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DISTURBANCE DURING LOGGING STIMULATES REGENERATION OF KOA

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The abundance and distribution of *Acacia koa* regeneration after logging were studied on a 500-acre (202-ha) tract of koa forest heavily infested with *Passiflora mollissima* vines on the island of Hawaii. Koa seedling density was about three times greater in disturbed areas than in undisturbed ones. Most of the koa seedlings in the sample that grew in response to ground disturbance during logging were established. None of those found in undisturbed areas were established. Seedlings in disturbed areas tended to be clustered near koa seed trees, with twice as many growing within 50 feet (15.2 m) of seed tree stems as beyond. Vines had just begun to climb into the crowns of oldest regeneration. They pose an imminent threat to normal growth and survival of infested trees.

Oxford: 176.1 *Acacia koa* (969):231.32
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In practically all cases where koa (*Acacia koa* Gray) forests have been logged in Hawaii, the land has been converted to grazing or other nonforest use. Little information, therefore, is available about survival and growth of koa regeneration. The few studies to date suggest that disturbance of soil around mature koa is followed by the emergence of abundant koa seedlings from seed stored in the soil.[1]

We were able to study the effects of logging on koa regeneration when, in 1970, the Hawaii Division of Forestry made the first large contract sale of koa timber from State-owned lands in Hawaii. Terms of the sale required the Division to "monitor the effects of harvesting on forest regeneration and noxious plant infestations."[2] The study was designed to determine the success or failure of logging disturbance to stimulate regeneration and establishment of koa in logged portions of the Laupahoehoe section, Hilo Forest Reserve, island of Hawaii.

We found that koa seedling density in the areas disturbed by logging was about three times greater than in comparable undisturbed areas. Most seedlings we tallied in the disturbed areas were established; none of those in undisturbed areas were established. Frequency and seedling density were not affected by overtopping vegetation.

Seedling distribution was not uniform in disturbed areas, but seedlings tended to be clustered in the vicinity of seed trees. Of the several variables measured, only distance between quadrats and the nearest seed tree and type of seedbed significantly affected seedling distribution.

Poka vines were just beginning to climb into the crowns of 2-year-old seedlings and had not yet begun to adversely affect growth or survival. Four-year-old koa seedlings in another portion of the forest were heavily infested with poka.

STUDY AREA

The 500-acre (202-ha) study area lies on the northeast flank of Mauna Kea between 4700- and 5300-feet (1433- and 1615-m) elevation. Annual rainfall averages 125 inches (3175 mm). Fog is common during afternoons. Daily temperature averages about 65° F (18° C). Topography is predominantly strongly sloping, with gradients generally between 10 and 30 percent.

Soils in the harvest area have been mapped as Maile, Puu Oo, and Piihonua series.[3] Formed in volcanic ash, these soils are well drained. The Maile and Puu Oo series are silt loams with subsoils that dehydrate irreversibly. The Piihonua series consists of silty clay loams that dehydrate irreversibly into fine gravel-sized aggregates. The Piihonua soils are more stony than the Maile or Puu Oo soils and in the study area are characterized by steeper slopes. Under the new Soil Taxonomy, the Maile and Puu Oo are classified as thixotropic, isomesic, Hydric dystrandepts. The Piihonua series is a thixotropic, isomesic, Typic hydrandept.

The forest on the study area is a mixed forest of ohia (*Metrosideros collina* [J. R. and G. Forst.] Gray, subsp. polymorpha [Gaud.] *Rock*) and koa. The tree canopy covers 40- to 60-percent of the ground.[4] Principal understory species are pilo (*Coprosma* sp. J. R. and G. Forst.), olapa (*Cheirodendron trigynum* [Gaud.] Heller), ohelo (*Vaccinium calycinum* Sm.), tree fern (*Cibotium chamissoi* Kaulf. and *C. splendens* [Gaud.] Krajina), ama'u (*Sadleria* sp.), and puu-lehua (*Microlaena stipoides* [Labill.] R. Br.). In the undisturbed forest, koa seedlings are scarce, but ohia seedlings are abundant.

Numerous openings up to several acres in size are found throughout the study area. In these openings, ama'u, puu-lehua, and knotweed (*Polygonum glabrum* Willd.) are the most abundant species. Blackberry (*Rubus penetrans* Bailey), an undesirable introduced plant, is found in some openings, and is becoming more widely established.

Banana poka (*Passiflora mollissima* [HBK] Bailey), an undesirable, vigorous climbing vine, is abundant. This introduced species produces abundant seed, and has become a serious pest. The vines, which climb to 70 feet (21 m) or more, drape themselves over trees and other plants.

THE HARVEST

The Division of Forestry administered the timber sale. In spring 1971, it flagged the boundaries dividing the study area into 12 equal administrative compartments. Only trees of highest merchantable quality were marked for cutting. The logger harvested one compartment at a time, completing the job in 18 months. He used a TD25 crawler tractor with a 13.5-foot (4-m) wide blade to ground skid logs and construct landings and roads. About 33 percent of the merchantable koa volume and 26 percent of the ohia volume were removed.

Numerous small openings in the forest canopy were created by the removal of marked trees. The ground in these openings was extensively scarified by the bulldozer. Skid trails, which meandered and crisscrossed through the forest, were also sites of extensive ground disturbance. In some places where the bulldozer was just moving to the next felled tree and not pulling logs, few traces of its passage were evident. Naturally occurring openings were not disturbed by logging. Slash piles were numerous. In many cases, unused portions of felled trees were left as they had fallen.

METHODS

To assess the effects of the disturbance, we set up line transects 6 months after logging was completed. A straight fenceline running the length of the northwest side of the sale area—a distance of 6000 feet (1829 m)—was selected as the base line. Seven straight-line transects were established per 1000 feet (305 m) of base line. Starting points were chosen randomly. About 29 miles (47 km) of transects were set perpendicular to the base line to intercept the greatest number of different site conditions.

Along each transect the lengths of intercepted disturbed and undisturbed segments were measured and recorded. A disturbed segment was one along which the litter and humus or underlying mineral soil or both had been mechanically rearranged by the movement of machinery or logs. Undisturbed segments were those showing no evidence of logging activity. Transect segments having slash concentrations were classed as undisturbed if the forest floor beneath had remained essentially undisturbed. This classification was used because experience has shown that ground disturbance is a prerequisite for germination of koa seed stored in the soil. All transects were used to determine the proportion of ground in the sale area actually disturbed by logging.

Two of the seven transects in each compartment were selected at random and sampled to gather detailed information about koa reproduction. Along these transects, 4-foot (1.22-m) square quadrats were randomly established within disturbed segments only. A total of 369 quadrats were examined. We recorded

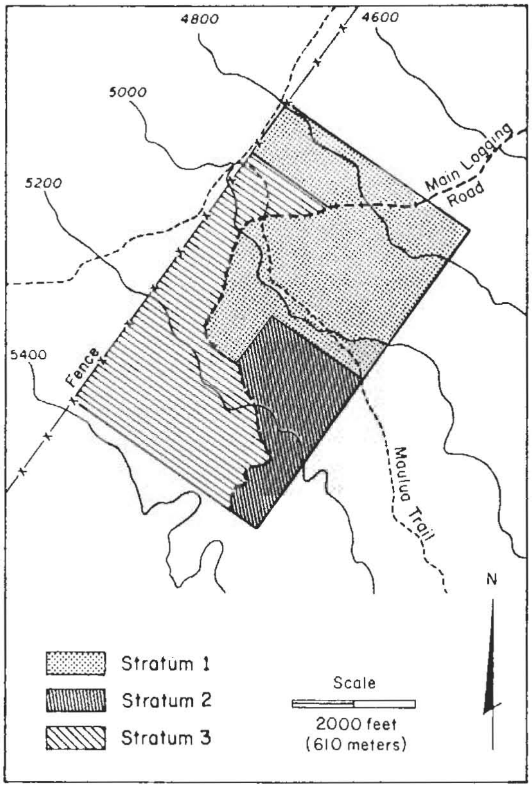

Fig. 1—Sampling strata in the 500-acre (202-ha) study area of the Laupahoehoe section, Hilo Forest Reserve, island of Hawaii.

data on (a) koa seedling counts, (b) predominant seedbed class, (c) position of the nearest koa tree capable of bearing seed relative to the quadrat, (d) quadrat position relative to the topography, (e) maximum and minimum koa seedling heights, and (f) type and degree of banana poka infestation of koa seedlings for each quadrat. When a quadrat was shaded by a tree crown directly overhead, the tree species was recorded.

For data analyses, we divided the sale area into three strata on the basis of time between the end of the logging and the establishment of the sample quadrats (*fig. 1*):

Stratum 1	7-12 months	212 acres (86 ha)
Stratum 2	13-18 months	82 acres (33 ha)
Stratum 3	19-24 months	206 acres (83 ha)

RESULTS

Area Disturbed

Logging activities disturbed the ground surface in 41 percent of the area. Nearly one-third of strata 1 and 2 had been disturbed, while slightly over one-half of stratum 3 had been disturbed. The pattern of disturbance (road, skid trail, and landing locations) was irregular, depending on topography, tree locations, and discretion of the operator.

Seedbed Classes

Five seedbed classes were recognized in disturbed areas: litter/humus, bare soil, slash (from logging), rock, and vegetated (*table 1*). About 36 percent of the 369 quadrats examined were classed as bare soil, 31 percent as litter/humus, and 24 percent as vegetated.

Table 1—*Percent of seedbed classes in each stratum*

Stratum	Seedbed classes				
	Litter/ humus	Bare soil	Slash	Rock	Vegetated
1	32	32	12	7	17
2	50	2	0	6	42
3	26	47	1	4	22
All	31	36	4	5	24

Koa Seedling Abundance

Estimates of koa seedling densities in undisturbed portions of the study area were developed in a separate study,[4] conducted in 1971 and 1973. Estimates were based on permanent 2-foot (0.6-m) square quadrats randomly located in the study area. In that earlier study, 1862 undisturbed quadrats contained 44 koa seedlings or an average of 257 per acre (635 per ha).[4] After logging, only 1037 quadrats remained undisturbed, and these contained 34 seedlings or 361 per acre (892 per ha).

None of the seedlings that had been tallied as alive in 1971 were alive in 1973. All of the seedlings recorded in both years were probably no more than 2 months old because the cotyledons were still attached to some and all were less than 3 inches tall (*fig. 2*). Rooting by feral pig and intolerance of shade by koa are probably the two agents most responsible for high mortality in natural koa regeneration.

An estimated 841 koa seedlings per acre (2078 per ha) occurred in disturbed portions of the study area (*table 2*). Although a high mortality rate is associated with koa regeneration, other studies have found tens of thousands of seedlings per acre shortly after ground disturbance.[1] Therefore, the threefold increase over densities in the undisturbed forest was much less than expected. The unexpected small increase in density was more than compensated for by

Fig. 2—Typical of koa regeneration in the undisturbed forest, this 2-inch seedling will likely succumb to rooting by feral pigs or to other adverse influences.

Table 2—*Occurrence of koa seedlings in Laupahoehoe logging area, Hilo Forest Reserve, by disturbance class and by stratum*

Disturbance class and stratum	Quadrats	Quadrats stocked	Seedlings	
			Tallied	Per acre
Undisturbed:[2]		*percent*		
1	522	1	5	104 (257)[1]
2	310	3	10	351 (867)
3	618	3	24	423(1045)
All	1450	2	39	293 (724)
After logging—disturbed:				
1	118	17	28	646(1596)
2	54	13	9	454(1122)
3	197	18	77	1064(2629)
All	369	17	114	841(2078)

[1] Units in parentheses are hectares.

[2] Scowcroft, Paul. 1971. Study plan to determine the effect of logging on the vegetation of the ohia-koa forest. 23 p. Unpublished report on file, Pacific Southwest Forest and Range Experiment Station, Honolulu, Hawaii.

the finding that almost all seedlings tallied were well established (*fig. 3*). By "established" we mean seedlings that were taller than the surrounding herbaceous vegetation, vigorous, and in little danger of being eaten or uprooted by pigs.

Fig. 3—Most koa reproduction in disturbed logging areas was established as shown by these 1.5-year-old seedlings.

Distribution of Koa Seedlings

The percent of quadrats in which koa seedlings occurred—hereafter referred to as "frequency"—was a gross measure of distribution. Within disturbed portions of the study area, frequency averaged 17 percent as compared to 2 percent for undisturbed areas (*table 2*).

Seedlings in both disturbed and undisturbed areas were contagiously distributed. They tended to cluster in the vicinity of koa seed trees. The distribution of quadrats by seedling density followed a Poisson curve—more than 80 percent of the sample quadrats in disturbed and undisturbed areas were unstocked.

Distribution of seedlings in disturbed areas was slightly affected by seedbed condition (*table 3*). Frequency for three of the seedbed classes was similar: i.e., litter/humus, 17 percent; bare soil, 24 percent; slash, 20 percent. Frequency was lower for seedbeds classed as either rock or vegetated.

Because the distributions of quadrats by seedling density for the five seedbed classes (*table 3*) were not "normal," we compared them by nonparametric techniques. The Kruskal-Wallis test when applied only to stocked quadrat data did not show statistically significant differences in seedling density attributable to the type of seedbed. However, when data for unstocked and stocked quadrats were combined, the results showed that type of seedbed did affect seedling density (at the 5 percent level of significance). Additional analysis showed that this significance was due to differences between litter/humus and vegetated quadrats (5 percent level), bare soil and vegetated quadrats (1 percent level), and slash and rock quadrats (1 percent level).

These analyses were based on seedling density data, but those data were segregated by presence or absence of koa seedlings on individual quadrats. By including unstocked quadrat data in the analysis, significant differences were apparent where none previously existed. The implication is strong that frequency is significantly lower for quadrats with vegetated seedbeds than for those with bare soil or litter/humus seedbeds. Similarly, quadrats with rock seedbeds are less likely to be stocked than those with slash seedbeds.

Within the limitations of the data, seedbed condition did not influence clustering of the seedlings.

Frequency was affected by location of seed trees relative to the quadrats. About 23 percent of the quadrats located within 50 feet (15.2 m) of the stem of a koa seed tree were stocked with koa seedlings, while only 9 percent of the quadrats lying more than 50 feet from a seed tree were stocked (*table 4*).

Seedling density was more than twice as great for quadrats within 50 feet of a seed tree as for quadrats which lay at greater distances. This difference, which was computed by using stocked and unstocked quadrat data, was statistically significant, at the 5 percent level. Seedling density for the two categories was not significantly different when only stocked quadrat data were used.

Slope position of the nearest koa tree capable of bearing seed relative to the sample quadrat did not affect frequency or seedling density (*table 4*).

The topographical position of quadrats—on a ridge, side slope, or in a drainage bottom—as it affects frequency and seedling density was also examined (*table 5*). Frequency was 18 percent for quadrats located on a ridge, 20 percent for those on a side slope,

Table 3—*Distribution of quadrats within each seedbed class, by number of koa seedlings per quadrat*

Seedlings per quadrat	Quadrats					
	Litter/ humus	Bare soil	Slash	Rock	Vegetated	All classes
0	96	100	12	17	82	307
1	13	16	1	2	4	36
2	4	5	2	0	2	13
3	2	5	0	0	0	7
4	0	2	0	0	0	2
5	1	1	0	0	0	2
6	0	1	0	0	0	1
7	0	1	0	0	0	1
Total quadrats	116	131	15	19	88	369
Frequency	17	24	20	10	7	17
Mean density (stocked quadrats)	1.6	2.2	1.7	1.0	1.3	1.8
Mean density (all quadrats)	0.3	0.5	0.3	0.1	0.1	0.3

Table 4–*Distribution of quadrats within seed tree distance classes and topographical position categories, by number of seedlings per quadrat*

Seedlings per quadrat	Quadrats: Distance of nearest seed tree from quadrat			Slope position of nearest seed tree from quadrat[1]		
	0-25 ft. (0-7.6 m)	26-50 ft (7.7-15.2 m)	51+ ft (15.3+ m)	Uphill	Level	Down-hill
0	74	86	147	52	81	27
1	13	16	7	11	14	4
2	3	6	4	4	4	1
3	3	3	1	2	4	0
4	1	1	0	1	1	0
5	0	0	2	0	0	0
6	0	1	0	1	0	0
7	1	0	0	0	1	0
Total quadrats	95	113	161	71	105	32
Frequency	22	24	9	27	23	16
Mean density (stocked quadrats)	1.9	1.7	2.0	1.8	1.9	1.2
Mean density (all quadrats)	0.4	0.4	0.2	0.5	0.4	0.2

[1]Positions of seed trees lying more than 50 feet (15.2 m) from a quadrat not determined.

and 13 percent for those in a drainage bottom. Topographical position did not affect seedling densities.

Seedling Heights

The average height of the tallest koa seedlings on each quadrat was 7 inches (18 cm) for stratum 1, 7 to 12 months after logging; 42 inches (107 cm) for stratum 2, 13 to 18 months after logging; and 41 inches (104 cm) for stratum 3, 19 to 24 months after logging. The mean minimum heights were 5 inches (13 cm) for stratum 1; 37 inches (94 cm) for stratum 2; and 27 inches (69 cm) for stratum 3. All seedlings tallied were taller than adjacent competing understory vegetation—even those only a few inches tall.

Table 5–*Quadrat stocking with koa seedlings, by topographic position of the quadrat*

Seedlings per quadrat	Quadrats: Ridge	Side slope	Bottom
0	44	114	149
1	8	15	13
2	2	8	3
3	0	4	3
4	0	0	2
5	0	2	0
6	0	0	1
7	0	0	1
Total quadrats	54	143	172
Frequency	18	20	13
Mean density (stocked quadrats)	1.2	1.8	2.1
Mean density (all quadrats)	0.2	0.4	0.3

Poka Occurrence

Banana poka seedlings and vines occurred on about 80 percent of the sample quadrats. However, poka vines were found on koa regeneration only in stratum 3, where logging had ended 19 to 24 months earlier. In stratum 3, 23 percent of the stocked quadrats had poka vines clinging to the stems of koa regeneration. The vines had grown into the crown of only one koa, an exceptionally tall 15-foot (4.6-m) sapling about 40 percent covered by poka vines. We saw poka in the crowns of other koa regeneration outside our quadrats.

Overtopping Vegetation

We examined the influence of overtopping vegetation on occurrence of koa regeneration in the quadrats. Only 37 percent (136) of the 369 quadrats had forest canopy directly overhead. Frequency for overtopped and nonovertopped quadrats was almost identical: 16.2 and 17.2 percent, respectively. Of the 62 stocked quadrats, 22 were overtopped by the forest canopy.

Of the 136 overtopped quadrats, 25 percent were overtopped by koa, but only 29 percent of these were stocked with koa seedlings. The average seedling density per quadrat varied little between overtopped (1.7) and nonovertopped (1.9) conditions.

DISCUSSION

Koa was probably a self-sustaining component of Hawaii's forests from the earliest times. When koa trees fell over they were replaced by either seedlings or root sprouts growing from the dislodged mass of soil and roots or from adjacent areas opened to sunlight. However, elements have been introduced into the environment which severely restrict the natural long-term one-to-one replacement.

On the island of Hawaii, interference is particularly great from feral pigs and in some areas from banana poka. Most koa seedlings will be eaten or uprooted by foraging pigs. Only those inaccessible to these animals are likely to survive the seedling stage. Those that do survive may have to compete with banana poka, which flourishes in full sunlight. Our observations show that koa, despite its rapid growth when young, cannot outgrow poka vines. Consequently, one-to-one replacement is not likely under the not-so-pristine forest conditions now prevalent.

This study has shown that the disturbance accompanying logging will stimulate regeneration of koa in quantities large enough to preclude total destruction by pigs. Seedling densities 1-1/2 to 2 years after disturbance were averaging nearly 1100 stems per acre in disturbed areas as compared to about 400 per acre in undisturbed areas. When coupled with the fact that most of the seedlings were established in disturbed areas but none in undisturbed areas, the significance of man-caused ground disturbance for regenerating koa is evident.

The problem of poka competition still persists, however. But poka is more subject to control in the case of planned disturbance than in the case of isolated, widely scattered natural disturbance, i.e. windthrow of single trees. Obviously it is not feasible to send crews through the forest looking for random windthrown trees just to remove poka from koa regeneration that may be growing in the openings. But poka control in a discrete area with a high concentration of koa regeneration is both feasible and reasonable.

NOTES

[1] Judd, C. S. 1920. *The koa tree.* The Hawaiian Forester and Agriculturist. 17(2):30-35.

Lamoureux, Charles H. 1971. *Some botanical observations on koa.* Hawaiian Botan. Soc. Newsletter 10(1):1-7.

Vogl, R. J. 1969. *The role of fire in the evolution of the Hawaiian flora and vegetation.* Proc. Annu. Tall Timbers Fire Ecol. Conf., Tallahassee, Fla., No. 9, p. 5-60.

Whitesell, Craig D. 1964. *Silvical characteristics of koa (Acacia koa Gray).* USDA Forest Serv. Res. Paper PSW-16, 12 p. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

[2] State of Hawaii. 1971. *Conservation district use application HA-71/1/28-175, for timber harvesting at Laupahoehoe, Hawaii.* TMK: 3-7-01:02, by the Div. For., Dep. Land and Nat. Resour., March 12, 1971. Approved by Board of Land and Nat. Resour., Honolulu, Hawaii, March 12, 1971.

[3] U.S. Department of Agriculture. 1973. *Soil survey of the island of Hawaii, State of Hawaii.* 115 p.

[4] Scowcroft, Paul. 1971. *Study plan to determine the effect of logging on the vegetation of the ohia-koa forest.* 23 p. Unpublished report on file, Pacific Southwest Forest and Range Exp. Stn., Honolulu, Hawaii.

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