Interactions Between Site and Koa Seed Source

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Introduction

Interaction between plants and their habitats is not simple. Sometimes, however, this complex of interactive process is treated as though two parts can be separated from all others. The approach might assume that when one process is modified, the other has a straightforward concomitant reaction to the change. In real life, changing one part of a process changes the entire process, it may change the way other processes function, and it may feed back to readjust responses to the intentional changes. Species having been once common in a particular habitat is not an assurance that they will return, even with careful nurturing. In particular, for example, the genetic material of even the most common species could be mismatched with the habitat after the biological and physical processes have changed.

Previous reports

This paper is an initial look at information from a Maui elevation-transect study showing some influences that site (location) has on how koa (*Acacia koa*) responds to environmental differences. In another paper, Ikawa and I (Conrad and Ikawa 1995) compared nutrient concentrations in young koa with the concentrations in young pines (*Pinus* spp.) grown in the same sites. As expected, because koa is a nitrogen fixing legume its tissues contained more nitrogen. Other differences were less expected. The needles of two pine species contained 5 and 10 times greater aluminum concentration than found in koa phyllodes. The concentration of aluminum was more than 3 times greater in pine twigs than in koa twigs.

Conrad et al. (1995) showed that koa seedlings from different native environments reflect the relative disparity of the environments by their survival and growth. This seed source study was at the Waiawa Correctional Facility on O'ahu. Survival of seedlings from several locations on Hawai'i Island was only 52–64 percent, and growth was 9–21 cm/yr. Waiawa receives about half as much rain as the native habitats of some seedlings from Hawai'i Island. Average temperature in their native habitat is 3.0–5.6°C (6-10°F) cooler. Seedlings from other islands did better. Survival was 79–98 percent and growth was 49–73 cm/yr for seedlings whose provenances were Kuiaha (Maui), koa-ridge on O'ahu, and Kamalomaloo (Kaua'i). Compared with Waiawa, temperatures in these habitats were within 1°C (1.8°F). Rainfall at Waiawa was about the same as nearby koa-ridge and 635 mm (25 in) less than at Kuiaha.

In an *Acacia* growth potential study, Cole et al. (1996) showed that intensive site preparation and fertilizing can overcome environmental deficiencies. They ran a growth potential study for 19 months. The F_0 treatment included deep plowing, rototilling, and a single fertilizer application at planting. This treatment resulted in 90 cm/yr Kaumana koa height growth. The F_1 treatment included the F_0 applications plus liming and more fertilizer; the resulting height growth of Kaumana was 220 cm/yr. The Kaumana provenance was also used in the seed source study (Conrad et al. 1995) and in the study discussed here. In the seed source study, Kaumana koa growth was 21 cm/yr with minimal site preparation and only two applications of NPK slow-release fertilizer (Conrad et al. 1995).

The Maui elevation transect

Three of the objectives of the Maui study were to (1) determine the influence of climate and soil on establishment and growth of the test species or varieties, (2) determine effects of site variability on tree performance, and (3) correlate site variability and understory herbaceous competition with tree performance. We chose to base the research on an elevation transect on Haleakala's north slope, where rainfall would remain roughly the same with increasing elevation but temperature would decline as a function of increasing elevation. Study units were established at three locations on an elevation transect (Table 1).

A low-elevation unit was located off West Kuiaha road about 2 km (1.25 mi) south of Kuiaha village. The middle elevation unit was about 3 km (2 mi) south of Makawao town at the University of Hawai'i's Haleakala

Table 1. Environmental features of the Maui study units.

Study unit	Elevation meters (feet)	Temperature °C (°F)	Rainfall mm (in)	Soil order
Kuiaha	305 (1000)	22 (71)	2184 (86)	Ultisol
Makawao	640 (2100)	20 (67.5)	2159 (85)	Ultisol
Olinda	1067 (3500)	16 (61)	1549 (61)	Andisol

Table 2. Environmental features of the koa provenances.

Provenance	Elevation meters (feet)	Temperature °C (°F)	Rainfall mm (in)	Soil order
Kaumana	670 (2200)	19 (66)	3556 (140)	Andisol
Kukaiau	1158 (3800)	16 (61)	3048 (120)	Andisol

Research Station on Pi'iholo road. A high-elevation unit was at the Olinda bird-rearing facility, 7.4 km (4.6 mi) south of Makawao on Olinda road. For many years, the Kuiaha location was used for pasture and the Makawao and Olinda locations were used for agricultural crop research.

Seedlings from Kaumana and Kukaiau koa provenances (Table 2) were planted in each study unit in March and April 1986. The Kaumana provenance was near Hilo, Hawai'i, and the Kukaiau provenance was on Kukaiau Ranch on Mauna Kea. The study also included Caribbean pine (*P. caribaea*) seedlings plus seedlings and tissue culture clones from two families of loblolly pine (*Pinus taeda*) provided by Weyerhaeuser Co. research from stock at an Arkansas facility. At each study unit, the seven test varieties were planted in 36-tree plots in a randomized block design with six replications. Planting was in a staggered-row pattern with trees in adjacent rows offset by one-half the distance between row trees. The minimum distance between trees was 1.8 m (6 ft) in the rows and the maximum was 2 m (6.6 ft) on the diagonal between rows.

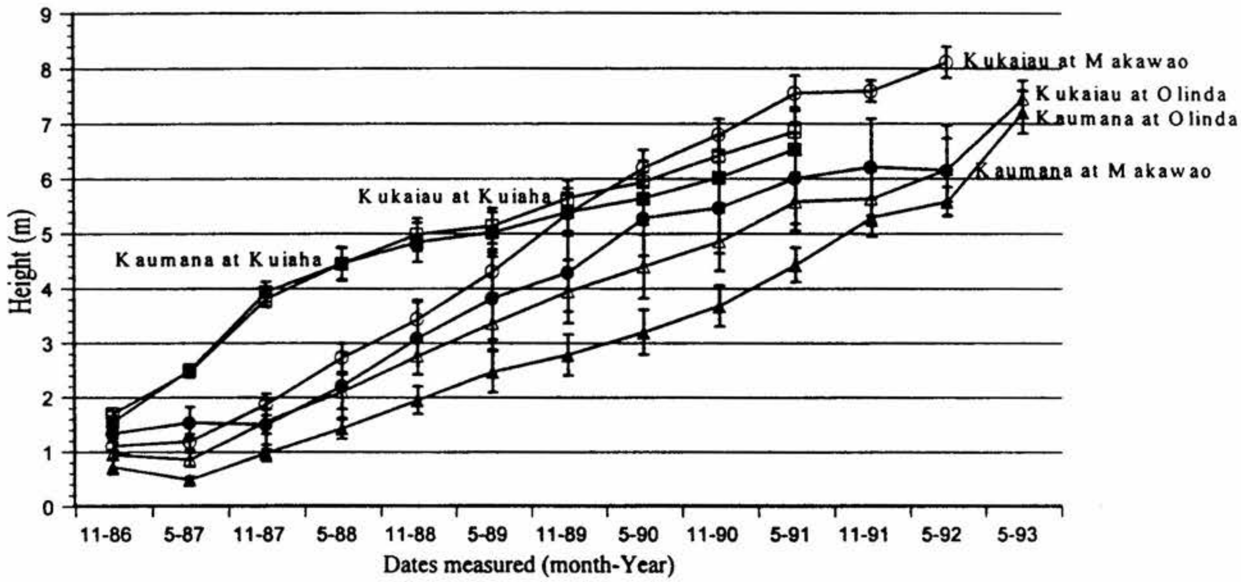
The seedlings were sown on greenhouse flats in a potting soil mixture. They were transplanted into 15 cm (6 in) dibble tubes after the cotyledons were fully developed. Planting in the field plots was done in March and April 1986 when the seedlings were at least 40 cm (15.5 in) tall. Before planting, each site was disk plowed several times to control immediate, severe herbaceous weed competition. After planting, an 0.8 m^2 (0.9 yd^2) area around each tree was hand-weeded once or twice a month for about 18 months or until the tree was above the competition for light. At planting time, each tree was given about 57 g (2 oz) of slow-release fertilizer (14-14-14 N-P-K) in dibble holes next to the seedlings. Nine to ten months after planting, another application at the same rate as at planting was broadcast and stirred into the soil in a 30-cm radius around the trees.

Temperature at Makawao was close to the temperature at Kaumana. Olinda and Kukaiau temperatures were also similar. Kuiaha was 3.0–6.0°C (5–10°F) warmer than the provenances (Tables 1 and 2). Rainfall at the three Maui sites was less than at either of the two provenances on Hawaii island. The extreme difference was 2007 mm (79 in) between Kaumana and Olinda and the least difference was 864 mm (34 in) between Kuiaha and Kukaiau. Even though rainfall and temperature varied considerably between the provenances and the study units, both temperature and moisture were within requirements of koa.

Field visits were done every two to four weeks during the first seven months after planting to monitor survival, control herbaceous weed competition, and to replant seedlings as needed. When replanting was required, we tried to use seedling stock grown from the same provenance. Unfortunately, we were not able to grow sufficient Kaumana seedlings to maintain full replacement at either Makawao or Olinda. Replanting seed-source treatment trees to use for analysis was stopped after May 1987. Replanting non-treatment trees was continued for about six months to maintain competition in plots.

We began regular tree measurements in November 1986 and continued every six months until sample trees were harvested. Harvesting began at Kuiaha in 1991 and followed in 1992 at Makawao and in 1993 at Olinda. Routine biannual measurements were done on the

Figure 1. Koa height over time. Solid symbols are Kaumana seedlings; open symbols are Kukaiau seedlings. Squares, circles, and diamonds indicate Kuiaha, Makawao, and Olinda study units. Error bar lengths are one standard error above and below the mean.



middle 16 trees of the 36-tree plots. Observations included measuring the height and stem diameter of each tree. Breast-height diameter (DBH) was measured when the seedlings exceeded 1.4 meters (4.5 ft). Before seedlings were tall enough to measure DBH, stem diameter was measured 2.5 cm (1.0 in) above the soil at the base of the seedling. At each measurement, we also observed and recorded several characteristics about each tree. These included seedling condition, leaf color, form, and growing tip quality. Tree form was classified for straightness and major branching below the crown.

Height growth

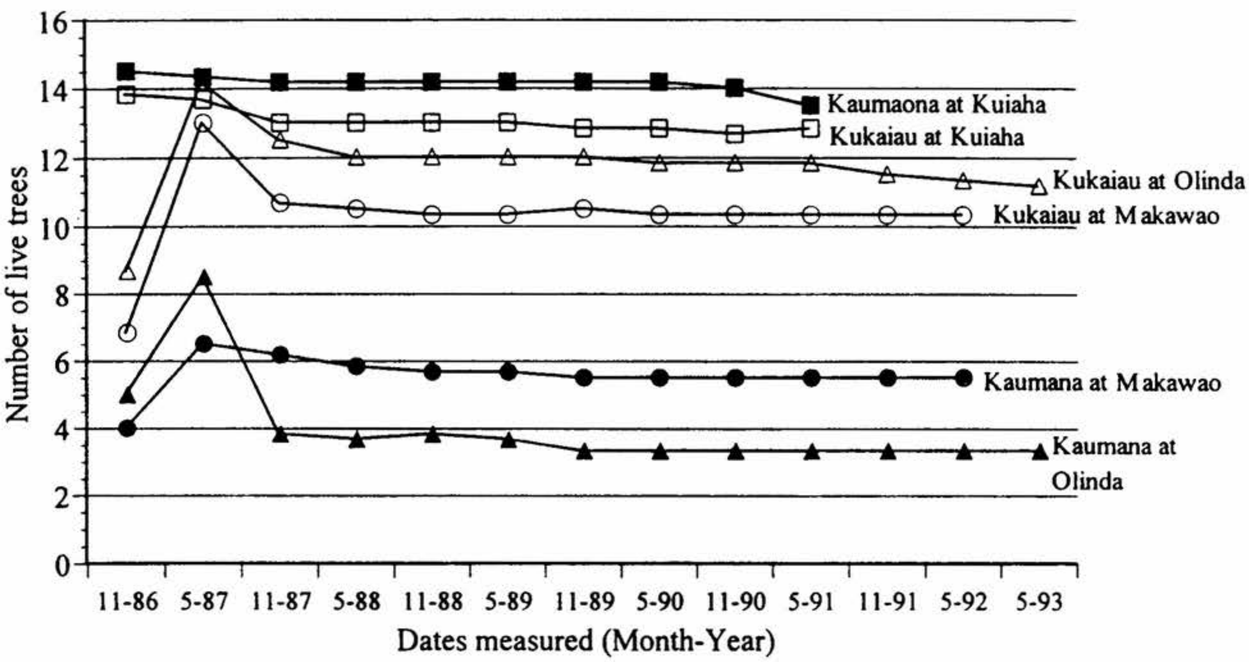
Tree height is presented here as an indicator of growth (Figure 1). Kaumana and Kukaiau koa growth was nearly identical at Kuiaha. At Makawao the data show 1.3 m/yr (4.26 ft/yr) average Kukaiau growth and 1.0 m/yr (3.28 ft/yr) Kaumana growth. By the end of the experiment, the difference was almost 2 m (6.4 ft). At Olinda, some significant differences in heights occured, but by the end of the experiment these differences were gone. Figure 1 also shows rapid growth at Kuiaha between November 1986 and November 1987, but then growth slows to less than at the other sites.

Live trees

Figure 2 shows the number of live treatment trees per 16 measure trees. At the end of the experiment, live trees numbered from an average of less than four Kaumana koa trees at Olinda to almost 14 at Kuiaha. Kaumana survival was greater than Kukaiau only at Kuiaha. Replanting between November 1986 and May 1987 was done at Makawao and Olinda because poor survival threatened to end the experiment. Replanting Kukaiau at Makawao and Olinda resulted in rebound from the initial 1986 survival. Kaumana replanting did little to improve the number of measurable Kaumana at Makawao and was of no benefit at Olinda. Non-treatment seedlings were planted as replacements when replanted Kaumana koa failed to survive. These trees were measured but not counted in the analysis.

Clearly, survival was best at Kuiaha. Poor survival at Makawao and Olinda was due partly to our inability to control competition. Herbaceous weeds and vines

Figure 2. Number of live treatment koa trees per 16 measure trees.



were the most serious competitors at both Makawao and Olinda. Grass competition at Kuiaha was not a threat to the seedlings.

Tree health

After the initial crash in survival, the tree health data did not indicate significant differences between the seed sources but did show differences between elevation transect units. The curves in Figure 3 were determined by dividing the number of healthy trees from both provenances by the number of all live measure trees. For this exercise, health was based on condition codes only. Trees in poor health sometimes continued to survive and remain in poor health. Rarely, seedlings that appeared dead recovered by resprouting from the base or lower stem. The ratio shows that health declined to about 90 percent at Kuiaha and was mostly near 98 percent at Makawao and Olinda.

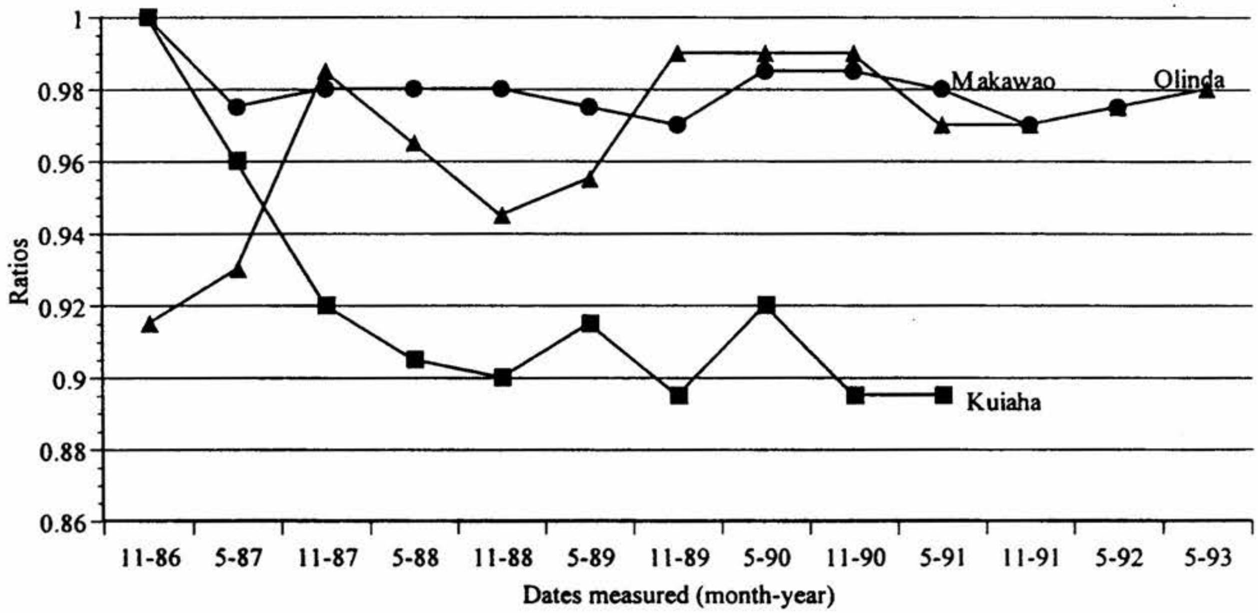
One major insect attack occurred at Kuiaha due to an outbreak of black twig borer in 1987 and 1990. The attack is reflected in the reduced health ratio shown in Figure 3. Various chewing insects attacked the trees at all three units but did not effect health enough to warrant assigning poor health codes.

Conclusions

Some of the reduced growth rate at Kuiaha might be due to the insect attack that occurred during the period of slow growth. The major difference among the study units was in the number of viable measure tree numbers. Clearly Kaumana koa survival was poorer at both Makawao and Olinda. The error bars for tree height were longer as a result. Kaumana koa heights did not reflect growth advantage from reduced within plot competition because we planted non-treatment koa into some of the gaps to maintain competition.

The data strongly suggest that new koa seedlings are most vulnerable to competition. In the first 19 months following planting, koa at Kuiaha grew at a rate of 2.27 m/yr. During the same period, average growth of both seed sources at Makawao and Olinda was only 0.69 m/yr. These estimates are based on healthy trees only and assume an average of 40 cm per seedling at planting time. A difference in the subsequent response was that the Kukaiau seed source recovered from the lack of early growth rate but Kaumana was less successful. Even though both seed sources showed good health after they became established, the Kaumana koa did not grow as rapidly as the Kukaiau. Further analysis is needed to

Figure 3. Ratios of healthy to live koa measure trees. Data are combined for both Kaumana and Kukaiau koa.



determine if these differences are likely to be real.

The number of live koa trees (Figure 2) continued to show some decline after the initial poor survival. This decline may not be significant, pending further analysis, but there is suggestion that the number of Kaumana koa at Kuiaha was declining because of latent effects of the twig borer attack. Several seedlings that were below the crowns of surrounding trees died during this period of decline. Kukaiau koa at Kuiaha did not appear to decline like Kaumana, but this may be artificial. Several trees in each plot from both provenances were not in the dominant layer of trees and probably would eventually have been lost. We did not observe any tree that was able to recover dominance after it was lost from any cause.

Acknowledgments

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References

Cole, Thomas G., Russell S. Yost, Richard Kablan, and Thomas Olsen. 1996. Growth potential of twelve *Acacia* species on acid soils in Hawai'i. Forest Ecology and Management 80:175–86.

Conrad, C.E., David M. Fujii, and H. Ikawa. 1995. Seed source and performance on koa tree establishment. In: Hawai'i agriculture: Positioning for growth. College of Tropical Agriculture and Human Resources, University of Hawai'i at Manoa. p. 88–89.

Conrad, C.E., and H. Ikawa. 1995. Mineral nutrient concentration in pine and Hawaiian koa tissue. In: Hawaii agriculture: Positioning for growth. College of Tropical Agriculture and Human Resources, University of Hawai'i at Manoa. p. 86-87.

Questions

Conrad: All of these sites are on Maui, on the north slope of Haleakala. If you remember the maps shown earlier today [Potter], we were just outside of that koa growing area at Kuiaha.

Q: Gene, can you say something about the need for weed control on your plots versus the plots that Tom and Russel Yost were fertilizing more heavily.
Conrad: They did a good job of weed control. I believe they used Roundup; is that right Tom? [Tom: A sickle, too.] We used a sickle also, but that wasn't adequate. We had a safety problem with sickles. Once we got into it I really didn't want to do a major job with weed control because that was not fair because we could only do it on a few plots, so we left them uniform, grass and vines. Kuiaha was almost entirely grass. We had a lot of leguminous vines at Makawao and vetch up at Olinda, which I was familiar with as a kid in Oregon.