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PASTURE ESTABLISHMENT IN TROPICAL BRUSHLANDS BY AERIAL HERBICIDE AND SEEDING TREATMENTS ON KAUAI

P. S. Motooka, D. L. Plucknett, D. F. Saiki, and O. R. Younge[1]

INTRODUCTION

While chronic famine and malnutrition afflict much of the world, 20 percent of the land area of the earth lies under jungle and brush in areas of abundant rainfall producing neither useful food nor fiber. Most of this land is in the very areas where starvation is rife: the tropics. If but a third of these lands were to be put into cultivation, the productive land area of the world would be doubled.

In Hawaii, 25 percent of the land is denied to productive use by thick jungles of essentially worthless brush and trees. These areas contribute little to the economy of the State, but marginally, they could provide pasture or timber or recreational use or a combination of these.

Under intense management on this type of land, excellent yields of many crops have been obtained at the Kauai Branch Station. Younge and Plucknett (9), for instance, reported live weight beef gains as great as 1,164 pounds per acre per year. Cognizant of the unrealized potential resource situated in these humid jungles, the Hawaii Agricultural Experiment Station has been conducting a study on clearing and reclaiming jungle lands. Because of the rough terrain, dense vegetation, extensive area, and labor involved, aerial application of herbicides appears attractive.

[1]Junior Agronomist, Associate Agronomist, Assistant in Agronomy, Agronomist and Professor of Agronomy, University of Hawaii, Hawaii Agricultural Experiment Station.

The approach taken in this study was an integrated one of land clearing (6) followed by pasture establishment, this to be followed by the development of management techniques to create stable, weed-free pastures.

In this systematic approach, one of the objectives was the establishment of pasture on cleared land by aerial methods. Therefore, aerial seeding and fertilization as feasible means of pasture establishment were tested. In addition, several pasture species were evaluated for suitability to this method.

The test area is a small, steepsided 40-acre valley, with only small areas level or gently sloping, located at the Kauai Branch Station of the Hawaii Agricultural Experiment Station at Wailua, Kauai. The annual rainfall is about 100 inches and the elevation about 600 to 700 feet. The soil is an Aluminous Ferruginous Latosol.

The vegetation consisted primarily of dense stands of false staghorn fern *(Dicranopteris linearis)* and melastoma *(Melastoma malabathricum)*. Less prevalent were ohia *(Metrosideros collina polymorpha)*, guava *(Psidium guajava)*, pandanus *(Pandanus sp.)*, tree fern *(Sadleria sp.)*, java plum *(Eugenia cuminii)*, and hau *(Hibiscus tiliaceus)* (7).

EXPERIMENTAL RESULTS AND DISCUSSION

Herbicide Treatment

The test area was treated with 4 pounds active silvex per acre on October 2, 1965 (6). Excellent control of melastoma and staghorn fern was obtained with melastoma responding rapidly and staghorn responding slowly. Good control of guava, pandanus, and lantana was observed. The other species showed moderate to little damage (Table 1).

On June 1, 1966, when recovery of the brush species began to accelerate, a second application of 4 pounds silvex per acre was applied. The growth response was similar to that of the first treatment.

It is important to note that response to any herbicide depends to a great extent on the species treated. Hence, selection of herbicides should depend on the principal species in the area to be treated. It will be noted, however, that information on this point is still lacking for many plant species.

Burning

Original plans called for burning the vegetation on a small part of the test area to compare it with unburned areas. Accordingly, on February 4, 1966, a small area was fired. Further preliminary tests, however, indicated that seeding into vegetative trash was unfavorable for seed germination. Therefore, on October 3 and 4, 1966, most of the rest of the test area was fired, leaving only small, unburned areas with trash on it for control.

These fires were set in the wet part of the year to take advantage of the moisture in controlling the intensity and spread of the burn and also to insure adequate water for satisfactory seed germination and growth.

The staghorn fern burned most readily, and fires stopped where there was none. Experience, in fact, has shown that staghorn burns even while fresh and immature and thus herbicide treatment may be unnecessary in clearing uniform stands of this fern. In the absence of staghorn fern, however, the burning of jungle forest is impractical except under extremely dry conditions.

In areas where the fire was started at the bottom of the valley, the fires burned fiercely, with flames ascending 50 feet or more, creating powerful updrafts that carried flaming debris which started new fires where it landed. In dense stands the staghorn burned completely, leaving a layer of ash over the bare ground.

On the other hand, fires started at the top of the ridge advanced slowly downward in a line with flames usually not more than 5 feet high. Although this type of burning was easier to control, it often left a mat of unburned rhizomes on the ground which later proved detrimental to plant growth.

Ohia trees surrounded by staghorn burst into flames and the staghorn rhizomes in a circle around them were burned to the ground even when rhizomes remained unburned nearby (Fig. 1). Apparently, the burning trees produced enough heat to promote complete burning of the staghorn rhizomes beneath them.

Pasture Species

Ideally, a pasture should be composed of one or two suitable grasses and one or two legumes, and for airplane application, they should be planted by seed. This requirement eliminated from aerial seeding kikuyugrass *(Pennisetum clandestinum)* and pangolagrass *(Digitaria decumbens)*, both popular in Hawaii, as both are essentially seedless and are planted as cuttings. In preliminary experiments, however, both of these grasses germinated very readily from two-node cuttings provided the soil was bare and moist. Also, pangola and *Desmodium intortum* spread by hand and by bulldozer in a part of the burned-out area established very well with thick, lush growth (Fig. 2). The intortum germinated from both seed and cuttings. If an airplane can be outfitted to distribute cuttings, there appears to be no reason why grass and legume cuttings cannot be used with success in plant establishment. However, this study was confined to seeded species, selected for this test as listed in Table 2.

Except for *D. intortum*, the legumes were imported from Australia and are considered suited to tropical conditions. Intortum seed was collected from established plantings at the Kauai Branch Station. The grass seed was obtained from the mainland.

Seed Pelletizing

Nitrogen-fixing bacteria living in a symbiotic relationship with a legume can convert atmospheric nitrogen, which is unavailable to plants, into available forms. Whitney, Kanehiro, and Sherman (8) have determined the amount of nitrogen fixed by *D. intortum* and centrosema to be 340 pounds and 110 pounds per acre per year, respectively, in grass-legume mixtures. Without adequately inoculated legumes no nitrogen would be obtained from the air. Thus the need for legume inoculation is apparent.

To ensure establishment of the nitrogen-fixing bacteria, the legume seeds were pelletized, since the microbes are short-lived unless maintained in a proper environment.

By this method (4), (J. L. Murgia—personal communication), the seed is coated with an adhesive, in this case a 5-percent solution of methyl-ethyl cellulose, into which the inoculant has been mixed. This can be done in a cement mixer. After the seed is thoroughly coated, a powder, such as finely ground calcium silicate slag as used here, is added to coat the seed. The pellets are then allowed to air-dry in the shade. The amounts of seed, cellulose, and slag used are listed in Table 2.

Because the aircraft was not equipped to spread seed, the seeds were mixed with granulated treble superphosphate and spread together with the fertilizer. Mixing in the cement mixer produced a uniform mix and this was done just prior to flight time since prolonged contact with the phosphate is lethal to the nitrifying bacteria (2), although pelleting should offer some protection in this regard.

Fertilization and Seeding

The application of phosphate was deemed essential to plant establishment not only because Hawaiian soils are low in phosphorus, but also because they have a tremendous capacity to fix phosphorus and thus severely limit its uptake by plants (9).

On October 13, the phosphate and seed were spread by air over the test plot. Immediate seeding after clearing and burning was deemed essential to get the pasture species started well ahead of the soil borne weeds. Fortunately, on the afternoon after seeding, heavy showers occurred and rainfall was adequate during the period of germination and early growth (Table 3).

On December 22, diammonium phosphate at a rate of 200 pounds per acre was applied, again by air. Thus 32 pounds of nitrogen per acre was applied and, with the earlier phosphate treatment, there were 86 pounds of elemental phosphorus per acre applied.

Results and Discussion of Treatments

Within two weeks of aerial seeding germination was evident and in eight weeks green panic, fastest growing of the species planted, was already heading. Within five months of seeding many of the legumes were flowering.

Uniformity of seed distribution as evidenced by germinated seedlings of the planted species was excellent.

Perhaps the most striking result of this test was the success of the plantings in areas protected from intense sunlight, such as the deeper parts of the valley and on the slopes exposed only to the morning sun. Presumably this prevents the surface soil from drying and maintains a moist environment suitable for growth. On slopes subject to the afternoon sun during the warmest part of the day, germination of all pasture species was sparse or nil. This suggests that there was enough dehydration to suppress the establishment of these plants.

Also, within the drip line of the burned ohia trees, growth of the pasture legumes was especially vigorous (Fig. 3, 4). In fact, outstanding growth on hillsides was confined to areas under these trees. The reasons for this remain to be investigated but it is surmised that the defoliated tree tops provide a partial shade, much as a lathhouse does, to the plants beneath, or that past cycling of nutrients by the trees from roots in the subsoils resulted in higher nutrient levels in the soil directly beneath the trees as compared with the soil beneath staghorn, which does not have as extensive a root system. Then, too, leaf ash from burning also contributed nutrients to the soil beneath.

In many cases, though not in all, the areas within the driplines of trees were the only areas in which the staghorn litter was burned completely. It was apparent that staghorn litter, for some reason, perhaps toxicity, restricted growth of plants on it. Wherever there was a thick, unburned mat of staghorn rhizomes, growth of even weedy species was nil (Fig. 5). Where the staghorn mat was thin, growth of both weeds and planted species was sparse.

The nutrient contributions of ash to the soil must be considerable. With the notable exception of nitrogen, which is volatilized, all nutrients remain in the ash when vegetative cover is burned. Thus burning fertilizes the soil and also, because of bases such as calcium in the ash, "limes" it too. Preliminary tests indicate that soil under staghorn increases in pH from 5.0 to 5.4 in the surface inch or two when the cover is burned.

The significance of ash nutrient yield becomes apparent when it is realized that smallseeded legumes, because they contain very little potassium in their seed, require considerable potassium from the soil to germinate successfully (3). Furthermore, potassium is necessary for nodulation of legume roots, without which legume stands would surely fail.

Another requirement for nodulation is that the soil pH not be too acid. Inhibition of *Rhizobium sp.* occurs if the soil is more acid than pH 5.5 (5). Although burning did not bring the soil pH to 5.5, it may have created a pH zone at the soil surface adequate for nodulation. Australian studies (1) have shown that on a soil of pH 5.2, legume growth on a plot planted with lime-pelleted subterranean clover seed was equivalent to growth on plots treated with 200 pounds of lime and planted with seeds not pelleted with lime. In this instance only 5 pounds of lime was required to pelletize the seeds. It was concluded from further study that microzones of favorable pH around a seed, not calcium availability, is responsible for good legume establishment in acid soils (1). In this regard, it is interesting to note that Loneragan *et al.* (5) obtained good legume growth on ash patches on an acid soil that otherwise produced poor stands. Therefore, it is reasonable to conclude that the ash from burning in the test reported here substantially aided legume establishment.

Not to be ignored also is the role of the calcium silicate slag used in coating the seed. It is considered a liming material and, in view of the Australian work, should have benefited nodulation.

Where a weedy ground cover such as honohono *(Commelina diffusa)*, hau *(Hibiscus tiliaceus)*, or grasses such as *Setaria sp.* and *Paspalum sp.* had already been established at the time of seeding, planted species failed. In large parts of the burned-over areas, fireweed *(Erechtites hieracifolia)*, so named because it is generally the first sign of life in burned-over areas, grew rapidly in heavy stands and shaded the pasture species. However, this weed, an annual, matured in seven months, releasing the planted species (Fig. 6, 7). Thus, fireweed should pose no serious problem to pasture establishment. Similarly, it is believed that through controlled grazing and judicious management, the forage species, because of their natural vigor under favorable conditions, should assert dominance over all low-growing weeds in areas similar to the test plot.

Overall, the more successful plants were green panic, stylo and *D. intortum*, as measured by their incidence and apparent vigor throughout the test area.

Total Cost of Pasture Establishment

The estimated total cost of the reported land clearing and pasture establishment was $98.93 per acre, which includes labor, materials, and value of aircraft services (Table 4). The cost to a rancher would be less than the experimental costs and is estimated to be about $80. This compares quite favorably with mechanical means of land clearing, which probably would cost close to $100 per acre on land where the terrain permits mechanical procedures. In areas of dense staghorn, the almost incendiary properties of which would lend themselves readily to fire clearing, pasture establishment would cost a very modest $50 per acre since the cost of the herbicide and herbicide application would be eliminated. Of course, smaller areas would result in higher per acre cost and, conversely, areas larger than 40 acres may be expected to have lower unit costs.

SUMMARY

Aerial seeding and fertilization of burned over brushland and the performance of several pasture species were evaluated.

Good germination and early growth were exhibited by green panic, stylo, *D. intortum*, and white clover.

Growth was excellent under burned trees and in areas not subjected to intensive sunlight and dehydration.

The liming effect of ash and of calcium silicate slag probably aided legume establishment.

Judicious management should result in a good, stable pasture.

Experimental cost of clearing, seeding, and fertilizing amounted to less than $100 per acre, and costs to a rancher are estimated at $80 per acre for extensive areas.

ACKNOWLEDGMENT

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Table 1. Effect of silvex on brush species, Wailua, Kauai

Species	Ratings after treatments of 4 pounds silvex per acre*	
	Five months after first treatment	Two months after second treatment
Staghorn	5.0	5.0
Melastoma	5.0	5.0
Ohia	3.0	2.5
Guava	3.5	3.5
Lantana	3.5	4.0
Pandanus	3.8	4.0
Hau	2.0	3.2
Java plum	2.0	2.0

*
1= No control–no visible damage.
2= Slight control–some defoliation and abnormal growth.
3= Moderate control–considerable defoliation and abnormal growth.
4= Good control–severe defoliation, death not apparent.
5= Complete control–total defoliation, apparent death of plant.

Table 2. Materials used per acre in the aerial establishment of pasture on jungle brushlands, Wailua, Kauai

SPECIES	MATERIALS PER ACRE			
	Seed	5% cellulose solution	Slag powder	Total
Legumes	Pounds	Pints	Pounds	Pounds
Centrosema pubescens (Centrosema)	1.00	1.000	1.00	2.00
Glycine javanica				
Tinaroo	0.75	0.150	0.75	1.50
Clarence	0.50	0.125	0.50	1.00
Cooper	0.50	0.125	0.50	1.00
Yatesco	0.50	0.125	0.50	1.00
Phaseolus atropurpureus (Siratro)	0.50	0.125	0.50	1.00
Stylosanthes gracilis (Stylo)	1.00	0.200	1.25	2.25
Lotononis bainesii	0.50	0.150	2.00	2.50
Trifolium repens				
Mother white clover	1.25	0.200	1.50	2.75
P. P. white clover	1.25	0.200	1.50	2.75
Ladino clover	1.25	0.200	1.50	2.75
Desmodium intortum	0.75	0.200	1.25	2.00
Grasses				
Panicum maximum (green panicgrass)	2.00	—	—	2.00
Cynodon dactylon (NK-37 bermuda)	2.00	—	—	2.00
Total	13.75	2.800	12.75	26.50

Table 3. Rainfall at the Kauai Branch Station from October 10 to December 31, 1966

Week of	Rainfall Inches	Week of	Rainfall Inches
Oct. 10	9.05	Nov. 21	3.73
17	1.45	28	0.85
24	0.12	Dec. 5	0.10
31	1.99	12	0.22
Nov. 7	1.97	19	0.82
14	0.53	26	1.97

Table 4. Experimental costs and estimated costs to a rancher of land clearing and pasture establishment

Item	Rate per acre	Experimental Costs Dollars per acre	Rancher's Costs Dollars per acre
Herbicide	2 gallons	23.68	23.68
Labor @ $2 per hour	4.65 hours	9.30	9.30
Fertilizer	200 pounds each of 18-46 and treble superphosphate	24.09	24.09
Slag	See Table 2	0.15	0.15
Cellulose	See Table 2		
Seed	See Table 2	29.09	11.27
Innoculant	See Table 2	0.62	0.25
Aircraft services @ $3 per acre per treatment	4 treatments	12.00	12.00
Total		**98.93**	**80.74**

Figure 1. Note complete burning of staghorn under trees (white ash patches), whereas staghorn rhizomes remain unburned between the trees.

Figure 2. Hand-sown pangolagrass and *D. intortum* about a year after sowing showed vigorous growth. This stand is about 30 inches high.

Figure 3. Legume growth was excellent under burned trees.

Figure 4. The delineation between good legume growth and poor growth shown here marks the drip line of an ohia tree.

Figure 5. Seven months after burning, staghorn litter still restricted plant growth.

Figure 6. Green panic and legumes growing through a stand of matured fireweed.

Figure 7. Siratro climbing on Fireweed stalks.