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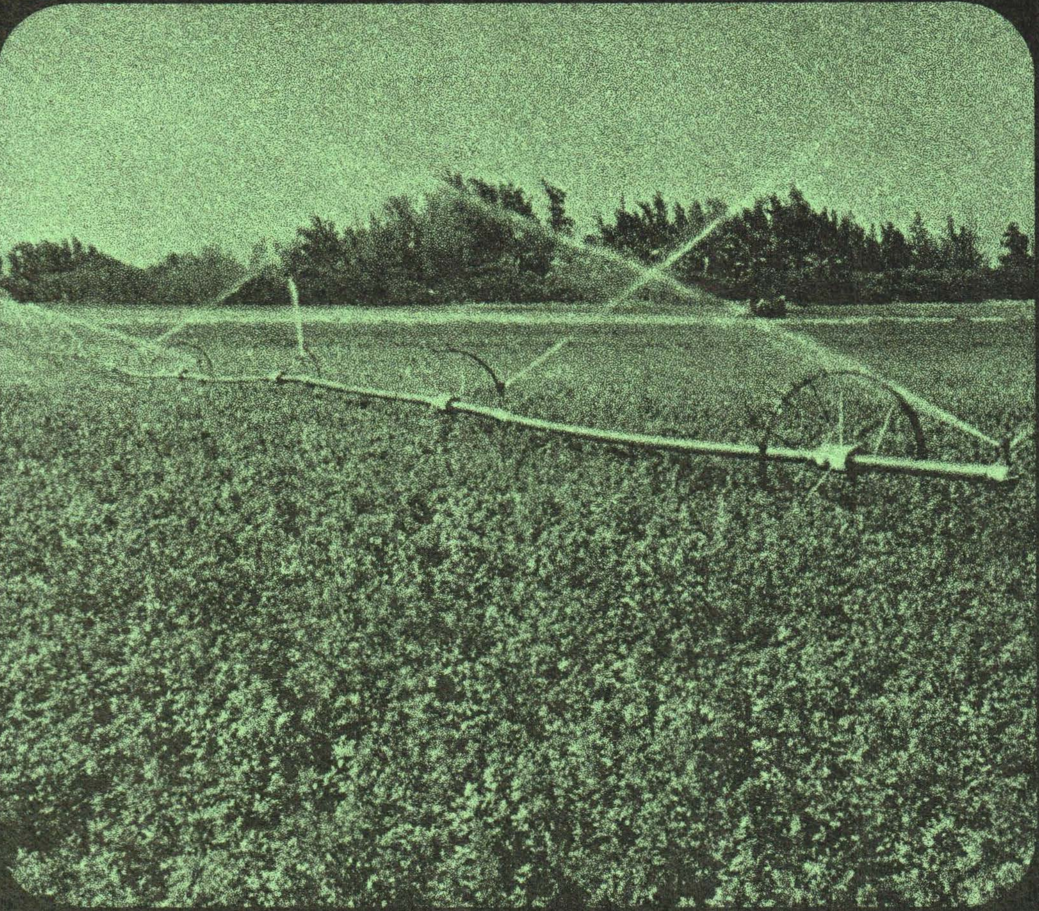
PRODUCING ALFALFA

IN HAWAII



THANKS

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Cover—Alfalfa grown with sprinkler irrigation at Mokuleia Ranch Company, Oahu. (Photo courtesy O. R. Younge)

PRODUCING ALFALFA IN HAWAII

by
Dale N. Goodell and Donald L. Plucknett

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is a short-lived perennial legume grown as a livestock forage crop in almost every country in the world. It is a native of Iran or southwestern Asia and was probably planted there long before recorded history. Alfalfa has been grown for dry hay and for cultivated pasture longer than any other forage plant. The Persians took it to Greece when they invaded that country in 490 B.C. Brought to North America in early colonial times, it was planted first in Georgia. From there it spread westward and has since become one of the most popular crops in the United States. Through intensive breeding and selection, varieties have been developed that are acclimated to certain areas, and which carry disease resistance and high yielding characteristics, making it probably the world's most important forage crop.

Alfalfa has been grown as a minor crop in Hawaii since 1895 (Younge, 1952); there is a renewed interest in its production, partly due to availability of sugarcane and pineapple lands that are being released from production. The comparative potential economic return in alfalfa is now greater than it has been in the past. Some of the more important reasons for this are:

- New, more readily adaptable varieties.
- Improved weed control methods.
- Laborsaving equipment for planting, harvesting, and drying the crop.
- A greater understanding of its potential as a feed and as a soil builder.
- A recognition of its value as a supplementary and complementary forage crop.

This report will review some of the previous research on alfalfa and will discuss management and growing of alfalfa under Hawaii conditions.

Fig. 1 – Dr. O. R. Younge (left) and former Dean M. M. Rosenberg (right) examine an excellent stand of alfalfa at Kekaha Sugar Company Ltd., Kauai. (Photo courtesy O. R. Younge)

Fig. 2 – One-year-old alfalfa at Mokuleia Ranch Company, Oahu. (Photo courtesy O. R. Younge)

PREVIOUS EXPERIENCE IN GROWING ALFALFA

Alfalfa has been grown off and on for many years (Hosaka, undated; Britten and Koshi, 1959). In 1911 there were 250 acres of alfalfa (Britten, 1956). The crop has been grown, with varying success, at Kekaha Sugar Company, Kauai (Figure 1); Kualoa Ranch Company and Mokuleia Ranch Company on Oahu (Figure 2); Waimea Dairy and Hutchinson Sugar Company, Hawaii; and at Molokai Ranch Company, Molokai. These projects, all located near sea level and irrigated, had problems with maintaining stands and with weed competition. Much of the forage produced was sold as greenchop[1]. Some was baled and marketed as hay; however, there were some problems with inadequate drying and the hay sometimes became moldy in the bales.

The market for alfalfa in Hawaii

There is a large untapped state market for alfalfa. One of the serious needs of livestock producers here is protein feedstuffs and a high protein roughage. In 1970 (Wallrabenstein, 1971), 24,715 tons of alfalfa were imported, most of it in the form of pellets. Also, 21,367 tons of protein concentrate feedstuffs were imported. A sizable portion of this importation could be replaced by locally produced hay, dehydrated meal or green alfalfa forage. The high vitamin A, mineral and digestible protein content as well as its palatability makes alfalfa greenchop especially desirable in a dairy operation. Alfalfa is an excellent feed for young animals and has been used in mixed feeds for swine and poultry (Younge, 1952).

It has been estimated conservatively that, if the price is competitive with mainland imports, there is a demand for the yield of at least 3000 acres of alfalfa in Hawaii, based upon present consumption rates.

Most suitable lands for alfalfa

The best lands for alfalfa in Hawaii are near neutral or slightly alkaline soils (often coral), near sea level, deep, well drained, free from stones and reasonably level, with slopes not exceeding 15 percent and preferably below 5 percent. Generally, Class A soils with available irrigation would be most suitable for alfalfa; however, these soils are now used mainly for sugarcane and pineapple.

Alfalfa grows at almost any elevation. Certain varieties have been known to grow at 3000 feet. At higher elevation, production decreases due probably to lower soil and air temperatures. Most production experience in Hawaii has so far been obtained from sea level to 1000 feet; however, best yields and results have been obtained at elevations below 500 feet. This may be due in

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[1] **Greenchop is a term applied to freshly cut forages which are fed in the fresh, uncured form to animals.**

part, of course, to the fact that the less weathered, near neutral or slightly alkaline soils which are best suited for alfalfa are usually found below 500 feet.

Soils

Alfalfa can be grown on slightly or mildly acid soils, but more acid soils may require lime. Acid soils in Hawaii are often low in calcium and phosphorus and may also have very high levels of active aluminum and manganese which can indirectly cause severe yield reductions. When an acid soil is limed, its pH rises, causing a reduction in active aluminum, iron and manganese and increasing the levels of calcium, phosphorus, and molybdenum.

In Hawaii, alfalfa has been grown most successfully on near neutral or alkaline dark alluvial soils or coral sand soils of the leeward coastal lowlands. Alfalfa on the red soils (or latosols) has usually not been very successful. In part this is due to soil acidity, but it has also been related to minor element deficiencies that result as the soil pH levels are raised by liming and as higher rates of phosphorus fertilizers are used. Achieving proper nutrient balance for alfalfa on the red soils is not an easy task.

In the past, most alfalfa production was carried out at three locations: Kekaha Sugar Company, Kauai, on coral flats using waste water for irrigation; Mokuleia Ranch Company, Oahu, on flats with some coral, using shallow well water for irrigation; and at Molokai Ranch Company, Molokai, on alluvial soils and some saline soils, using brackish water from shallow wells. As is the case with most diversified crops in Hawaii, these lands were either idle or wastelands not suitable or marginal for pineapple or sugarcane production. For information on managing alfalfa in Hawaii soils, especially regarding soil fertility, see the section on Specific Soil Problems.

Seasonal growth

In the Islands the weather of certain areas is likely to be more of a limiting factor than the soil itself. Growth seems to be directly proportional to sunlight hours and day length. Even in high producing areas, there is a one-third reduction of growth during the winter months (based upon yield records at Kekaha and Molokai ranches). Of course, alfalfa consumes large quantities of water, and generally large amounts of natural rainfall do not go hand in hand with high sunlight hours and high soil temperatures. In wet areas, leaf spot diseases will show up during warm humid periods if there is little air movement. For these reasons, optimum production is generally found in the hot, dry areas of the Islands under irrigated conditions.

Water requirement

Alfalfa has one of the highest water requirements for optimum growth of any field crop. The amount of water required for an alfalfa plant to produce 1 pound of dry matter would be 844 pounds, or 7.5 acre-inches of irrigation water for each ton of dry matter (hay) produced. By contrast, the water requirement for grain sorghum is about 304 pounds of water for each pound of dry matter produced.

The alfalfa taproot will penetrate 4 to 6 feet in 3 years of growth, and the plant will stand considerable drought if the taproot is in moist subsoil. Alfalfa taproots have been known to go as deep as 25 feet in search of water. On the other hand, soil that is waterlogged or has a high water table will soon kill the crop. Alfalfa can stand a higher salt content in the water than most crops; however, if the taproot strikes a water table of high salt content the plant will die. Irrigation frequency will vary according to soil type, rainfall, soil salinity, and evaporation and transpiration rates. For most arid or semiarid areas in Hawaii, probably at least 1.5 to 2 acre-inches of irrigation water every 2 weeks will be required, except during periods of heavy rainfall. This usually amounts to 3 to 4 acre-inches (80,000 to 108,000 gallons) of irrigation water per cutting, or about 880,000 to 1,188,000 gallons per acre per year. In saline areas it may be advisable to apply more water to leach away high salt concentrations at the surface. It may be necessary to apply 3 acre-inches every 2 weeks or 6 acre-inches per cutting, which could amount to as much as 1,782,000 gallons of water per acre per year for an 11-cutting per year crop. The estimated water requirement is admittedly high and could be reduced somewhat depending upon rainfall conditions. However, in areas with high temperatures, low relative humidity and constant windy conditions, 66 to 72 acre-inches of irrigation water per acre per year might be necessary to obtain high yields.

Saline soils and irrigation water

Alfalfa is usually quite tolerant of saline conditions in soils or irrigation water. In Hawaii the crop has been grown successfully with water containing high concentrations of salts. For example, Nightingale and Yoshida (1954) found that Hairy Peruvian alfalfa grew well on a nonsaline, virgin red soil on Molokai when irrigated with water containing 241 grains per gallon (4200 ppm) of salts. During a 4-month period, 39 acre-inches of irrigation water (furrow) was applied; during the same period there were 8.34 inches of rainfall. Planting was in February. The water table was at 20 feet or more below the surface. Experimental sprinkler irrigation even at sunny midday did not injure the foliage. The fertilizers used for the alfalfa were: 100 pounds P_2O_5 (43 pounds P) covered in the bottom of the furrow but with little mixing with the soil, boron at 5 pounds per acre, and sprays of molybdenum

Table 1. Performance of nine alfalfa varieties on Molokai Ranch Company with saline irrigation water (2 acre-inches per week of 96-grain water) on a soil with a high water table (3 feet). (Nightingale and Yoshida, 1954).

Variety	Yield, fresh-cut forage, lb/acre[1]
African	8200
Caliverde	9000
Buffalo	9460
Nomad	9700
Ranger	9820
Indian	9910
Common (Chilean)	9980
Ladak	10410
Hairy Peruvian	11460

[1] Values are means of four cuttings. Plant crop = 63 days, ratoons averaged 31 days. Fertilizers applied were: at planting, 50 pounds N, 200 pounds P_2O_5, 50 pounds K_2O as calcium nitrate, superphosphate and potassium sulfate, respectively, plus 50 pounds of a commercial minor element mix. Later when boron deficiency appeared, Mo at 0.5 pound per acre and B at 2.3 pounds per acre were applied as a spray at 100 gallons per acre.

as sodium molybdate (30 gallons per acre of a 1 ppm molybdate solution). In these experiments no yields were recorded but growth was generally good.

In another experiment with 96-grain water and with a water table 3 feet below the surface, nine varieties were planted: African, Buffalo, Caliverde, Common (Chilean), Hairy Peruvian, Indian, Ladak, Nomad and Ranger (Table 1). Hairy Peruvian yielded highest, followed by Ladak, Indian and Ranger. Only fresh-cut forage yields were recorded, and these ranged from an average cutting yield of 6,850 pounds per acre for African to 10,930 pounds per acre for Hairy Peruvian. Irrigation amounted to 8 acre-inches of 96-grain water per month, in 2-acre-inch weekly increments. Under such conditions, salt concentrations at the soil surface were greatly reduced; however, leaving out only one irrigation caused an increased soil salinity which in turn resulted in typical excess salt effects on the alfalfa, including dark blue-green foliage, reduced leaf size and much slower growth.

Molokai Ranch Company grew alfalfa on flats near the coast for more than 12 years, using brackish water (Henry Meyer, Personal communication). The irrigation schedule was 3 acre-inches every 2 weeks, or 6 acre-inches per cutting. The major difficulty with such growing conditions was related to the high water table on some of the lowlands, mainly on poorly drained lands subject to periodic flooding. On well-drained lands few problems were encountered.

On Kauai, Kekaha Sugar Company has grown alfalfa, using drainage water ranging from 80 to 150 grains per gallon for irrigation. The soil there is a well-drained Jaucus sand, consisting mainly of coral sand with some olivine. Few problems have been encountered with salinity; however, water salinity levels are often high enough to cause injury (Figure 3.)

Life expectancy

The life expectancy of the crop depends upon the variety planted and upon the management it receives. Individual plants that are more than 20 years old can be found in Hawaii. This should in no way, however, serve as an indicator of the life of a commercial crop. Under heavy harvesting conditions, plants will succumb to mechanical injury, to disease, and to unfavorable weather conditions until the stand thins. When this happens, weed infestation becomes a problem and the quality as well as the quantity of cut forage may be no longer economical. It is probably safe for a grower to assume no more than 4 years of commercial production before the field is plowed and replanted. In Hawaii, where 10 or 11 crops per year may be harvested, this is still a record number compared to the expectations for a commercial planting on the Mainland.

Varieties

A number of varieties of alfalfa have proved to be acclimated to Hawaii (Figure 4). Choice will depend somewhat on the kind of products to be marketed. Indian and African varieties are first choice from the standpoint of total production. They are tall, vigorous, and regrow rapidly after harvest. On the other hand, they are inclined to be rather stemmy and make coarse hay. Both of these have been grown with success on Kauai and Oahu.

Hairy Peruvian will not yield as heavily as the above varieties but is finer stemmed, leafier, and will produce a hay of higher quality.

Hairy Peruvian was grown successfully on Molokai by Molokai Ranch Company for 12 years.

Indian is an erect variety with rapid recovery after cutting and with less than average susceptibility to disease. It has little drought or cold resistance. It is thought to have originated in the plains of south India.

African, originally introduced from Egypt, is a somewhat coarse, upright plant that grows well in warmer regions of the southern or southwestern United States, especially in Arizona and California. *Moapa,* a new variety, with some resistance to the troublesome spotted alfalfa aphid, was developed by selection from African which is usually susceptible. Moapa may be more resistant to bacterial wilt than African. Moapa has purple flowers and an upright growth.

Hairy Peruvian, a warm season variety, grows erect and recovers quickly after cutting. It is susceptible to bacterial wilt.

Fig. 3 – Right–Effect of saline drainage water (120 grains per gallon) on alfalfa at Kekaha Sugar Company Ltd. Left–Plants were irrigated with fresh water. (Photo courtesy O. R. Younge)

Fig. 4 – An alfalfa variety trail at Waimanalo. The College of Tropical Agriculture has conducted many such trials on alfalfa at several of its experimental stations throughout the State. (Photo courtesy O. R. Younge)

Table 2. Effect of location on the number of cuttings of alfalfa per year in Hawaii (after Younge, 1960).

Site	Elevation, feet	Rainfall, inches/year	Cuttings/year
Poamoho Station	700	35	9
Waimanalo Station	65	35	10
Kekaha Sugar Co.	20	20	12–13
Mokuleia Ranch	25	25	11–12
Haleakala Station	2100	55	7

Table 3. Yield of green matter, in irrigated alfalfa trials, at low elevation and at low rainfall at Kekaha (Britten and Wallis, 1964).

Alfalfa variety	Yield of green matter tons/acre/cutting average of 17 harvests
African	4.373 *
Moapa	4.366
Indian	4.295
Du Puits	4.119
Hairy Peruvian	4.096
Caliverde	3.623
Williamsburg	3.525
Rhizoma	3.204
Talent	3.002
Lahontan	2.849

*Varieties bracketed by vertical line show no statistically significant yield difference. Yields of varieties not bounded by the same line are different from a statistical point of view.

Lahontan, another newer variety, is resistant to spotted alfalfa aphid and bacterial wilt, and almost immune to stem nematode. It has purple flowers.

New varieties under test

Two new varieties of alfalfa of the non-winter-dormant group have been developed in recent years and appear to have possible value in Hawaii. Test plantings have been made but no yield data are presently available in Hawaii.

Mesa-Sirsa, released in 1966, is non-winter-hardy and nondormant. Mesa-Sirsa plants have a high degree of resistance to six known biotypes of the spotted alfalfa aphid in the western United States. They also have some tolerance to downy mildew, but are susceptible to leaf diseases that sometimes will occur in areas of high humidity.

Hayden is a high yielding Arizona alfalfa, developed under the double-cross method from two of the highest yielding strains of Mesa-Sirsa. Hayden alfalfa exhibits exceptional tolerance to the spotted alfalfa aphid and Mainland yield tests are impressive.

The spotted alfalfa aphid has not appeared in Hawaii, but there will always be danger of its arrival under long-time commercial production.

Alfalfa yields in Hawaii

Well-grown alfalfa should produce 12 to 13 tons of dry hay or forage product (about 15 percent moisture) per acre per year. This dry forage yield would be equivalent to about 45 to 50 tons of fresh-cut forage (greenchop) per acre per year. In lowland areas these yields can be obtained in about 10 cuttings in the year planted and about 11 cuttings thereafter. At higher elevations, as few as 7 cuttings per year are obtained (Char, 1957; Younge, 1960) (Table 2). Yields of several varieties are given in Tables 3, 4, 5, and 6.

At Volcano Farm on Hawaii, yields of Indian and Williamsburg were compared (Rotar *et al.*, unpublished) (Figure 5). Percent dry matter of the Indian was very low at this comparatively high, cool and wet location, ranging from 9.5 percent in early March to 16.8 in May. For Williamsburg, the lowest dry matter recorded was 12.6 percent in May to 23.8 in September. Both dry matter and total green forage yields tended to increase or decrease with increasing or decreasing solar energy. Under the rather cool, wet and overcast conditions prevailing at Volcano, growth durations for cuttings averaged 46 days for Indian and 56 for Williamsburg.

Culture and harvesting

Because of the varying soil and climatic conditions to which alfalfa is adapted, no set rule can be laid down to be followed throughout the State. Alfalfa produces well in hot, dry areas if irrigation water is available. It also grows in areas of heavier rainfall and on different soil types but requires somewhat different management. Before going into alfalfa production, the grower should have complete knowledge about his soil, the availability of water and its cost, equipment and labor requirements, the nearness of his market, and the form in which he wants to market his harvested crop. In most areas of the State, hay must be artificially dried. If the crop is to be irrigated, the grower must decide which type of irrigation system he will use: flood irrigation, buried soak system, or one of the many sprinkler systems. Before any seed is planted, fields must be designed to make the best use of the chosen irrigation technique.

The plan for harvesting and marketing must also be firmly in mind before the crop is planted. The planting schedule, the number of acres to be

Table 4. Varietal performance of alfalfa at two locations on Oahu (Younge, unpublished data).

Variety	Rank	Crude protein pounds/acre	Dry matter at 70 C pounds/acre
Poamoho (3 years, 26 ratoons)			
Rhizoma	1	3,743	18,755
Narragansett	2	3,651	19,429
Williamsburg	3	3,231	18,169
Atlantic	4	3,078	16,598
Arizona Chilean	5	3,061	18,402
Hairy Peruvian	6	3,058	18,826
Poamoho; shallow, high manganese soil (2 years, 18 ratoons)			
Rhizoma	1	3,479	14,330
Indian	2	3,118	15,897
Talent	3	2,586	11,387
African	4	2,129	11,610
Waimanalo (1 year, 10 ratoons)			
Rhizoma	1	4,343	20,800
Indian	2	4,094	20,689
Talent	3	3,697	18,356
Hairy Peruvian	4	3,649	17,631

Table 5. Yield performance of alfalfa varieties at Poamoho Station, Oahu, 1949–51, pounds per acre per year (Younge, 1952).

Variety	Protein	Relative yield of protein	Dry matter	Fresh material
Narragansett	3,410	100	19,280	77,120
Rhizoma	3,410	100	18,390	73,560
Williamsburg	3,090	91	18,300	73,200
Hairy Peruvian	2,800	82	18,370	73,480
Arizona Chilean	2,790	82	18,280	73,120
Ranger	2,530	74	14,880	59,520
Grimm	2,450	72	13,750	55,000

Table 6. Yields of alfalfa varieties at Volcano Experimental Farm, Hawaii. First harvest July 14, 1964; five cuttings to Jan. 4, 1965 (Rotar, *et al.* in press)[1].

Variety	Total green forage yield tons per acre	Dry matter yield tons per acre
Du Puits	40.0	4.7
Williamsburg	33.0	4.2
Atlantic	27.9	3.6
S. W. Common	27.8	3.4
Moapa	26.7	3.3
Terra Verde	25.6	3.3

[1] Elevation 4000 feet; annual rainfall 100 to 147 inches; solar energy range = 196 – 786 calories per cm^2 per day, although overcast conditions prevail; average monthly maximum temperatures are from 65 to 70 F during summer and from 55 to 65 F during winter. All plots received potassium at 300 pounds per acre, boron at 10 pounds per acre, molybdenum at 1.25 pounds per acre, and phosphorus at 500 pounds per acre.

committed, and even the variety planted will be affected by the kind of marketing arrangements made.

Following are a few basic practices growers should become familiar with, and a list of equipment needed (Goodell and Wallis, 1957).

Clearing land and preparing seedbed

Alfalfa oftentimes is planted on uncleared land or land that has been allowed to revert to trees or brushy growth. Cost of clearing will depend upon the type of material to be removed. An alfalfa field must be fairly level and free of obstructions if the crop is to be handled with machinery. Surface rocks, pieces of tree limbs or roots, or other debris can seriously damage mowers, crimpers or hay balers and cause expensive delays. It may be necessary to walk through the field and clean up this loose material by hand. The amount of time saved in later operations will make the effort worthwhile. Equipment needed–large crawler tractor and bulldozer blade.

In preparing the seedbed, give the land one deep plowing or disking with tractor and disk plow.

Follow this with three or four shallow diskings, spaced 2 weeks apart to allow time for weed seeds to sprout. Equipment–tractor and common disk harrow. Note: If the crop is to be irrigated, irrigation pipes should be in and sprinkler equipment should be available before starting to prepare the seedbed. A light irrigation 1 week before each disking will stimulate germination of weed seeds.

Fig. 5 – Alfalfa grown at Volcano Experimental Farm. At these higher elevations (4000 feet at Volcano) fewer crops per year will be possible. Also, the crop may be very low in dry matter, often below 20 percent. (Photo courtesy O. R. Younge)

Seeding rates

For optimum stand and yield in Hawaii, 20 pounds of seed per acre are recommended; such a seeding rate will provide about 100 seeds per square foot. This is somewhat higher than in many Mainland alfalfa producing areas, but experience has shown that a large plant population per acre and optimum moisture and nutrient conditions are the best insurance against weed infestation. A thick stand of vigorously growing alfalfa can hold its own with most weeds.

Inoculating the seed

Alfalfa, like other legumes, has the ability to take nitrogen out of the air and fix it in the plant. This is done through the help of nitrogen-fixing bacteria that form small nodules on the roots of the plant. Soil that has never grown alfalfa before cannot be counted on to have these bacteria. However, the seed can be treated with a commercial alfalfa inoculum that usually is prepared in powder form. Dampen the seed and mix thoroughly with the commercial inoculum powder to ensure that some of the bacteria will be sown with each seed. If the bacteria are located near the young seedlings in the soil, they may quickly infect the plant roots and promote rapid seedling growth.

In pot experiments, Sherman and Chang (1954) found that highest alfalfa yields were obtained with inoculated seed grown on a limed (2 tons of hydrated lime per acre) soil of the Wahiawa series.

Another method of inoculating alfalfa seed is to pellet the seed with an adhesive and lime (Plucknett, 1971). Prepare an adhesive solution (5 percent methyl ethyl cellulose is satisfactory). Mix the inoculum with part of the prepared adhesive solution and add to the seed which is being tumbled in a small cement mixer. Add just enough more of the adhesive to coat all of the seeds. Then add sufficient lime to coat the seeds. The pelleted seeds can be stored overnight to dry before sowing.

Seed treatment

Alfalfa can have a high percentage of hard seed–seeds that do not germinate readily because the seed coats are impermeable to water. If many of the seeds are hard, it may be necessary to scarify the seed by scratching the seed coat. Some seed companies scarify seed before sale, but scarified seeds do not remain viable for long and should be sown quickly before germination percentages decline.

If a fungicide is used on the seed to prevent damping off of the seedlings, care should be taken to ensure that the fungicide will not kill the rhizobia in the inoculum.

Time of seeding

Time of year for sowing is not as important in Hawaii as it is on the Mainland. Alfalfa grows here the year around, but there is considerable difference in growth rate in summer and winter months. It is desirable to get a fast growth and heavy stand so that weeds do not get a headstart over the alfalfa. From this standpoint, a crop started during the spring or summer months is likely to have an advantage over one started in winter.

Depth of seeding

Alfalfa should not be planted more than ½ to 1 inch deep. When seed is broadcast, it should be just covered with soil. In sandy soils, an alfalfa seedling may emerge from as deep as 2 inches, but this could not happen in heavy clay soils.

Methods of sowing

The seed can either be drilled in 6- to 8-inch rows, or broadcast on the surface and covered by dragging with a spike-tooth harrow.

Equipment for drilling–tractor and common grain drill with grass seed attachment.

Equipment for broadcasting–small broadcast or "Cyclone type" seeder (Figure 6) followed by tractor and spike tooth harrow.

Fig. 6 – Alfalfa can be planted with a conventional grain drill; however, a small rotary hand seeder, such as this machine at Kekaha Sugar Company Ltd., can also be used successfully.

Fig. 7 – Postemergence weed control with eptam at 4 pounds per acre (left) and 2,4-DB at 1 pound per acre. Note untreated weedy border at the rear. New herbicides make selective weed control possible, even for seedling alfalfa. These treatments were applied 7 days after seeding; the photograph was take 48 days later. (Photo courtesy O. R. Younge)

Rolling will help to cover the seed, conserve moisture, and make a firm seedbed which is desirable. If the crop is to be irrigated immediately following seeding, the rolling operation is unnecessary.

Equipment—tractor and roller.

Early care of the planted field

The field should be irrigated regularly and carefully during the growth of the seedling crop which may take 50 to 60 days to mature. Light but frequent irrigations, perhaps as many as two or three per week, should keep the soil moist for the tender young plants. In heavier soils, a moist soil surface will help prevent crusting of the surface that may deter seedling emergence.

Other problems that may arise during this period could include weed competition or attack by diseases or insects.

Weed control

One of the most common problems of alfalfa production in Hawaii is weed competition (Goodell, 1956). When allowed to get out of hand, weeds can cause serious trouble and shorten the productive life of the stand (Younge, 1958). The kind of weeds depends upon the soil and weather conditions. Some of the most common weed pests include sand burr *(Cenchrus echinatus),* spiny amaranth *(Amaranthus spinosus),* hilograss *(Paspalum conjugatum),* and some of the hardier pasture grasses such as bermudagrass *(Cynodon dactylon)* and kikuyugrass *(Pennisetum clandestinum).* Weed growth does not need to be a problem, however.

Herbicides are available that can provide good weed control for alfalfa. Preemergence herbicides cleared for use are benefin, eptam, CIPC, isopropyl N-phenylcarbamate and planavin. In Hawaii, eptam can provide good preemergence control (Figure 7). For postemergence control of grass weeds, dalapon is probably most suitable. For broadleaved weeds, the butyric relative of 2,4-D (often referred to as 2,4-DB or 4-(2,4-DB)) can be used successfully with little injury to the crop. A contact postemergence herbicide is DNBP and its derivatives which can be applied directly following harvest and before any new growth appears. Eptam also can be applied as a postemergence treatment, as can CIPC and trifluralin. To be sure of current information on the best materials to use, it is best to check with your county agent. For safe handling be sure to follow the directions on the label.

Insect and diseases

Insects have not been a serious problem in Hawaii (Goodell and Hosaka, undated). The lack of insect buildup is probably at least partially due to the lack of extensive plantings of alfalfa in any single area. The pea aphid and grasshopper have shown significant population buildup from time to time but so far have not caused serious damage. Hawaii has managed also to remain free of the spotted alfalfa aphid which has become a serious pest in southern states on the Mainland. Several insecticides are cleared for alfalfa.

Nematodes have been known to attack alfalfa roots but there has been no report of serious damage.

Diseases common in alfalfa on the Mainland have not been serious in Hawaii. Bacterial wilt, one of the most serious of these diseases, causes stunting and wilting of the plants. Root rot and crown rot are caused by the invasion of microorganisms into plants through bruised or injured areas, such as crowns crushed during harvesting.

Leaf spot, anthracnose and downy mildew tend to flourish during periods of rainy weather or high humidity. Most modern alfalfa varieties have resistance to at least some of the above diseases.

Specific soil problems

Lime will probably be required for all soils except the coral sands or coral flats. The soil reaction should be at least pH 6.0 or higher for best production. Lime requirements for most of Hawaii's soils have been worked out (Sherman et al., 1946; Foster and Matsusaka, 1952; Matsusaka and Sherman, 1964). Lime should be applied only after obtaining the results of a soil test. For some soils, only 1 to 2 tons of a liming material may be required; however, for very acid soils or for soils that have a high resistance to pH change by additions of lime, much higher rates may be needed. Liming materials available in Hawaii include crushed coral stone, coral sand, hydrated lime, and press cake from sugar purification at sugar mills (Younge and Plucknett, 1964).

Phosphorus

Alfalfa has often failed on some soils, and many times this may be due to low soil phosphorus (Younge, 1960) (Figures 8 and 9). In soils other than the coral flats, the crops become sparse and weakened after the first year, resulting in bare spots and open stands that are readily invaded by weeds. Dr. Otto R. Younge's statement (1960) still stands: "Indeed, the ultimate test for the green thumb in Hawaii is the ability to maintain a productive stand of alfalfa on noncoral soils over a period of years."

Hawaii's soils, notably the red and brown lateritic soils belonging to the Gibbsiorthox, Tropohumults, and Hydrandepts, are noted for low phosphorus (P) availability and for their tremendous capacity to "fix" or tie up P in forms unavailable to the plant.

According to Younge (1960), a ton of alfalfa hay will remove about 0.1 to 0.5 percent P on a dry matter basis, or from 2 to 10 pounds of P per ton. For a 12-ton per acre per year yield, this nutrient removal could amount to from 24 to 120 pounds of P per year. Assuming a mean value of 60 pounds of P removed per year, he estimated that 625 pounds of superphosphate would be

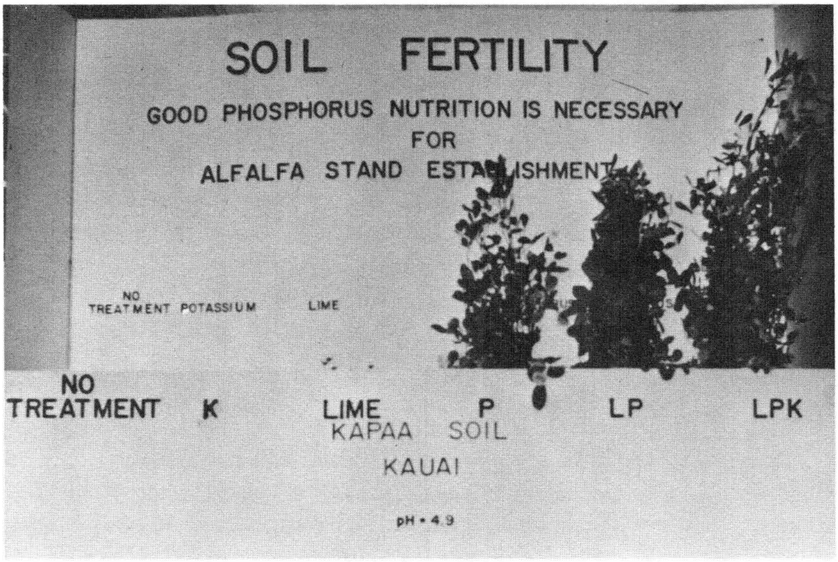

Fig. 8 – An illustration of the need for phosphorus (P), lime (L) and potassium (K) for alfalfa establishment on upland soils on Kauai. These acid soils readily fix large quantities of phosphorus.

Fig. 9. – Poor stands of alfalfa grown on a phosphorus-fixing soil high in aluminum and iron, Kauai Branch Station. Only poor to fair stands resulted with heavy phosphorus fertilization (more than 500 pounds P per acre). This photograph illustrates a main difficulty in growing alfalfa on upland soils.

required just to replace P removed in the harvested forage.

In experiments at Waimanalo, Younge (1960) obtained significant increases in yield with higher levels of P fertilizer. From these results he concluded that just adding P removed in annual cropping may not be adequate for Hawaii; when 110 pounds of P per acre were applied, stands declined and weeds still invaded. However, he concluded that P at 143 and 243 pounds per acre could be profitable, provided hay prices were $20 and $30 per ton, respectively. Higher rates of P also resulted in increased growth and vigor of alfalfa and slowed weed invasion.

The effects of lime on P availability are discussed in the section on liming.

Potassium

Alfalfa is a heavy feeder of potassium (K). One ton of dry forage may remove as much as 35 to 40 pounds of K (about 45 pounds K_2O) from the soil. With good yields in Hawaii reaching about 12 tons, this means that 420 to 480 pounds of K per acre per year may be removed from the soil. If the soil is low in K, this requirement must be supplied through fertilization. In commercial production, Molokai Ranch Company applied about 100 pounds K per acre once a year (Henry Meyer, Personnal communication), while Kekaha Sugar Company applied 200 pounds K per acre per year.

Plants deficient in K will show spotting of the outer margins of the leaf, sometimes followed by a marginal or tip burn. Older leaves may drop early, reducing crop quality.

Potassium is applied most frequently as muriate of potash (potassium chloride) or as potassium sulphate.

Boron

Boron (B) is essential for good alfalfa growth and is usually the micronutrient most likely to be a problem in the crop. Boron is less available in soils with high pH, therefore liming the soil may decrease B availability. Minimum soil levels of B for alfalfa are probably about 0.35 ppm (water soluble); however, 0.9 ppm is more than is needed (Bear and Wallace, 1950).

Plants deficient in B show twisted and deformed tip bud growth, bleached or chlorotic leaves that sometimes may become reddish, bright yellow or purple, and also rosetted or bunched and packed growth of the young tips (Bolton, 1962) (Figures 10 and 11). Severe B deficiency may result in complete failure to obtain a stand (Younge, 1952).

In most of Hawaii's soils, B will be required to grow alfalfa (Younge, 1952). Borax can be used to supply B—as much as 50 pounds of borax per acre may be required for most soils. For some soils, however, as much as 100 pounds of borax per acre may be needed. Younge (1952) recommended an annual topdressing of 20 pounds of borax per acre in the fall for soils that require B for good alfalfa production.

Fig. 10 – Boron deficiency in alfalfa. Young leaves are yellow or bronzed and somewhat distorted.

Fig. 11 – Manganese toxicity in kaimi clover *(Desmodium canum)* on a Wahiawa soil, which was corrected by adding boron. Note leaf distortion and small size of plants without boron (right).

Molybdenum

Molybdenum (Mo), a micronutrient that is very important for good legume growth, is essential for good nodulation and nitrogen fixation. In Hawaii Mo can be deficient for good legume growth, especially for alfalfa. Younge and Takahashi (1953) discovered Mo deficiency on Eutrustox, formerly a low humic latosol, (Wahiawa series) at Poamoho. In these experiments 2 pounds of Mo, as ammonium molybdate, increased dry matter production 146 percent and protein production 163 percent. Among 13 varieties used, Hairy Peruvian, Kansas Common, and Atlantic showed greatest response to Mo. In the year after the original applications, an additional 2 pounds of Mo per acre caused a 52 percent increase in production over the first year; this indicated that the rate of 2 pounds Mo per acre was not sufficient to meet the requirement.

Any alfalfa grower in Hawaii should use Mo in his fertilizer program. He should apply as much as 4 pounds per acre at the start. Sodium molybdate, a satisfactory material, supplies 1 pound of Mo in 2.6 pounds of the commercially available material.

Younge (1952) described alfalfa plants deficient in Mo as lacking a dark-green healthy color, light green, indicating poor nitrogen nutrition. Yields decline, recovery after cutting is slow, and some plants yellow and die. Recovery can be dramatic when a molybdate solution is applied on deficient plants. After an initial application of 2 to 4 pounds Mo per acre, it may be necessary to apply ½ to 1 pound per acre each fall for subsequent crops.

Zinc

Zinc (Zn) deficiency may appear in soils with high pH, especially after liming of the soil. Plants deficient in Zn may be stunted and have chlorotic and sometimes deformed new tip growth (Figure 12).

Younge and Plucknett (1963) reported Zn deficiency on an old stand of alfalfa on coral sand flats at Kekaha Sugar Company. The tips of the plants were yellow and chlorotic, and new leaves and shoots were somewhat crinkled and twisted. Zinc at 0 to 40 pounds per acre, as zinc sulphate, was topdressed after harvest in August. Yield increases as high as 38 percent were obtained at about 17 pounds of Zn (Figure 13). This yield increase amounted to one-fourth ton of dry forage per acre per cutting. It was suggested that 2 to 4 pounds Zn per acre per year should be sufficient to maintain high yields.

Size of operation

Alfalfa lends itself well to mechanization. In fact, production costs are prohibitive unless the operation is mechanized. With this investment in machinery, a farmer should plan to be growing alfalfa on at least 50 acres in order to efficiently use his equipment. For small farmers, there is great

Fig. 12 – Leaf crippling and distortion caused by zinc deficiency. Leaves are small, distorted, very pale green.

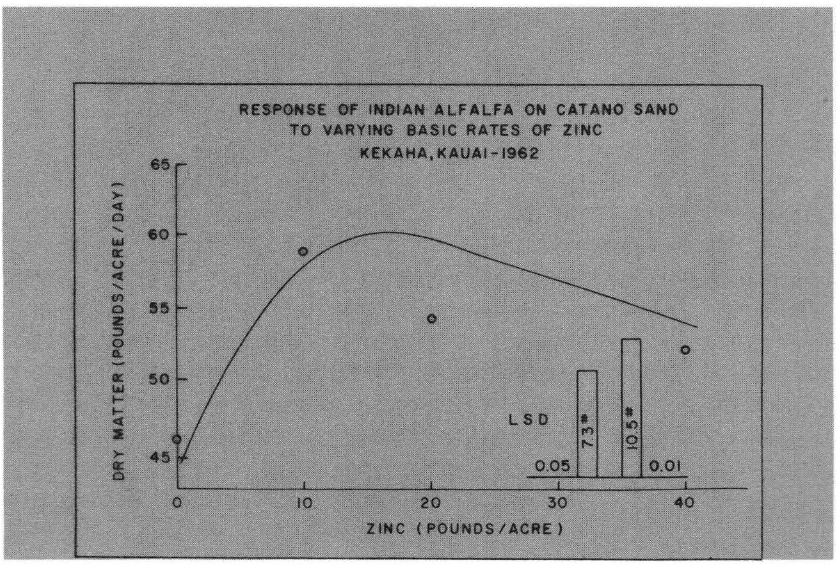

Fig. 13 – Yield response of an old stand of alfalfa, when topdressed with zinc sulfate after harvest. The test period began in August and included three ratoons in 100 days. Maximum yield increases of 38 percent occurred at 17 pounds of zinc per acre, which is highly significant at the 0.01 percent probability. Untreated alfalfa exhibited some crinkling and twisting of leaves and stems, suggesting zinc deficiency (Younge and Plucknett, 1963).

economic advantage in cooperative purchase of the more expensive pieces of equipment that have the capacity to serve the needs of more than one farmer.

Production costs

Cost studies together with the cost figures of commercial operations indicate that, under proper management and with present prices, alfalfa can be produced competitively with the imported product. Many factors must be considered: land, rainfall, availability of good irrigation water, nearness to market, and type of end product (dry or green).

The cost of harvesting, hauling, dehydrating and grinding alfalfa meal can run between $30 and $35 per ton. At this cost, it should be possible to produce a locally grown dehydrated product that would compete with West Coast prices plus shipping costs. One of the popular forms of marketing alfalfa in Hawaii has been as freshly chopped green material. This works out best, of course, when the alfalfa operation is near the potential buyer, such as a dairy or a feedyard, thus cutting down hauling costs. Prices for green-cut alfalfa range from $12 to $15 per ton, depending upon quality.

Harvesting methods and frequency

Alfalfa may be ready for harvest in as short a period as 28 days in summer to 35 or 40 days in winter, or an average of about 33 days. Alfalfa usually is harvested when at least some of the plants have produced flowers. Recommendations for the best time to harvest alfalfa are usually given in percentages of the crop that has produced flowers. On the Mainland it is frequently from the one-tenth to one-half bloom stage, or when from one-tenth to one-half of the crop has flowered. At this time of maturity, food reserve levels in the roots have built up enough to allow good regrowth potential in the next crop. Too early or too frequent cutting, for example cutting at every 21 days or so, will quickly exhaust root reserves and plants will begin to die and thin out.

Wilsie and Takahashi (1937) studied cutting frequency for Hairy Peruvian in Hawaii. They found that highest yields were obtained when the crop was harvested at full bloom stage, and that cutting at one-tenth to one-quarter bloom gave higher yields than cutting at the bud stage. They concluded that, in addition to higher yields, stand persistence was greatest when cut at full bloom. For hay production, however, cutting at full bloom may cause the crop to be very stemmy, to lose leaves and protein, all of which would result in lower quality feed.

It appears that cutting at one-fourth to one-half bloom in Hawaii should provide high quality forage and still allow long stand persistence.

Alfalfa may be harvested in several ways but, except for greenchop production, most methods require mowing, crimping and windrowing. Baling can follow field drying in the windrow. Cubing or pelleting may also be done

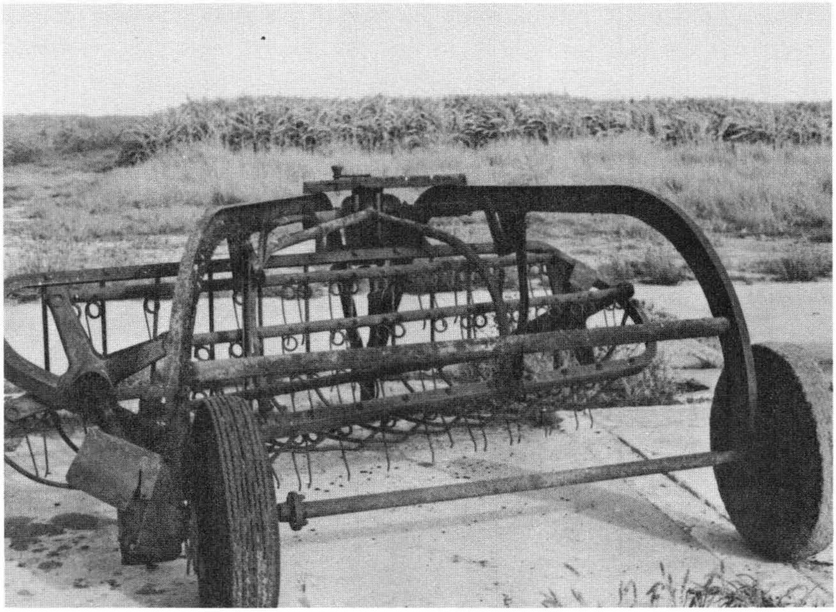

Fig. 14 – Side-delivery rake may be used to rake into windrows and also to turn drying hay in the swath.

Fig. 15 – Hay drying in the swath (foreground). In the background are bales in the process of being loaded and hauled to storage.

from a windrow. If a stationary pelleting machine is used, the forage must be hauled to the pelleting machine.

Alfalfa greenchop can be made using a flail-type forage harvester to cut and load on self-unloading trucks or wagons which then will haul the greenchop to the feedyard or dairy.

Crop drying

A major problem of alfalfa production is adequately drying or curing the crop after harvest. The prevailing high relative humidity in most areas makes field drying of hay very difficult, often resulting in molding and spoiling in the field, or in some cases spoiling of the baled hay. Improperly dried hay, if stored in enclosed areas, generates a surprising amount of heat. Such hay has been know to ignite spontaneously and cause fires. This problem is much more severe during winter when humidity and rainfall are usually highest. Heavy dew can also be a problem. Younge and Takahashi (1954) stated that artificial drying would be essential for alfalfa on the Waimea Plain on Hawaii.

Field drying requires mowing of the crop, "crimping" or crushing the stems to allow better drying, and raking the mown crop into windrows (Figures 14, 15). In the windrow or swath, the hay should dry in the sun to less than 20 percent moisture before baling (Figure 16). The windrow must be turned with a side-delivery rake at least once to prevent spoilage of the underside that is in contact with the soil.

Younge and Takahashi (1954) recommended a harvest system that would use a harvester/chopper in the field, wagons to haul the chopped fresh forage from the field, and a rotary dryer to dry the forage from 70 to 80 percent moisture down to 12 to 15 percent to prevent spoilage. At that time a commercial alfalfa dryer required at least 8000 tons of fresh forage per year, or 2500 tons of dry matter. The crop area required for this production was estimated at 300 to 400 acres.

In its hay production operations, Molokai Ranch Company depended upon natural field drying, with usually good results (Henry Meyer, Personal communication). During rainy weather, however, they had great difficulty in field drying the hay and also in the mechanical operations. Under near-sea-level conditions at Kaunakakai, the following schedule was followed in hay production: Mow and crimp on Monday; rake into windrows on Tuesday as soon as the dew evaporated; rake again on Wednesday, bale, load and ship the bales on the barge to Honolulu in the afternoon. It is more practical to start mowing and baling operations after the dew is off in the morning. Baling can then continue into the evening when dew again becomes a problem.

For baling the hay, 15 percent moisture is desirable. If above 20 percent moisture, spoilage can occur.

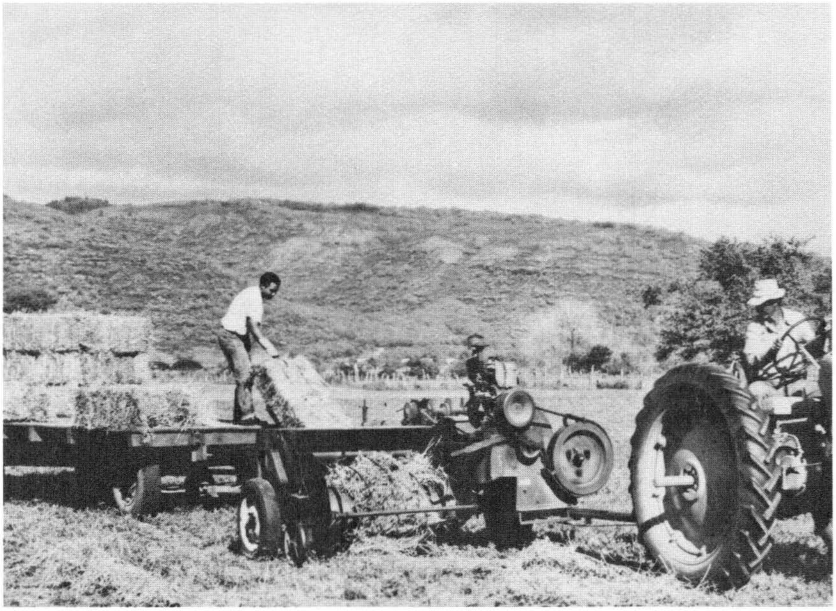

Fig. 16 – Baling and loading alfalfa at Kekaha Sugar Company Ltd. Note windrow in the foreground. (Photo by Charles Kaneyama, Kekaha Sugar Company)

Fig. 17 – Harvesting alfalfa by forage chopper at Kekaha Sugar Company Ltd.

Fig. 18 – Kekaha Sugar Company Ltd. self-unloading truck unit (see also Figure 17) dispensing greenchop alfalfa into feed bunks at Meadow Gold Dairy, Waimea, Kauai. Such trucks can save much time and labor in a well-planned greenchop production system.

In wetter areas, the advantages in harvesting the crop as a fresh-cut greenchop cattle feed become obvious. Figures 17 and 18 show some steps in greenchop production.

Economic considerations

The decision to embark on an alfalfa operation must be based upon the same economic considerations as any other business enterprise. Many of the inputs will vary in size and relative importance, depending upon the individual situation. In the final analysis then, the farmer must build his own balance sheet and make up his own mind.

Included in the following pages are labor and equipment time studies and general cost estimates of various prices of field equipment which should be helpful as management decision guidelines. Another publication dealing in more detail with economic factors of production will be forthcoming. Approximate machinery hours and man-hours required for various alfalfa operations are from work studies made at Kekaha and represent output at 75 percent efficiency.

A. **Establishment** (**requirements for 1 acre of 75 acres**)

1. **Preplant**

Operation	No.	Equipment	Equip. hours	Man-hours
Deep plow	1	Crawler tractor & towner plow	1	1
*Diskings	4	Wheel tractor & light disk	2	2
*Irrigations	4	Electric pump & sprinkler	8	1

*These are alternate diskings and irrigations to sprout weeds.

2. **Planting (up to first harvest)**

Operation	No.	Equipment	Equip. hours	Man-hours
Fertilize	1	Flat bed trailer, tractor, fertilizer spreader	1/3	2/3
Harrow	2	Tractor & harrow	1/2	1/2
Broadcast seed	1	Knapsack type seeder	2/3	2/3
**Irrigations	9	Electric pump & sprinkler	17	2¼

**Best results were obtained when irrigations were shallow and frequent until crop was established; hence the 9 irrigations during the first 2 months. This would not necessarily hold true in heavy soils.

B. **Production and Harvest** (**requirements for 1 acre of 75 acres**)***

Operation	No.	Equipment	Equip. hours	Man-hours
Irrigations	2	Electric pump & sprinkler	6	1/2
Harvest (baled dry hay)				
Mow	1	Wheel tractor & mounted mower	1/3	1/3
Rake	1	Wheel tractor & side-delivery rake	1/4	1/4
Turn	1	Wheel tractor, side-delivery rake	1/4	1/4
Bale	1	Wheel tractor, baler, flatbed trailer	1	1
Harvest (green)	1	Wheel tractor, forage harvester, feed truck	1	1

***Note: These are man-hour requirements for one harvest cycle only.

C. Equipment Investment Costs

The cost of obtaining equipment for a new agricultural operation is significant and can be the deciding factor in determining whether or not to go into production. To provide the prospective grower with an idea about the general cost of alfalfa equipment, the following estimates have been obtained from a farm equipment company. (Please note that these are suggested FOB factory prices.)

50-horsepower rubber-tired tractor	$7500
Pull-type mower-conditioner	3000
Twine tie baler (PTO)	4000
Side-delivery rake	800
Self-propelled windrower-conditioner	5500
Disk harrow	1700
Four bottom plow	900
Grain drill	1000
Knapsack-type cyclone seeder	15
Flail chopper	1850
Forage feeder wagon	1800
Forage harvester	3000

The above equipment would be used if alfalfa is to be marketed as greenchop or baled hay. If it is to be marketed as cubes or pellets, other equipment investment will be required.

Cubing of alfalfa directly from the field produces a "slug" or wafer that is ordinarily larger than the ground alfalfa pellets. The major piece of equipment in this process is the cubing machine. It may be stationary or it may move through the field picking up the hay from the windrow. Cost of this machine may range from $25,000 to $35,000 depending upon its capacity and extra features incorporated.

The production of ground ***alfalfa pellets*** involves large scale and expensive pieces of equipment such as dehydrators, hammer mills and pelleting machines. Such an operation involves much larger investment, both in machinery and labor, than any of the other processes. To be economical, a dehydration-pelleting operation must be built on large volume and deserves a more complete study than can be made here.

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