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AUSTRALIAN TOON PLANTED IN HAWAII : tree quality, growth, and stocking

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CONTENTS

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Figure 1–*Areas of pahoehoe were often grass-covered. Here (foreground) seedling planted to Australian toon survival was poor and growth slow in contrast to higher survival and rapid growth on as sites (background).*

Figure 2–*Multiple branching at a node, is a common characteristic of Australian toon, limits log length. If it occurred below 12 feet the tree was classed as a cull.*

Australian toon *(Toona australis)* is used extensively for reforestation in Hawaii. Since 1959, some 5,000 acres of ohia rain forest in the Waiakea and Olaa Forest Reserves, island of Hawaii, have been converted to Australian toon plantations through land clearing and hand planting. About 250,000 Australian toon seedlings are planted annually. They are generally planted on a 10- by 10-foot spacing at the rate of 436 per acre in pure stands, but occasionally in mixture with tropical ash *(Fraxinus uhdei),* Queensland-maple *(Flindersia brayleyana),* saligna eucalyptus *(Eucalyptus saligna)* or other species. On a few sites, natural reproduction of koa *(Acacia koa)* has become an important stand component.

Australian toon seedlings can vary considerably in growth form and in growth rate–even within short distances. Natural differences in site conditions and the growth characteristics of the species probably combine to produce patchy stands with many stems of less than acceptable growth rate and quality. On some sites, they may grow well for a year or two after planting, then decline in growth rate and begin to deteriorate. The branching habit of some trees may be a significant factor limiting future stem quality.

If we can identify early in the stand's life those trees which will likely be of low quality in the mature stands, we can develop criteria for stand improvement. We need to know the number of seedlings to plant to obtain desired stocking. And if we can relate survival and growth to site factors, we would be able to develop more precise guidelines for selecting areas for land clearing and reforestation.

The paper reports a study of the condition of the young (5- to 8-year-old) plantations of Australian toon, Australian toon-tropical ash, and Australian toon-koa to determine levels of stocking and tree growth and quality, and how these levels are related to site factors. The site factors studied were soil depth, microtopography class, soil drainage class, and kind of parent rock. The seedlings were planted from 1961 to 1965.

STUDY SITES

The plantations lie on the lower east slope of Mauna Loa on the island of Hawaii, between 800 and 3,100 feet elevation. Lava flows of different kinds and ages account for topographic differences. Microrelief is rough. The soils are acid and mostly extremely stony silt loam, such as Koloa extremely stony muck. Soils within short distances differ widely, especially in soil depth. Annual rainfall ranges from 170 inches at the lower elevation to 200 inches at the upper elevations.

Before clearing, ohia *(Metrosideros collina),* treefern *(Cibotium* spp.*),* and false staghorn fern *(Dicranopteris* spp.*)* were the dominant vegetative cover, but many other species were present, including such undesirable introduced species as Malabar melastome *(Melastoma malabathricum),* guava *(Psidium* spp.*),* lemi-wai *(Passiflora ligularis),* and melochia *(Melochia indica).*

Plantings have generally been made in 40-acre blocks, identifiable by surrounding access roads. Reforestation records enabled us to determine the dates of planting.

METHODS

Sample plots were randomly set up in seedlings planted each year from 1961 to 1965. All plots included Australian toon; a few plots also included koa or ash:

Date planted	*Plot No.*	*Elevation (feet)*	*Annual precipitation (inches)*
1961:			
April	1	1,100	175
May	3	1,800	190
June	2	1,000	170
June	4	1,200	175
1962:			
July	7	1,700	190
July	[1]8	1,800	195
August	5	3,000	180
August	[2]6	3,000	180
1963:			
January	[1]10	1,800	190
July	[2]9	2,800	190
October	11	1,100	175
December	12	1,200	180
1964:			
January	15	1,700	190
February	[2]13	3,100	180
March	[2]16	2,500	195
August	14	2,700	190
1965:			
March	17	1,200	175
March	18	1,600	190

Each sample plot was a 1/2-acre strip (33 ft. by 660 ft.) oriented perpendicular to the general lava flow pattern, in order to intercept a variety of site conditions. In November 1968, each surviving planted tree and koa tree on a plot was located, measured, and evaluated for quality. Four site factors in the immediate vicinity of each tree were recorded:

- *Soil depth:* determined by probing with a steel rod, and recorded as maximum depth of several probings around the tree. Because of extreme rockiness, the measure is an approximation. Exploratory digging showed that soil depth or volume of soil material may be extremely variable within short distances.
- *Parent rock:* most of the area sampled was aa lava. Some was obviously pahoehoe. In places, shallow soil on compacted aa may have been recorded as pahoehoe.
- *Drainage:* classed as adequate or as poorly drained (wet, boggy).
- *Topography:* Microrelief was classed as swale, side slope, ridge, or level. The study site had no major ridges or canyons.

The sample data collected were first analyzed to determine levels of stocking (survival of planted trees) and its quality. Stocking estimates were based on the trees tallied on the plots. Stocking is the residual from an assumed [3] initial planting of 436 trees per acre plus any koa reproduction. Each tree was graded and placed in one of three tree quality classes:

- *Desirable:* a growing stock tree of commercial species having no serious defects, of good vigor and having no serious pathogens; the type of tree forest managers try to grow. Specifically, the tree must have now or potentially a sawlog length of more than 32 feet; less than 4 inches sweep or crook in the butt 16 feet; no scale reducing seams, rot, splits, or cracks; and a clear panel at least 8 feet long in the poorest of the best three faces in the butt log.
- *Acceptable:* growing stock trees not meeting the specifications for desirable trees but having, now or potentially, a butt sawlog length of at least 12 feet and not culled due to forking, sweep, crook, or other factor indicated below.
- *Cull:* trees having characteristics which prevent them from being classed as desirable or acceptable. Trees were classed as cull if they had one or more of the following characteristics: (a) Lodged or arched over; (b) stem lean of more than 8 degrees; (c) fork below 12 feet; (d) heavy branching below 12 feet having the effect of forking or excessive taper; and (e) overtopped and of low vigor.

Chi-square techniques were used to test the effect of site factors on stocking and quality. For the test we hypothesized that if site factors did not affect stocking or quality, then the number of trees found on a given kind of site would be proportional to the area occupied by this site. For example, if 10 percent

[1] This plot is a mixture of Australian toon and koa. The koa component is from natural regeneration.

[2] This plot is a mixture of Australian toon and tropical ash.

[3] We assumed that 436 seedlings were planted per acre on the basis of Hawaii Division of Forestry records. No post-planting surveys were made to determine the actual number planted. We cannot infer that 436 trees were planted in each acre on a well controlled 10- by 10-foot spacing.

of the area was pahoehoe, 10 percent of the stocking would be expected to be found here. This expected value would be compared with the actual number of trees found on pahoehoe. Estimates of areas with different site factors were developed from scale maps of the plots.

RESULTS

Stocking

Twelve of the sample plots were in pure toon stands; stocking averaged 236 trees per acre, and ranged from 46 to 376 trees per acre *(table 1).* In the four plots of mixed Australian toon-tropical ash, the Australian toon averaged 127 trees per acre and the tropical ash 200 per acre. In the two plots with mixed Australian toon and koa, the Australian toon averaged 306 per acre and the koa 94 trees per acre. The koa was not, however, located uniformly over the transect, but clustered around parent trees. Over-all, of the original planting of 436 trees per acre, an average of 274 trees have survived.

Soil parent rock, microtopography, soil depth, and soil drainage class all had a highly significant [4] effect on the distribution of stocking.

Parent rock: more seedlings than expected were found on aa and broken pahoehoe and less seedlings were found on pahoehoe than expected *(table 2).*

Soil drainage class: only 4 percent of the sample area was considered poorly drained. There were only about half as many trees on the poorly drained soils as we expected *(table 2).*

Microtopography: more stocking than expected occurred in swales and on ridges and less than expected occurred on the level topography and on side slopes *(table 2).* Swales and ridges make up only 12 percent of the sample area.

Soil depth: if soil depth were a factor in stocking, we would expect greater stocking in deep soils than in shallow soils. But we found no consistent relationship: we counted more seedlings than expected in the shallow (0 to 12 inches) soils, less than expected in the intermediate (12 to 24 inches) soils, and more than expected in the deep (25 inches or more) soils *(table 2).* Soil depth measurements appear to be questionable because of the nature and variability–mainly rockiness–of these plantation soils. Only 2 percent of the area is in the deep soil class.

[4] In this paper "significant" means statistically significant at the 5 percent probability level, and highly significant means statistically significant at the 1 percent level.

Combination of Factors

Besides testing the effect of a single site factor on stocking, we combined factors. We found that these combinations had a highly significant effect: (a) microtopography class combined with soil depth, with drainage class, and with parent rock; (b) soil depth class combined with drainage class, with parent rock, and with drainage class and parent rock; (c) drainage class with parent rock *(tables 3, 4, 5).*

If we assume that a uniform number of seedlings were planted initially on each acre, stocking was higher proportionally than would be expected on these types of soils: (a) shallow soil: swales, level, and ridges; well drained; aa and pahoehoe; (b) medium soils: swales and ridges; (c) deep soil: all microtopography classes; well drained; aa and broken pahoehoe. And stocking was less proportionally than would be expected on these types of soils: (a) shallow soil: side slopes; poorly drained; pahoehoe; (b) medium soil: level, side slopes, and ridges; poorly drained; pahoehoe; (c) deep soils: pahoehoe.

Quality of Stocking

Australian toon trees were generally of better quality than the tropical ash or the koa–31 percent of the Australian toon trees were classified as desirable and 43 percent as acceptable. Only 26 percent of the Australian toon trees were classified as culls, while 64 percent of the tropical ash and 58 percent of the koa were classed as culls. Only about 11 percent of the ash and koa trees were rated desirable.

Species differed widely in cause for culling *(table 6).* Forking below 12 feet was the major cause for culling Australian toon (56 percent of trees culled) and tropical ash (81 percent of trees culled). Excessive lean, the second major culling factor, accounted for 30 percent of the Australian toon cull trees, 13 percent of the tropical ash cull trees, and 36 percent of the koa cull trees. Other causes for culling were lodging, low vigor; and excess branching.

Parent rock, drainage class, and microtopography are the site factors which were significantly related to

tree quality *(tables 7, 8).* Soil depth class, however, did not appear to be significantly related to tree quality class.

Stocking Distribution

Since distribution of stocking is important to the development of forest stands, we measured this by counting stocked quadrats in the measured plots *(table 9).* The data suggest that:

- If 400 well distributed desirable or acceptable trees, or both, per acre is the goal, stocking averaged only 38 percent. This measure of stocking showed a range from 12 percent to 66 percent. Only a small part of the lack of stocking can be attributed to site factors of poor drainage or pahoehoe rock.
- If 100 well distributed desirable or acceptable trees, or both, per acre is the goal, stocking averaged 75 percent. By this measure, one transect plot was fully stocked. If 100 well distributed desirable trees per acre is the goal, stocking averaged only 41 percent, ranging from 10 percent to 87 percent.

Site factors influence stocking distribution, but inconsistencies mask the degree of influence.

Tree Growth

In general, diameter and height growth of the acceptable and desirable trees has been good *(table 10).* In Australian toon stands, the average annual diameter growth was 0.51 inch, with a range between plots of 0.31 to 0.76 inch. Average annual height growth was 3.9 feet, with a range between plots of 2.2 to 6.0 feet. In mixed Australian toon-tropical ash stands, the ash had an annual diameter growth of 0.44 inch and an annual height growth of 4.3 feet. The average rate of growth of acceptable and desirable koa trees exceeded that of Australian toon or tropical ash: diameter growth–0.76 inch; height growth–6.7 feet.

DISCUSSION

One objective of this study was to determine the number of desirable and acceptable trees in the young planted stands. In the pure toon stands sampled, the stocking in desirable trees ranged from 14 to 228, averaging 75 trees per acre *(table 1).* The number of acceptable trees averaged 98 per acre. Thus the present stocking of desirable and acceptable trees (173 per acre) represents only 40 percent of an assumed initial planting of 436 seedlings per acre.

The number of cull trees in the pure Australian toon stands averaged about 63 trees per acre. This, combined with the acceptable and desirable trees, gives on the average 236 trees per acre. This represents only 54 percent of an assumed initial planting of 436 seedlings per acre.

We believe that one objective of reforestation work should be to attain a specified stocking level. Perhaps 400 acceptable and desirable trees per acre, well distributed over the area, would be a desirable stocking level for sapling and pole stands. Results of this study suggest that about 1,000 seedlings should be planted initially per acre to achieve that goal. If adequate survival can be assured, it might be possible to plant as few as 600 seedlings initially per acre to reach that stocking level. Such a possibility is suggested by data from experimental spacing plots on the Waiakea Forest Reserve, island of Hawaii. [5] In these trials, survival of 8-year-old plantations averaged more than 90 percent, although the seedlings were considered inferior at the time of planting. The high survival rate could be attributed to careful planting and to weeding about 9 months after planting. About 80 percent of the trees were rated desirable or acceptable.

Even if the minimum goal is 100 acceptable or desirable trees per acre, well distributed over the area, more seedlings must be planted initially or greater survival obtained. Only 1 of the 12 toon plots had this level of stocking distribution.

The four mixed toon-ash stands sampled averaged 52 desirable and 108 acceptable trees per acre. There were proportionally fewer cull toon trees than ash trees. Sample data were not adequate to estimate survival rates for tropical ash. However, the high proportion of cull ash trees indicate a need to plant more ash seedlings initially to achieve desired stocking.

Two of the toon stands had natural regeneration of koa. In these stands the number of desirable and acceptable toon trees averaged 241 per acre, or 55 percent of the initial planting. There were 64 cull toon trees per acre. Stocking of koa trees averaged 11 desirable, 28 acceptable, and 56 cull trees per acre. However, koa reproduction is patchy and sporadic so there is no inference intended that koa occurs throughout the stands at this level of stocking.

[5] Unpublished data on file at Pacific SW. Forest & Range Exp. Sta., U.S. Forest Service, Honolulu, Hawaii.

A second objective of this study was to relate site factors to stocking and to tree quality. All four site factors measured (microtopography, soil depth, drainage class, and parent rock) significantly affected stocking. All these factors except soil depth were significantly related to tree quality. Parent rock and drainage class seem to be of the most practical importance.

On areas of poor drainage and pahoehoe parent rock there were fewer seedlings than expected, growth was slower, and quality was lower. It should be possible and practical to avoid clearing and planting areas of poor drainage or pahoehoe rock that are large enough to be identified. Survival and quality were generally better on the deeper soils, well-drained soils, and soils on aa and broken pahoehoe.

Elevation, date of planting or weather, and other factors may also affect stocking and growth. Data collected were not sufficient for analysis of these and other variables.

RECOMMENDATIONS

This study has developed the first quantitative information about stocking and quality of planted stands in the Waiakea-Olaa reforestation area. On the basis of the results, we recommend that...

1. Areas of pahoehoe, shallow soils on compacted aa, or poorly drained areas should not be planted with Australian toon or tropical ash.
2. A large number (600 to 1,000) of seedlings should be planted per acre and tended, including weeding and spot replanting during the first few months. Initial plantings of Australian toon should be at a spacing about 6 by 7 feet to 8 by 9 feet–depending on expected survival. Tropical ash should probably be planted at even a closer spacing.

Other practices might be effective in improving planted stands. Since stem forking below 12 feet is a major culling factor, pruning may be a means of achieving a higher number of acceptable or desirable trees. Also, it may be possible to convert cull trees to growing stock through coppice sprouts. Before such practices are carried out on any large scale, their effectiveness should be studied.

SUMMARY

Wick, Herbert L., Robert E. Nelson, and Libert K. Landgraf

1971. **Australian toon planted in Hawaii: tree quality, growth and stocking.** Berkeley, Calif., Pacific SW. Forest & Range Exp. Sta., 10 p., illus. (USDA Forest Serv. Res. Paper PSW-69)

Oxford: 176.1 *Toona australis* (969):232.4.
Retrieval Terms: Toona australis; plantation stand establishment; stocking density; soil factors; Hawaii.

Australian toon *(Toona australis)* is used extensively for reforestation in Hawaii. About 250,000 seedlings are planted annually. Even within short distances, seedlings can vary widely in growth rate and form. Criteria for stand improvement can be developed if the trees that likely will be of low quality can be identified early in a stand's life. Such standards would include the number of seedlings to be planted to obtain desired stocking, and the precise guidelines in selecting areas for land clearing and reforestation based on the relationship of tree survival and growth to site factors.

The condition of 5- to 8-year-old plantations of Australian toon, toon-tropical ash, and toon-koa on the Waiakea-Olaa reforestation area, island of Hawaii, was studied to determine (a) levels of stocking and tree growth and quality, and (b) how the levels are related to site factors. The site factors investigated were soil depth, microtopography class, soil drainage class, and kind of parent rocks.

Sample plots were randomly set up in plantings made each year from 1961 to 1965. Each plot was a 1/2-acre strip oriented perpendicular to the general lava flow pattern to intercept a variety of conditions. Data were analyzed to determine levels of stocking (survival of planted trees) and its quality. Each tree was placed in a quality class. The effects of site factors were tested by chi-square techniques.

From records of the Hawaii Division of Forestry we assumed that 436 seedlings had been planted on each acre. Of this initial planting, an average of 274 trees per acre had survived. Stocking in plots of pure

toon averaged 236 trees per acre. In plots of mixed toon-tropical ash, stocking averaged 127 toon trees and 200 tropical ash trees per acre. In plots of mixed toon and koa, it averaged 306 toon trees and 94 koa trees per acre.

Distribution of stocking was significantly affected by soil parent rock, microtopography, soil depth, and soil drainage class. And all of these site factors, except soil depth class, were significantly related to tree quality.

The Australian toon trees were generally of better quality than tropical ash or koa: 31 percent of the toon were classified as desirable trees, and 43 percent as acceptable. Only about 11 percent of the ash and koa trees were rated desirable. Generally, the diameter and height growth of acceptable and desirable trees have been good.

Results of this study suggest that (a) Australian toon or tropical ash should not be planted on areas of pahoehoe, shallow soils on compacted aa, or poorly drained areas; and that (b) about 600 to 1,000 seedlings should be planted on each acre and properly tended, including weeding and spot replanting during the first few months. Initial planting of toon should be at a spacing of about 6 by 7 feet to 8 by 9 feet–depending on expected survival. Other cultural practices may help stand improvement, but they should be studied before being carried out on a large scale.

APPENDIX: *Tables*

Table 1–*Number of trees per acre on 18 sample plots, by species and quality class Waiakea-Olaa Reforestation Area, island of Hawaii*

Year planted and plot no.	Total trees/acre				Desirable trees/acre				Acceptable trees/acre				Cull trees/acre			
	Toon	Ash	Koa	Total	Toon	Ash	Koa	Total	Toon	Ash	Koa	Total	Toon	Ash	Koa	Total
1961:																
1	104	–	–	104	14	–	–	14	34	–	–	34	56	–	–	56
2	234	–	–	234	22	–	–	22	132	–	–	132	80	–	–	80
3	192	–	–	192	30	–	–	30	96	–	–	96	66	–	–	66
4	322	–	–	322	24	–	–	24	162	–	–	162	136	–	–	136
1962:																
5	146	–	–	146	44	–	–	44	44	–	–	44	58	–	–	58
6	202	216	–	418	34	4	–	38	112	92	–	204	56	120	–	176
7	376	–	–	376	108	–	–	108	222	–	–	222	46	–	–	46
8	354	–	144	498	166	–	22	188	146	–	40	186	42	–	82	124
1963:																
9	66	184	–	250	10	14	–	24	34	34	–	68	22	136	–	158
10	258	–	44	302	34	–	–	34	136	--	16	152	86	–	30	116
11	330	–	–	330	162	–	–	162	136	–	–	136	32	–	–	32
12	286	–	–	286	72	–	–	72	128	–	–	128	86	–	–	86
1964:																
13	98	224	–	322	46	48	–	94	36	56	–	92	16	120	–	136
14	256	–	–	256	122	–	–	122	88	–	–	88	46	–	–	46
15	334	–	–	334	228	–	–	228	78	–	–	78	28	–	–	28
16	142	174	–	316	30	20	–	50	48	20	–	68	64	134	–	198
1965:																
17	158	–	–	158	22	–	–	22	40	–	–	40	96	–	–	96
18	96	–	–	96	56	–	–	56	18	–	–	18	22	–	–	22

Table 2–*Sample area and trees observed and expected on sample plots, by site factor class, Waiakea-Olaa Reforestation Area, island of Hawaii*

Site factor	Sample area in each class	Trees observed	Trees expected
	Percent	*No.*	*No.*
Microtopography:			
Level	36	868	888
Swale	6	257	160
Side slope	52	1,080	1,285
Ridge	6	264	136
Total	100	2,469	2,469
Soil depth (inches):			
0-12	69	1,758	1,713
13-24	29	627	709
25+	2	84	47
Total	100	2,469	2,469
Drainage:			
Good	96	2,420	2,361
Poor	4	49	108
Total	100	2,469	2,469
Parent rock:			
aa	74	1,935	1,820
Broken pahoehoe	9	253	228
Pahoehoe	17	281	421
Total	100	2,469	2,469

Table 3–*Trees observed and expected on sample plots, by microtopography class combined with other site factors, Waiakea-Olaa Reforestation Area, island of Hawaii*

Micro-topography class	Soil depth			Drainage			Parent rock		
	Class	Trees observed	Trees expected	Class	Trees observed	Trees expected	Class [1]	Trees observed	Trees expected
	Inches	*No.*			*No.*			*No.*	
Level	0-12	661	662	Good	830	807	1	698	650
	13-24	196	221	Poor	38	81	2	45	35
	25+	11	5				3	125	203
Total		868	888		868	888		868	888
Swale	0-12	170	102	Good	252	154	1	199	119
	13-24	79	51	Poor	5	6	2	44	30
	25+	8	7				3	14	11
Total		257	160		257	160		257	160
Side slope	0-12	751	860	Good	1,078	1,268	1	834	956
	13-24	281	395	Poor	2	17	2	136	148
	25+	48	30				3	110	181
Total		1,080	1,285		1,080	1,285		1,080	1,285
Ridge	0-12	176	89	Good	260	132	1	204	95
	13-24	71	42	Poor	4	4	2	28	15
	25+	17	5				3	32	26
Total		264	136	–	264	136	–	264	136
Total	–	2,469	2,469	–	2,469	2,469	–	2,469	2,469

[1] Parent rock class: 1 = aa; 2 = broken pahoehoe; 3 = pahoehoe.

Table 4–*Sample area, trees observed and expected on sample plots, by soil depth class, parent rock and drainage class, Waiakea-Olaa Reforestation Area, island of Hawaii*

Soil depth class (inches)	Parent rock				Drainage			
	Class	Sample area	Trees observed	Trees expected	Class	Sample area	Trees observed	Trees expected
		Pct.	*No.*			*Pct.*	*No.*	
0-12	aa	52.7	1,446	1,302	Good	66.3	1725	1636
	Broken pahoehoe	3.2	96	80	Poor	3.1	33	77
	Pahoehoe	13.4	216	331				
13-24	aa	19.9	434	491	Good	27.5	611	679
	Broken pahoehoe	5.4	131	133	Poor	1.2	16	30
	Pahoehoe	3.5	62	85				
25+	aa	1.1	55	27	Good	1.9	84	46
	Broken pahoehoe	.6	26	15	Poor	(1)	0	1
	Pahoehoe	.2	3	5				
Total		100.0	2,469	2,469		100.0	2,469	2,469

[1] Less than 0.1 percent.

Table 5–*Sample area and trees observed and expected, by drainage class and parent rock Waiakea-Olaa Reforestation Area, island of Hawaii*

Parent rock	Percent of sample area	Trees observed	Trees expected
		No.	
GOOD DRAINAGE			
aa	73.4	1,930	1,809
Broken pahoehoe	9.2	250	228
Pahoehoe	13.1	240	324
POOR DRAINAGE			
aa	.4	5	11
Broken pahoehoe	(1)	[2]3	0
Pahoehoe	3.9	41	97
Total	100.0	2,469	2,469

[1] Considered less than 0.1 percent.
[2] For all analyses these trees were included in "Good" drainage class.

Table 6–*Cull trees tallied in sample plots, by species and cull factor, Waiakea-Olaa Reforestation Area, island of Hawaii*

Cull factor	Toon	Ash	Koa
	Percent		
Fork below 12 feet	56	81	34
Excessive lean	30	13	36
Lodging	6	6	18
Low vigor; suppressed	6	–	12
Excessive branching	2	–	–
Total	100	100	100

Table 7–*Cull trees observed and expected, by site factor class Waiakea-Olaa Reforestation Area, island of Hawaii*

Class	Trees observed	Trees expected
	No.	
Microtophography:		
Level	270	293
Swale	60	86
Side slope	401	363
Ridge	99	88
Total	830	830
Soil depth (inches):		
0-12	585	591
13-24	211	211
25+	34	28
Total	830	830
Drainage:		
Good	804	814
Poor	26	16
Total	830	830
Parent rock:		
aa	593	651
Broken pahoehoe	80	84
Pahoehoe	157	95
Total	830	830

Table 8–*Cull trees tallied in sample plots in each microtopography class, by site factor combination, Waiakea-Olaa Reforestation Area, island of Hawaii*

Micro-topography class	Soil depth			Drainage			Parent rock		
	Class	Trees observed	Trees expected	Class	Trees observed	Trees expected	Class [1]	Trees observed	Trees expected
	Inches	*No.*			*No.*			*No.*	
Level	0-12	204	223		249	279	1	180	235
	13-24	63	66	Good	21	14	2	19	15
	25+	3	4	Poor			3	71	43
Total		270	293		270	293		270	293
Swale	0-12	33	57		58	85	1	44	67
	13-24	25	26	Good	2	1	2	9	14
	25+	2	3	Poor			3	7	5
Total		60	86		60	86		60	86
Side slope	0-12	284	252		401	363	1	302	280
	13-24	99	95	Good	–	–	2	41	46
	25+	18	16	Poor			3	58	37
Total		401	363		401	363		401	363
Ridge	0-12	64	59		96	87	1	67	69
	13-24	24	24	Good	3	1	2	11	9
	25+	11	5	Poor			3	21	10
Total		99	88		99	88		99	88
Total		830	830		830	830		830	830

[1] Parent rock class: 1 = aa; 2 = broken pahoehoe; 3 = pahoehoe.

Table 9–*Stocking distribution of desirable and acceptable trees in Australian toon stands, Waiakea-Olaa Reforestation Area, island of Hawaii*

Plot No.	Quadrats stocked with desirable or acceptable trees		1/100-acre quadrats [2] stocked with desirable trees
	1/400 acre [1]	1/100 acre [2]	
	Percent		
1	12	35	10
2	36	81	15
3	29	68	27
4	41	85	19
5	21	63	34
7	65	98	73
11	66	100	81
12	45	90	47
14	46	87	40
15	63	95	87
17	14	48	15
18	17	52	39
Average	38	75	41

[1] Basis of 378 quadrats systematically located in each transect plot.
[2] Basis of 62 quadrats systematically located in each transect plot.

Table 10–*Average annual diameter and height growth of acceptable and desirable trees in Australian toon stands of different ages, Waiakea-Olaa Reforestation Area, island of Hawaii*

Stand age (months)	Plot number	Average diameter growth and range	Average height growth and range
		Inches per year	*Feet per year*
92	1	0.43 (0.10-0.78)	3.0 (1.9-4.6)
91	3	.41 (.04-1.18)	2.8 (.8-5.3)
90	4	.50 (.07-1.29)	3.4 (1.5-5.6)
89	2	.56 (.19-1.28)	3.7 (1.8-7.3)
77	7	.58 (.16-1.33)	4.2 (1.9-7.9)
76	5	.31 (.03-0.69)	2.2 (1.1-4.7)
62	11	.70 (.12-1.30)	5.8 (1.9-9.3)
60	12	.76 (.14-1.70)	6.0 (1.8-11.4)
59	15	.49 (.06-1.32)	4.1 (1.2-9.7)
51	14	.37 (.02-1.18)	3.0 (1.2-7.5)
45	17	.61 (.32-1.20)	4.6 (2.9-6.6)
45	18	.43 (.13-1.15)	3.7 (1.6-8.5)

GPO 980-964

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1971. **Australian toon planted in Hawaii: tree quality, growth, and stocking.** Berkeley, Calif., Pacific SW. Forest & Range Exp. Sta. 10 p., illus. (USDA Forest Serv. Res. Paper PSW-69)

Tree quality and rates of growth and survival were higher in 5- to 8-year-old Australian toon *(Toona australis)* plantations on sites with deep soils, good drainage, and as or broken pahoehoe rock than in plantations on sites with poor drainage or unbroken pahoehoe rock. Stocking averaged 236 trees per acre. Spacing in initial plants should be about 6 by 7 feet to 8 by 9 feet–depending on expected survival. And during the first few months, weeding and replanting should be done.

Oxford: 176.1 *Toona australis* (969):232.4.
Retrieval Terms: Toona australis; plantation stand establishment; stocking density; soil factors; Hawaii.

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