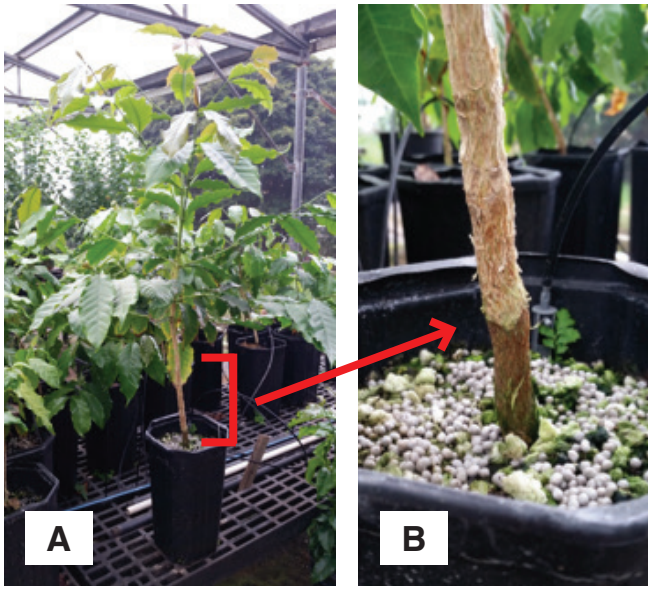

Figure 14a. Successful and healed coffee graft connection closeup. Figure 14b. Closeup of healed graft.

Acknowledgments

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References and Literature Cited

Bittenbender, H.C., and D. Hamasaki. 2002. The Case of the Nematode Nemesis. VS-157. College of Tropical Agriculture and Human Resources, University of Hawai‘i, Honolulu, HI, U.S.A. (dvd).

Bittenbender, H.C., D.P. Schmitt, M. Serracin, and C.G. Cavaletto. 2001. Fukunaga, a coffee rootstock resistant to the Kona coffee root-knot nematode. New Plants for Hawaii: NPH-6, 2 pp. College of Tropical Agriculture and Human Resources, University of Hawai‘i, Honolulu, HI, U.S.A. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/NPH-6.pdf.

Eisenback, J.D., E.C. Bernard, and D.P. Schmitt. 1994. Description of the Kona coffee root-knot nematode, *Meloidogyne konaensis* n. sp. *Journal of Nematology* 26:363–374.

Fleming, K. and S. Mauri. 2001. The economics of producing grafted coffee plants. Agribusiness: AB-14, 4 pp. College of Tropical Agriculture and Human Resources, University of Hawai‘i, Honolulu, HI, U.S.A. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/AB-14.pdf.

Hue, N.V., M. Serracin, D.P. Schmitt, and H.C. Bittenbender. 2005. Nutrient and nematode status of

coffee and soils from orchards in Hawaii. *Communications in Soil Science and Plant Analysis* 35(13,14):2023–2036.

Kawabata, A.M., R. Myers, A. Cho, and S.T. Nakamoto. 2018. Coffee root-knot nematode sampling procedures. Plant Disease PD-114. 3 pp. College of Tropical Agriculture and Human Resources, University of Hawai'i, Honolulu, HI, U.S.A.

Nelson, S., D. Schmitt, and V. Easton Smith. 2002. Managing coffee nematode decline. Plant Disease: PD-23, 11 pp. College of Tropical Agriculture and Human Resources, University of Hawai'i, Honolulu, HI, U.S.A. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-23.pdf.

Reyna, E.H. 1966. La técnica del injerto hipocotiledonar del cafeto para el control de nemátodos. *Café* 7(1):5–11.

Ripperton, J.C., Y.B. Goto, and R.K. Pahau. 1935. Coffee cultural practices in the Kona district of Hawaii. Hawaii Agricultural Experiment Station Bulletin No. 75, 64 pp. College of Tropical Agriculture and Human Resources, University of Hawai'i, Honolulu, HI, U.S.A.

Schmitt, D.P., F. Zhang, and M. Meisner. 2001. Potential for managing *Meloidogyne konaensis* on coffee in Hawaii with resistance and a nematicide. *Nematropica* 31:67–73.

Serracin, M., and D.P. Schmitt. 2000. *Meloidogyne konaensis* and coffee rootstock interactions at two moisture regimes in four soils. *Nematropica* 32:65–76.

Serracin, M., D. Schmitt, and S. Nelson. 1999. Coffee decline caused by the Kona coffee root-knot nematode. Plant Disease: PD-16, 2 pp. College of Tropical Agriculture and Human Resources, University of Hawai'i, Honolulu, HI, U.S.A. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-16.pdf.

Smith, J.G., and C.R. Blacow. 1907. Cultivation of tobacco in Hawaii. Hawaii Agricultural Experiment Station Bulletin No. 15, 29 pp. College of Tropical Agriculture and Human Resources, University of Hawai'i, Honolulu, HI, U.S.A