TECHNICAL BULLETIN NO. 59 JUNE 1964

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HONOLULU, HAWAII JUNE 1964

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ACKNOWLEDGMENT

Grateful acknowledgment is made to K. Murakami, Farm Manager, Haleakala Experimental Farm, and staff for supervision of experiments on the island of Maui, and to the management of Hawaiian Commercial and Sugar Company for use of lands at Halehaku, Maui.

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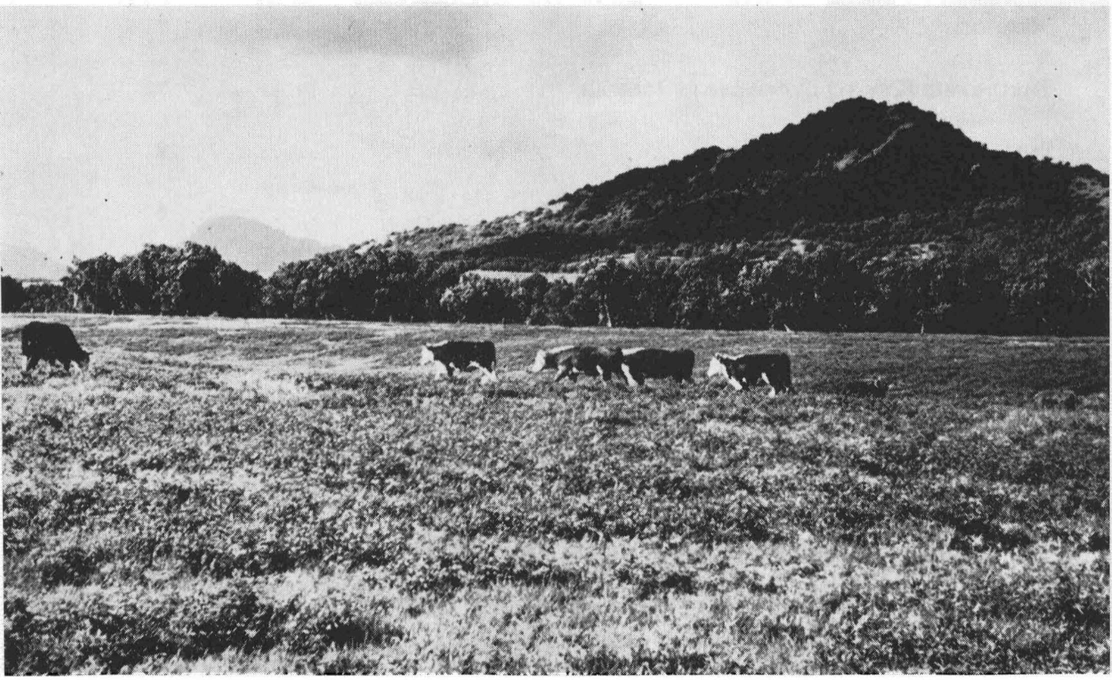

Young cattle pastured on mixed kaimi clover (dark vegetation) and kikuyugrass (light, low vegetation). Fairly productive pastures requiring minimum care can be established from mixed planting of kikuyugrass and kaimi clover. Such pastures withstand severe overgrazing and underfertilization and yet far exceed unimproved range in productivity.

Culture and Yield Performance of *Desmodium intortum* and *D. canum* in Hawaii

O. R. Younge, D. L. Plucknett, and Peter P. Rotar

INTRODUCTION

Forage production in tropical and subtropical areas is dependent upon productive, well-adapted, and hardy forage species of good nutritive value. In the tropics many desirable grass species are capable of producing good forage under widely varying conditions of climate and soils. Such is not the case, however, with tropical legumes. Little information is available on desirable tropical legumes which can produce good forage while persisting in a mixture with the more aggressive grasses. In addition, little specific information is known about nitrogen-fixation capacity, fertility requirements, forage yields, and grazing management for legumes in tropical areas.

In Hawaii there has been considerable interest in finding desirable legume species for the wide array of climatic zones and especially for the potentially productive humid lowland regions. The humid lowlands are located in vegetation zones C1 and D1 (*10*), and comprise an area something less than one-half million acres. Few desirable forage legumes are currently used in this area, because of difficulties in establishing and maintaining a legume in competition with aggressive weedy vegetation under conditions of very low soil fertility.

Often in the tropics, forage species tested with success in one area are not suitable for other areas, and frequently legume species thought to be wayside plants or weeds in some situations may be valuable forage species elsewhere. Such is the case with intortum (*Desmodium intortum* (Mill.) Urb.) and kaimi clover (*Desmodium canum* (Gmel.) Schinz and Thellung), which are the subject of this report.

At this time no definitive report exists, in the world literature, on the culture, yield, and utilization of any *Desmodium* species. This report attempts to supply some information on the economic potentials of some *Desmodium* species under Hawaii conditions.

LITERATURE REVIEW

The genus *Desmodium*, to which kaimi clover, spanish clover (*D. sandwicense*), and intortum belong, is a large genus of legumes of about 500 species distributed throughout the temperate and tropical regions of the world. Despite the considerable number of species, only a few are recognized for their forage value. Probably the best-known species in the northern areas is tickclover or beggarweed, *D. tortuosum*, a short-lived perennial stemmy herb attaining a height of 4 to 7 feet, which is the only *Desmodium* grown commercially on the U.S. mainland. It has been grown there on a small acreage since about 1890, chiefly for grazing, but is used also as a cover crop or game bird feed, and for hay, which is difficult to cure (*12*). Several temperate zone *Desmodium* species are useful for soil conservation or as a source of food for game birds (*6*).

Many of the *Desmodium* group are indigenous to and widely distributed throughout South America (*18*, *24*), where many species constitute small but important parts of the forage and browse of the native grasslands. Several research centers report various species under observation but none of the centers quote their commercial culture.

In Hawaii the first *Desmodium* species of record is *D. tortuosum*, Hawaii Agricultural Experiment Station accession No. 839, introduced from New York in 1913 (*1*). Since this first introduction, the HAES has introduced nearly 150 selections from about 50 species for observation and potential utilization in agriculture.

The first recognition of the potentials of kaimi appeared in Hawaii in 1945 (*8*), covering such aspects as adaptation, establishment, and maintenance in pasture, seed production, and harvesting. Further information stated that kaimi spread rapidly in rangelands, because the seeds were ingested by cattle and later distributed in the droppings, and also the hairy seed pods adhered to wandering animals (*11*).

In 1956, kaimi was reported to perform well in improved pastures when mixed with kikuyu, pangola, dallisgrass, and native grasses (*22*). Moderate liming and fertilization also gave marked responses in yield and quality of the various forage components.

Elsewhere, the only reported observation on kaimi comes from Brazil (*7*), where the legume is stated to be the most important forage legume in the southern areas during the summer.

Intortum was first introduced into Hawaii in 1947 when several strains were brought in from different areas of tropical America by the HAES. The legume produced seed readily and was readily established by direct seeding (*23*). By 1952, three well-developed strains of intortum had been selected (*21*).

Intortum performs well in combination with pangola in Hawaii (*9*, *22*, *29*). Several compatability factors comprise high palatability, rapidity of recovery after grazing, trailing growth habit, and high productivity.

Following the discovery of toxicity in *Indigofera spicata* (*I. endecaphylla*) (*14*), or creeping indigo, as it is known in Hawaii, the question of potential toxicity of *Desmodium* to livestock was also investigated. Assay of potential toxicity was made by using the test forage in chick rations, in comparison with alfalfa. Of the 28 selections from 18 species of *Desmodium* assayed, only 1 selection showed slight toxicity, whereas 8 selections showed stimulant values exceeding those of alfalfa by 10 percent or more (*1*).

Elsewhere, some interest has been shown in intortum in recent years. In Guatemala, dehydrated intortum in experimental rations for baby chicks and rats has been reported (*20*); also, intortum was under test where volunteer stands were observed in former corn areas (*19*). Intortum has recently been introduced into Australia, where it is reportedly defoliated by light frosts. Growth of intortum in Australia does not begin until September, when the warm weather starts (*5*). Recently introduced into Taiwan, intortum has shown some adaptation to areas below 1000 meters in altitude in central and northern regions, where it appears promising in mixture with pangola (*3*).

METHODS

In this report an attempt has been made to provide a taxonomic key to the *Desmodium* species found in Hawaii. The description and culture of intortum and kaimi clover are given in detail, as observed under Hawaii conditions.

The results of six field experiments on various aspects of yield performance of intortum and kaimi clover, with or without admixtures of adapted grasses, are also presented. The experiments were conducted over the period 1951–61 at five sites on Oahu, Kauai, and Maui, in medium- to high-rainfall areas at elevations below 2200 feet. For each test site the specific conditions for the experiment have been presented in the section on experimental results. To facilitate interpretation and comparison of diverse field data, all results are reported on the annual acre basis.

The various fertilizer materials utilized were commercial grade except that technical-grade materials were used for molybdenum and zinc. Dry matter and chemical analyses based on standard methods are reported on material dried at 70° C., unless otherwise indicated.

Forage yields were obtained by clipping and weighing the top growth from measured strips in the various test plots. Representative samples of the clippings were taken for further analyses in the laboratory.

The beef cattle used in the grazing experiments were improved grade, long yearling ranch cattle. They had free access to salt, bonemeal, water, and grazeable forage. At the time of purchase they averaged about 500 pounds in weight and when sold about a year later, generally weighed about 1000 pounds. They were inspected and weighed at every change in rotational grazing.

TAXONOMIC KEY TO *DESMODIUM* IN HAWAII

In order that the *Desmodium* species common to Hawaii may be identified, the following key is presented. The local *Desmodium* species are herbaceous to shrubby plants with trifoliate leaves and with seed pods indented and chainlike.

KEY

1. Erect or semierect plants.
   2. Fruit segments circular; stems and petioles densely pubescent; leaflets oval to ovate. (Giant beggarweed.)
      —*D. discolor*.
   2. Fruit segments rectangular or not symmetrically circular; leaflets lanceolate; flowers yellowish or pinkish, arranged on open panicles; pods twisted, 2- to 6-jointed, joints rounded. (Florida beggarweed.)
      —*D. tortuosum*.

1. Creeping or prostrate plants.
   2. Leaflets with white-colored area along midrib.
      3. Leaflets round to oval on prostrate stem, lanceolate on upright stem; flowers red or lavender; seed pod notched only on lower edge. (Kaimi clover, kaimi spanish clover.)
         —*D. canum.*
      3. Leaflets ovate or narrower; flowers white, greenish-white, or slightly pink; pods notched on both upper and lower edges. (Spanish clover.)
         —*D. sandwicense.*[1]
   2. Leaflets without white-colored area along midrib.
      3. Leaflets oval to obovate, cloverlike; flowers clustered at leaf bases, usually three together, pink or purplish; pods curved, 3- to 6-jointed. (Three-flowered beggarweed.)
         —*D. triflorum.*
      3. Leaflets ovate; flowers purplish-pink; pods notched on upper and lower edges. (Intortum.)
         —*D. intortum.*

PLANT DESCRIPTIONS

Intortum

Intortum is a perennial decumbent plant with long, creeping stems which readily root at nodes approximately 4 inches apart (fig. 1). The long, reddish-brown, pubescent branching stems are often 15–20 feet long, and $\frac{3}{16}$ inch in diameter. The leaves are ovate, and 2–3 inches wide and 2.5–4 inches long when mature. The upper leaf surface is dark green with very fine gray hairs; the lower surface is grayish-green with many fine white silky hairs. Young leaves are usually fine silky pubescent. Mature leaves are larger in summer, smaller in winter.

In the short-day period, December to March, intortum blooms and sets seed. The flowers are purplish-pink when mature, ¾ inch long by ⅜ inch wide, and are borne on terminal portions of upright stems 1–2.5 feet high. The flower is complete and self-fertile, and produces a serrated pod with 8 to 12 seeds. A few flowers are also borne on short stems arising from some of the upper leaf axils. The inflorescence is a raceme. Older petals rapidly turn blue before dropping. The pod (a loment) is 1–1.5 inches long and less than ⅛ inch wide, and is covered with short brown hairs which give it a furry appearance. Both the upper and lower sutures of the pod are notched, with the lower suture more deeply notched than the upper. The pod easily breaks apart into 8 to 12 segments, each of which yields one seed. The light-brown seed is kidney-shaped and about 1.5 mm long and 1 mm wide. About 385,000 intortum seeds weigh 1 pound. Some of the seeds are hardcoated and remain dormant when planted; however, the percentage of hard seeds is usually greatly reduced in the process of mechanical threshing and the seeds do not require further scarification.

Intortum is native to Central and South America and was first introduced into Hawaii in 1947 (*23*). In test plantings conducted in various areas, intortum showed

[1]Formerly this was called *D. uncinatum,* but based on recent taxonomic authority it has been found that the proper classification is *D. sandwicense.*

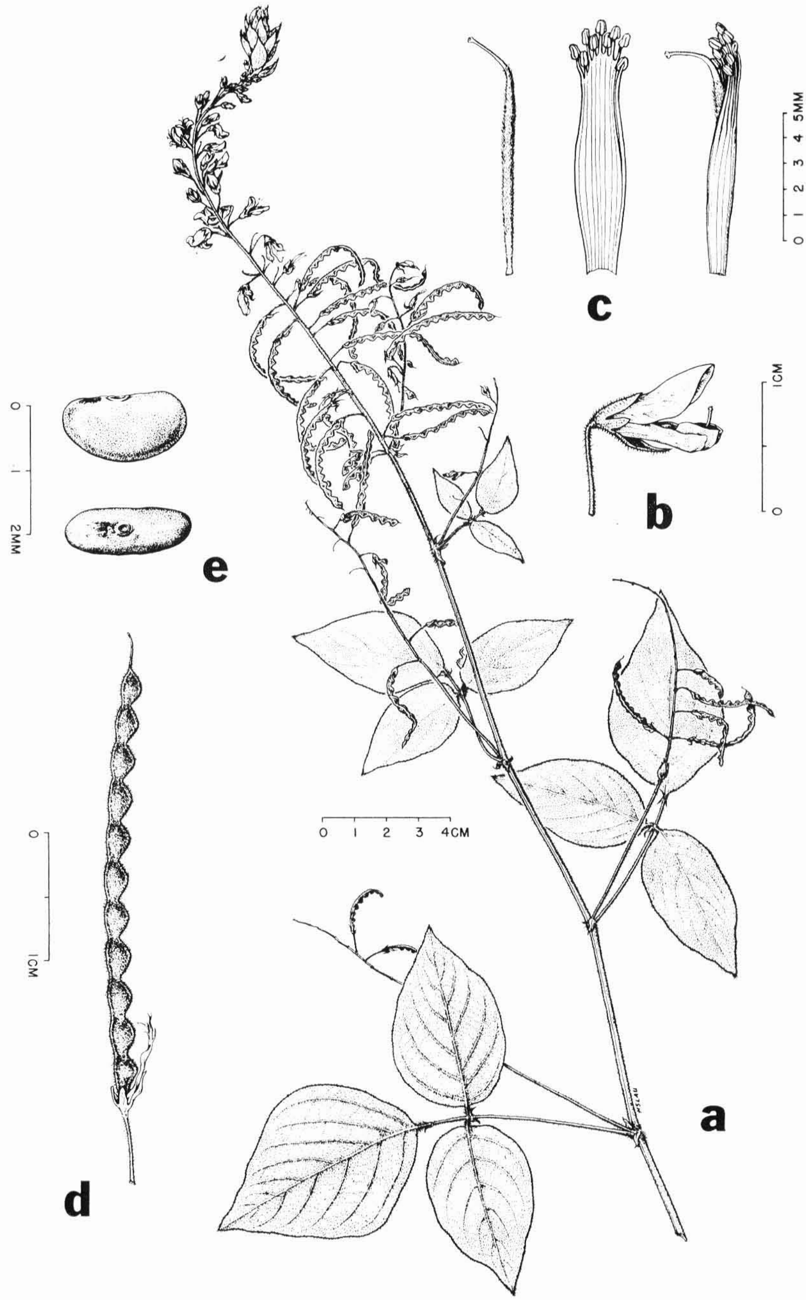

FIGURE 1. Morphology of intortum (*Desmodium intortum*) showing (*a*) habit of growth, (*b*) flower, (*c*) floral parts, (*d*) pod containing seed, and (*e*) seed.

adaptation in the high-rainfall areas at elevations up to 3000 feet. Intortum, like most other *Desmodium* species tested, slows in growth during the short-day winter period, and little vegetative growth results even if flowering and fruiting is discouraged by grazing or clipping.

Intortum is difficult to establish on poorly prepared land, which is one major reason for its slow spread and acceptance. However, it is readily established from seed on well-tilled, weed-free land. The seeding rate is usually 2 to 5 pounds per acre. Intortum belongs to the cowpea bacterial inoculation group (*2*), and no inoculation is required in areas growing koa haole (*Leucaena leucocephala*), mimosa (*M. pudica*), crotalaria (*C. incana*), or Japanese tea (*Cassia leschenaultiana*), the soil already being adequately supplied with the required bacteria.[2] The seed of intortum germinates slowly, and early growth is slow for the first month or so, whereafter runners appear and the plant spreads rapidly to give a solid ground cover.

Under favorable rainfall conditions, intortum has also been established in existing pastures. The forage must be grazed or mowed very closely prior to broadcasting intortum and no cattle must be permitted on the land for about 2 to 3 months after the intortum seed begins to germinate and produce seedlings.

In places where only poor to fair land tillage is possible, intortum may be established from vegetative cuttings. The land is tilled on the contour in strips 6–10 feet wide, spaced 20–30 feet apart. Planting may proceed by sprigging mature stem cuttings with several nodes in holes or furrows at intervals of 6–10 feet. Alternatively, if vegetative material is plentiful, it may be run through a forage chopper, producing cuttings several inches in length. The cuttings are scattered over the tilled land or tilled strips and covered by light discing. Mixed grass and intortum forage run through a forage chopper and planted in this manner has given excellent grazing on fertilized land in less than 3 months. Whatever the method of planting, it is essential that adequate fertilization be provided; otherwise, poor growth will result.

Intortum, unlike kaimi, will require resting and time for regrowth after heavy grazing; therefore, light to medium continuous grazing or heavy rotational grazing should be utilized. Continuous heavy grazing soon exhausts the root reserves in the cropped intortum and results in death of the plant.

In our cultural experiments, intortum has shown little response to lime, and a soil reaction as low as pH 5.5 permits excellent production. Intortum has a high requirement for phosphorus and potassium, which is one of the reasons why this legume has never been properly appreciated in the region of its origin where the native soils are relatively infertile and little fertilization is practiced. Where the soils are infertile, intortum makes little growth.

The top growth of intortum is a mass of leafy, prostrate creeping vines, with succulent, juicy stems about $\frac{3}{16}$ inch thick, which are extremely slow to dry and cure for hay. The top growth is readily consumed by cattle in mixtures with grasses or alone, although cattle require some time to acquire a liking for intortum. It is readily eaten as fresh-cut soilage. It has not been tested as a silage. As soilage,

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[2]Cultures of Rhizobium more specific for *Desmodium* species may be obtained from the Nitrogen Company, Milwaukee, Wisconsin.

intortum yields three or four ratoons per year. About the same number of rotational grazings are obtained, in which grazing is continued until about 20 percent of the yield remains in the form of coarse stems denuded of leaves. More intense grazing results in stand depletion and early extermination of all the intortum. Under proper management, intortum will maintain a full stand indefinitely and will hold its own with paragrass (*Brachiaria mutica*[3]) and with napiergrass (*Pennisetum purpureum*).

Kaimi

Kaimi clover is a long-lived, prostrate to upright plant with two kinds of stems, each of which bears a distinctive type of leaf (fig. 2, 8). On upright stems, lanceolate (longer than broad) leaves with a white marking in the center are produced. On decumbent to creeping stems, oval to round leaves without leaf markings develop, and at a distance the plant often resembles white clover. When the plant is cut or trampled, there is a development of strong decumbent and prostrate stems. These root at the nodes where they lie on moist ground.

On mature plants, numerous reddish or lavender flowers are produced on the upright stems. The calyx is small and the lobes are pointed. Each flower is complete and self-fertile and gives rise to a four- to seven-seeded pod. The pods are 1 to 1½ inches long and about ⅛ inch wide. The upper suture is straight and the lower margin is indented. The whole pod, which is covered with short brown hairs, clings to clothing and to the hair of animals. The pod breaks apart easily at the joints. The light-brown seed is kidney-shaped and is about ⅛ inch long and 1/16 inch wide. Wild-growing kaimi clover, *D. canum*, native of the West Indies and probably an accidental introduction, was first reported in Hawaii in 1916 (*17*). It first received agronomic recognition in 1945 (*8*). Kaimi clover has several desirable forage characteristics—it is a moderately palatable, persistent, prostrate, perennial pasture plant readily established from seed in grass sward or tilled land, and is compatible and competitive with most local aggressive grasses grown in the lowland, medium- to high-rainfall areas. Kaimi, being prostrate in habit, is not a heavy yielder and probably makes its major contribution in mixed forage by stimulating the associated grass in yield, palatability, and quality, through its capacity to fix and transfer atmospheric nitrogen. Kaimi is widely distributed in the moist to wet lowlands up to about 1500 feet elevation. Its makes little growth at higher elevations or in dry areas where annual rainfall is less than 50 inches. Under favorable conditions, the young kaimi plant grown from seed or stolons will spread only a few inches in the first few months. After 6 months, growth is accelerated by branching and rooting at the nodes, and spread is rapid if plant competition is not intense.

Kaimi is most readily propagated from seed. The usual rate of seeding is 5 to 10 pounds per acre. It may be drilled or broadcast on tilled land, preferably covered with soil to a depth from 0.2 to 0.5 inch. On established pasture or range, it may be broadcast on closely grazed land without further coverage. If seeded in matted vegetation, poor establishment will result. The kaimi belongs to the cowpea bacterial inoculation group (*2*), and no inoculation is usually required in areas growing

[3] *Brachiaria mutica* (Forsk.) Stapf = *Panicum purpurascens* Raddi.

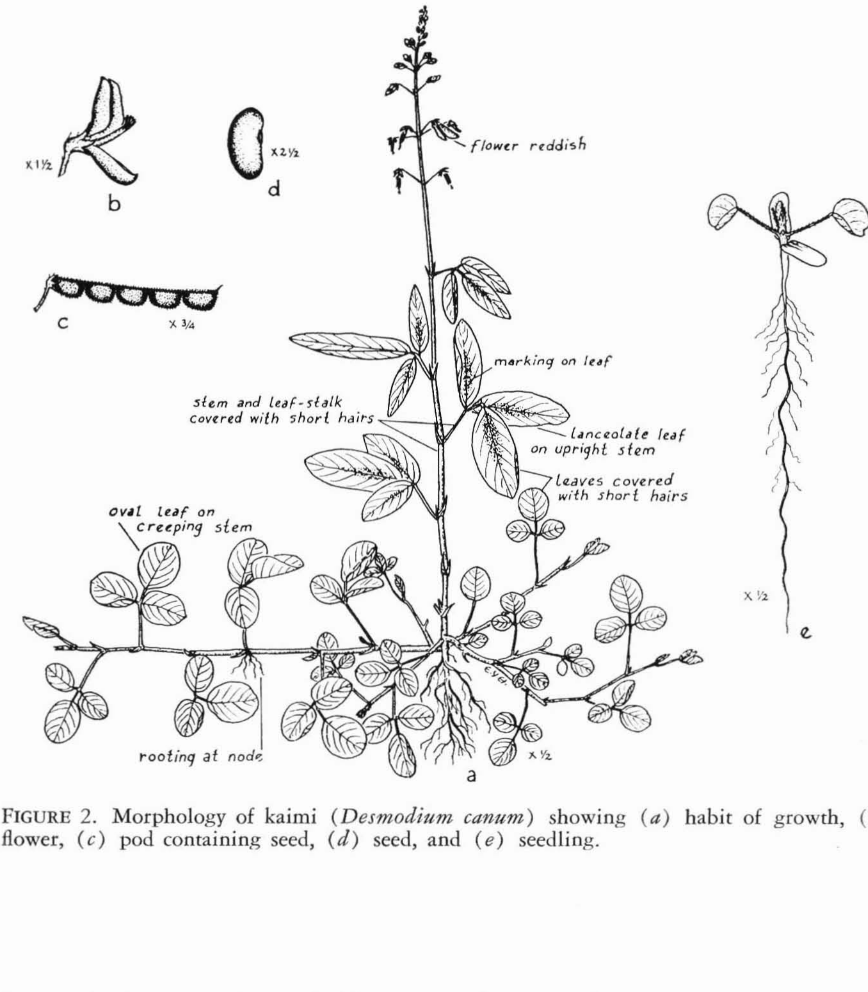

FIGURE 2. Morphology of kaimi (*Desmodium canum*) showing (*a*) habit of growth, (*b*) flower, (*c*) pod containing seed, (*d*) seed, and (*e*) seedling.

koa haole (*Leucaena leucocephala*), mimosa (*M. pudica*), crotalaria (*C. incana*), or Japanese tea (*Cassia leschenaultiana*), the soil being already well inoculated with the proper inoculation group. Once introduced in an area, kaimi spreads readily by means of seed pods adhering to animals or it may be distributed in their droppings.

For seed production, an open stand or row planting is preferred. Hull-less kaimi seed yields may exceed 200 pounds per acre, but usually run much lower (*26*). Flowering is indeterminate and begins in the short-day period in March and may continue into July. Harvesting proceeds by stripping the ripening seed heads mechanically or by hand. After the seed pods are dried, the seed is threshed by a slow-speed hammer mill, which also scarifies the seed for ready germination when planted. Seed turnout ranges up to 50 percent on an air-dry basis, depending on the amount of trash in the seed strippings.

EXPERIMENTAL RESULTS AND DISCUSSION

Performance of various legumes under partial irrigation, Waimanalo, Oahu

The performance of 11 seeded legumes, from six genera, fertilized at the start with a basic treatment of lime, boron, and NPK, is reported for a 3-year period at the Waimanalo Experimental Farm (table 1). The details of the experiment and description of the test site are presented in footnotes to table 1.

The *Leucaena* and *Desmanthus* species reported are normally shrubs or small trees, but which, when thickly planted and cut close to ground level at periodic intervals before flowering, produce herbaceous topgrowth readily consumed by cattle in its entirety. The spanish clover is a low, bushy shrub when undisturbed, but herbaceous when cropped. The tropical kudzu, intortum, and alfalfa are all herbaceous trailing vines or upright stems. Herbaceous stems are readily eaten by stock, whereas woody material is rejected.

The yield results show that with limited irrigation the alfalfa selections died out the second year after about 4 months of inadequate irrigation. A further contributory cause to failure of the alfalfa may have been the lack of available P (phosphorus) in the soil. Some 100 pounds of P per acre were disced into the soil prior to planting. However, a subsequent experiment proved that at the Waimanalo Farm the alfalfa yields increase with massive P application up to about 1000 pounds per acre, and that for rates up to 300 pounds, the alfalfa fails during the second year of growth (*27*). In all probability, all the legumes reported in this test grew with insufficient P and yields may have suffered accordingly.

The highest yielders among the 11 legume selections were the el salvador koa haole, local koa haole, and desmanthus, which all exceeded 10,000 PAY (pounds per acre per year) dry matter for a 2-year period, and produced in excess of 2100 PAY of crude protein (total N $\times$ 6.25). Part of this protein, possibly about 20 percent, is in the form of mimosine or tannin, for which little is known on animal digestibility and nutritive efficiency.

The intortums, kudzu, and spanish clover all yielded about 8000 to 10,000 PAY dry matter. The intortum yields were reduced by time out for one seed crop each year in addition to the yields shown. Also for this group, the slow growth in the year of planting reduces over-all performance. The protein yields, free from mimosine and tannin, range from about 1300 to 1800 PAY, well below the yields of koa haole and desmanthus.

Segregations of the harvested yield indicate that the leaf portion varies from 40 to 60 percent of the total dry matter and that the leaves contain 60 to 80 percent of the total protein in the top growth of all the tested legumes. This indicates that the high quality of this forage is primarily an attribute of the leaf portion, whereas the stems provide mostly carbohydrates. The legume leaves, with a protein content of 20 to 33 percent, provide excess protein suitable for raising the dietary levels of low-protein cattle rations, such as is the usual state of range forage consisting mostly of grasses. The higher protein values of the *Leucaena* and *Desmanthus* leaves suggest that their leaves contain most of the mimosine and tannin proteins of these plants.

The yield performances of the various legume selections are comparable to that of productive alfalfa on the Mainland but are only about half of the yields of irrigated alfalfa in other areas of Hawaii.

Seed and forage yield response of established *Desmodium intortum* to molybdenum treatment, Waimanalo, Oahu

The effect of broadcast treatment of 2 pounds molybdenum per acre, as MoO_3, on an established stand of intortum at the Waimanalo Farm, is shown in table 2. The objective was to establish the degree of need for Mo treatment on intortum, Mo deficiency having previously been recorded in other local areas for both alfalfa and kaimi clover (*25*, *31*).

The 2-year mean dry matter yields of intortum show statistically significant responses to Mo ranging from 2.8 to 11.1 percent for the three varieties of intortum, the over-all mean yield increase being 7.1 percent. The yield response to Mo is highest the first year after treatment and drops by one-half the second year. This suggests the need for annual booster of Mo at about 25 to 50 percent of the original treatment.

The response to Mo in the seed yield for one crop only is shown to range from 23 to 37 percent for two varieties of intortum, or increases of 31 and 41 pounds clean seed per acre, which retails locally at $2.00 to $2.50 per pound. The response of intortum to Mo treatment is here shown to be several times greater in seed production than in dry matter yield. The much higher response to Mo in fruiting suggests that seed crops other than legumes might also benefit from Mo treatment in the Waimanalo area. Severe Mo deficiency in Hawaii soils was dramatically shown for alfalfa on Wahiawa silty clay at the Poamoho Experimental Farm in 1949 (*31*), and it would appear logical that it also exists for other crops, including horticultural and plantation crops such as sugar cane and pineapple.

Mixed intortum and pangolagrass yields on bauxite stripsoil and topsoil, Wailua, Kauai

Since 1958, field experimentation on reclamation of lands stripmined of bauxite ores has been underway on Kauai, using a wide array of agricultural crops. The results of various forage experiments show that the exposed stripsoils are readily tillable with heavy farm equipment and that abundant crops can be grown when the soils receive a heavy basic treatment of fertilizer and a light application of lime (*30*). The initial treatment should consist of N at 200, P at 1000, K at 1000, and lime at 5000 pounds per acre, disced in on tilled soil prior to planting of improved crops. On topsoil returned to stripsoil and on undisturbed native topsoil, a rate of P at 600 appears adequate. The heavy rates of P and K appear to saturate the fixation complex of these highly deficient soils, and to provide the nutritive conditions for high yields for long periods with only moderate retreatment.

Yield performance of mixed intortum and pangolagrass forage grown on stripsoil and returned topsoil at Wailua, Kauai, is shown in table 3. Statistically significant yield responses are shown each year of the test for the original basic treatment of P and for retreatment of K during the second year of the test. The treatment Oa shows yields of dry matter in the range of 18,000 to 20,000 PAY, or 50 to 56

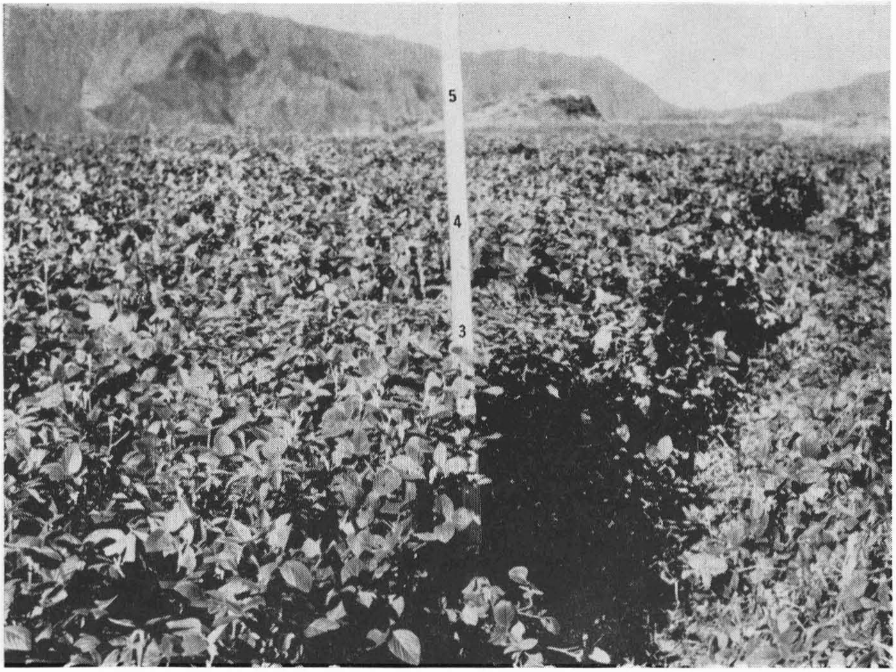

FIGURE 3. Vigorous growth of intortum has nearly smothered the pangolagrass component. Yields of this type will exceed 50 pounds of dry matter per acre per day.

pounds per acre per day, sufficient fodder for 2.0 to 2.2 cattle units of 1000-pound liveweight per acre per day. Adjacent unimproved pasture or range carries only about 0.1 cattle unit. Once established, the intortum in the pasture mixture supplies sufficient available nitrogen through the symbiotic root-nodule bacteria to meet all nitrogen needs of both crops without cost.

As indicated by the lack of response to various other nutritive elements, the forage mixture received adequate supplies from the soil of elements such as magnesium, boron, molybdenum, manganese, and zinc. Experimentation with sudangrass and alfalfa in the same area, however, has shown that deficiencies exist for magnesium and for zinc. Treatments with copper and sulfur have shown no yield responses in any crops tested.

Grazing of limed and fertilized intortum and pangolagrass mixtures, Camp Maui, Maui

The effect on 2 years' grazing performance of varying rates of lime plus a basic complete fertilizer on mixed intortum and pangolagrass pasture is reported in table

FIGURE 4. A desirable grass-legume mixture of forage ready for grazing or for soilage as green-chop. This mixture contains 40 percent, by weight, pangolagrass and 60 percent intortum. This yield exceeded 5000 pounds dry matter per acre. When adequately fertilized, production in the wet areas exceeds 50 pounds dry matter, feeds more than two 1000-pound cattle units on a year-round basis, and provides weight gains in excess of 4 pounds per acre per day.

4. As shown in column 2, the soil reaction was altered by varying rates of lime from pH 5 in the no-lime check to pH 6.2 for 5200 pounds of lime per acre disced in on tilled soil at the start of the test. Grazing commenced about 1 year after the test was installed and when the forage was well established. No yield records were taken during the year of establishment. Short yearling steers weighing about 450 pounds at the start of each year were grazed more or less continuously on each treatment, which was unreplicated. As shown by the liveweight gains, table 4, columns 12 to 16, liming was most profitable up to about 3000 PA (pounds per acre), which produced weight gains of 208 PAY (pounds per acre per year) for a 2-year gross of $57.20, after deducting $26.00 for the lime (exclusive of labor costs), and pricing the weight gain at $0.20 per pound. No doubt, further profit from liming would accrue with a longer period of years of grazing, since the residual effect of liming may be expected to continue for a period of 6 to 10 years.

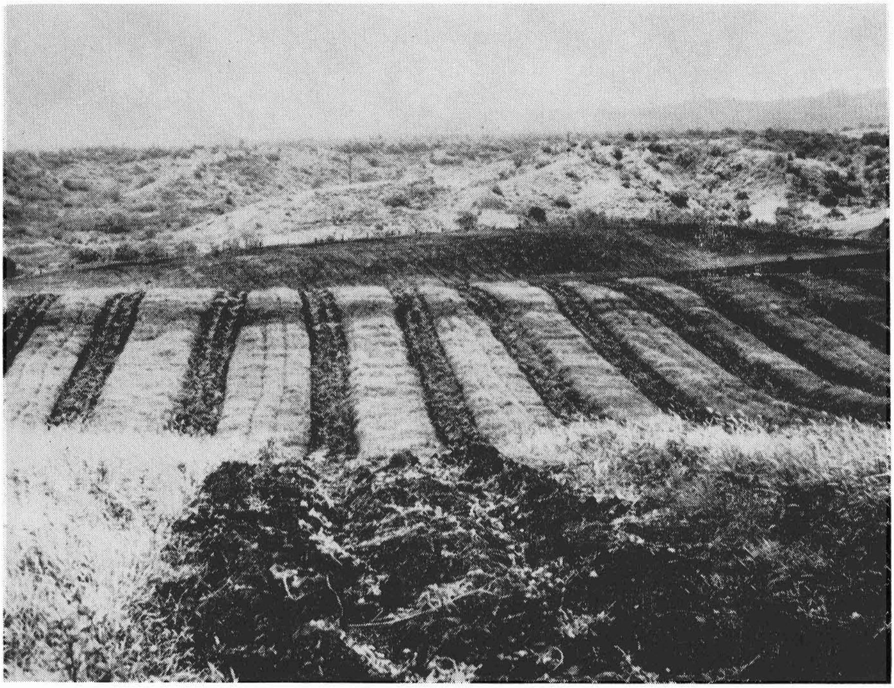

FIGURE 5. Method of establishing intortum in strips across pangolagrass pasture. Intortum cuttings are dropped in the open furrow and covered by a second furrow. Success depends on excluding the grass from the intortum while it is getting established. Later the trailing vines of the intortum will cover the entire pasture.

The gains resulting from the use of a basic starting fertilizer containing N at 44, P at 84, K at 104, B at 3.5, and Mo at 2.5 pounds per acre, valued at $44.45, are shown by treatments 5 and 6 in columns 12 and 13, 17 and 18, table 4. The yearly gain for fertilization is 410 pounds for a total gain of 820 pounds in the 2-year test period, which at $0.20 per pound leaves a gross profit of nearly $119.00 per acre after deducting $45.00 for the basic fertilizer (exclusive of labor costs for treatment and pasture establishment, which may be amortized over several years). The drop in weight gains for the second year in treatment 6, lime only, shows that native fertility of the test soil is readily exhausted, and further grazing would soon reduce the returns to near the 10- to 20-PA gains secured on adjacent unimproved pasture and range. It is noteworthy that test results prove conclusively that nearly unproductive rangelands can be made profitably productive even when lightly fertilized as in this test, when planted to high-yielding intortum and pangolagrass forage. Compare weight gains of 20 PAY on native range, valued at $4.00, against weight gains of 800 PAY on fertilized and improved forage, valued at $160.00 at a cost

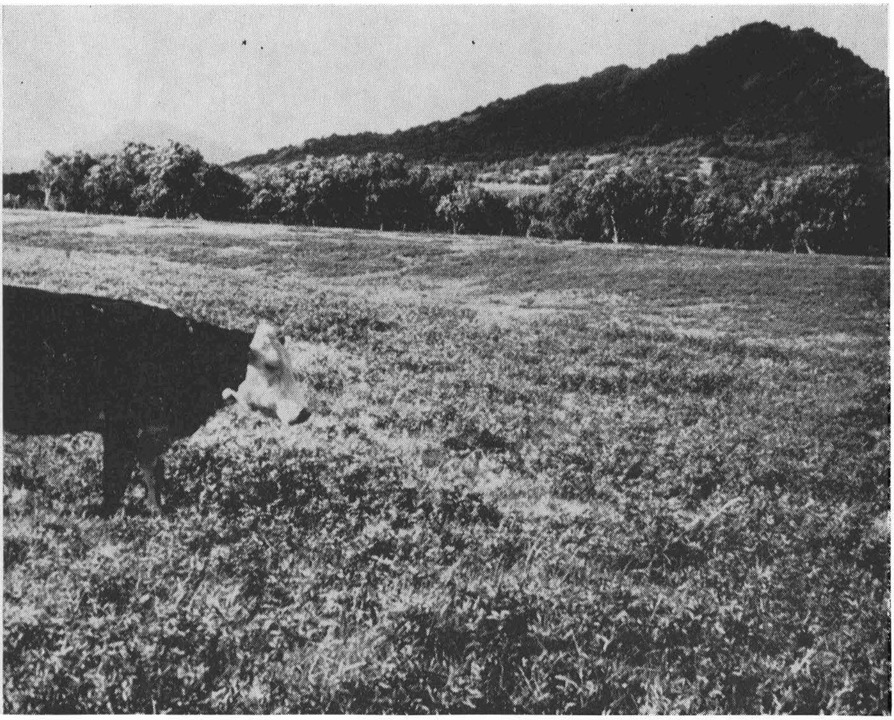

FIGURE 6. Young cattle grazing a mixed stand of kaimi clover and kikuyugrass. Kaimi may be established on an old stand of kikuyu by the simple procedure of overseeding with kaimi seed at the rate of 5 to 10 pounds per acre. This type of pasture when adequately fertilized will produce more than 700 to 800 pounds liveweight gains per acre per year.

for materials of less than $75.00 the first year. The obvious conclusion is that it is folly not to graze improved pastures exclusively. However, Hawaii ranchers in the high-rainfall areas (more than 60 inches rain annually) have done little to improve their grazing lands, and, therefore, fail to make the type of income here reported (confirmed also in tables 5 and 6, with field demonstrations extending back to 1951). This failure to adopt a proven profitable farm practice is quite serious, since about one-fourth of the Hawaiian rangelands are unproductive low wetlands capable of trebling the current annual beef production.

The Maui tropical wetlands alone, comprising some 100,000 acres below 4000 feet elevation, are fully capable of being improved in the above manner, which at a production potential in excess of 700 pounds beef liveweight gains conservatively would give a total of 70 million pounds of live beef, which at $0.20 per pound would equal 14 million dollars, or roughly one and one-half times the current total beef production in Hawaii. This poses the question: Why the delay in wetland improvements?

Seed and forage yields of fertilized mixed kaimi, dallisgrass, and native grasses, over a 7-year period, Halehaku School, Maui

The performance of variously fertilized mixed stands of kaimi clover, dallisgrass, and native grasses in the unproductive lower wetlands of Maui is presented in table 5. All fertilizer treatments were broadcast and disced in on tilled soil at the start before planting. During the first year of the test the forage was removed and no data were taken. Yield data were taken during the 2 succeeding years and the test was then opened to general grazing for 3 years. In the seventh year, grazing was excluded and yield data were again collected.

The yield data on kaimi clover and associated grasses show statistically significant responses only to lime, molybdenum, and zinc fertilization. In general, 2 pounds of Mo gave about half the yield increase of 4000 pounds of liming material, with coral sand and burned lime from coral sand of the same source being about equally effective in increasing yields of forage during the early period of the test. In the seventh year of the test the effect of Mo was still very much in evidence in forage yield, but the content of kaimi was less than when lime was part of the treatment.

In seed production the yield data show liming to be very effective and Mo and Zn to be about 25 to 35 percent as effective as the lime alone. The yield data suggest that a continued treatment of lime, Mo, and Zn would be highly effective in the test area.

It should be noted, also, that more recent experimentation has shown that treatments of P and K, considerably more liberal than those used in this field experiment, are necessary for maximum yields. Rates of P and K should probably be increased to about 750 to 1000 pounds each at the start.

Grazing of fertilized kaimi clover mixed with pangola, dallisgrass, kikuyu, or native grasses on low wetlands, Halehaku, Maui

In table 6 are recorded the 4-year grazing performances of four fertilized kaimi clover-plus-grass mixtures on the unproductive low wetland soils at Halehaku, Maui. The soils of this area have been in and out of both sugar cane and pineapple production and much of it is currently poor pasture requiring 10 to 20 acres to graze a 1000-pound cattle unit per year, which is a fairly representative production on low wetlands throughout the State of Hawaii. In this field experiment as in the previously discussed test at Halehaku School, the rates of P and K treatments were probably grossly inadequate for maximum production as shown by later research. However, the results show clearly that any change in the type of forage mixture that will include an adapted legume plus liming and fertilization, even when below standard, will produce heavy liveweight gains of grazed young beef cattle. The fairly adequate weight gains averaged from 1.63 to 1.74 pounds per head per day over a 4-year period (column 10). The weight gains on an acreage basis averaged 524 PAY for the native grass and kaimi mixture. The most productive forage mixture was pangola and kaimi with average weight gains of 720 PAY (column 11). The cost of the fertilizer and lime treatment applied only at the start of the 4-year test was $101.50 per acre (exclusive of labor costs).

The kaimi clover in this test was a free source of nitrogen for the forage mixture, thereby continuing good forage production and beef weight gains. Also, the clover carried twice the protein percentage of the grass, thus materially increasing the quality of the grazeable forage to near adequate dietary levels for young beef cattle.

It will be noted that kaimi is a desirable legume even in otherwise unimproved grass pastures and that it adds to the quality of such pasturage without appearing at the same time to add much to the quantity of the forage material. This situation results from the fact that kaimi will be preferentially grazed in a poor grass-and-clover mixture and, therefore, that the clover will appear as an inconspicuous ground cover which is easily undervalued. In general, kaimi clover should be preferred over other adapted legumes for pastures that are to be underfertilized, overgrazed, and otherwise neglected and abused. In such situations, the kaimi clover is an unexcelled forage legume under Hawaii conditions.

SUMMARY

The culture and taxonomy of *Desmodium intortum* and *D. canum* (kaimi) are reported for Hawaii conditions. Six field experiments of intortum and kaimi in various mixtures with tropical grasses showed that intortum, when adequately fertilized, yields in excess of 20,000 pounds dry matter per acre per year. Controlled grazing of intortum and grass mixtures will give beef liveweight gains of 800 pounds per acre per year with only moderate fertilization.

Kaimi clover stimulates yields of associated grasses, but is a poor yielder in pure culture. Cattle weight gains over a 4-year period averaged 600 pounds per acre on four kaimi and grass mixtures under low rates of fertilization.

Both intortum and kaimi show marked response to P, K, Mo, and Zn on one or more common Hawaii soils. Additions of lime, Mo, and Zn give marked increases in seed. The response of wetland soils to fertilization is dramatic with both legumes. Inadequate fertilization is shown to cause poor stands and low quality yields of *Desmodium*.

Adequately fertilized, the intortum is shown to be fully competitive with aggressive grasses, such as kikuyu, pangola, and dallisgrass. Kaimi is superior in forage mixtures where little or no fertilization and/or where overgrazing is practiced.

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APPENDIX

TABLE 1. Performance of various forage legumes under partial irrigation, Waimanalo, Oahu, 1953–56[1]

LEGUME SPECIES OR VARIETY	FIRST YEAR						SECOND YEAR						THIRD YEAR		AVERAGE	
	Ratoons	Dry matter, pounds per acre	Total protein, pounds per acre	Percent protein in dry matter	Leaf yield, pounds per acre	Percent protein in leaf	Ratoons	Dry matter, pounds per acre	Total protein, pounds per acre	Percent protein in dry matter	Leaf yield, pounds per acre	Percent protein in leaf	Ratoons	Yield, total dry matter	Dry matter for period, pounds per acre per year	Total protein for period, pounds per acre per year
Leucaena leucocephala (L. glauca)																
El Salvador	6	13,320	2,940	22.1	6,510	33.5	5[2]	9,570	1,660	17.3	4,560	28.4		–	11,445	2,300
Koa haole	5	10,220	2,300	22.5	5,140	30.4	4	13,040	2,440	18.7	6,020	23.9		–	11,630	2,350
Desmanthus virgatus	5	10,670	1,990	18.7	4,570	28.2	5	13,040	2,260	17.2	6,740	24.0		–	11,870	2,125
Pueraria thunbergiana																
Tropical kudzu	4	7,960	1,480	18.6	5,110	23.7	4	10,800	1,780	16.5	6,960	19.5		–	9,380	1,630
Desmodium intortum																
4331 Guatemala	4	8,970	1,600	17.8	5,110	25.1	4[2]	11,950	1,950	16.3	6,830	21.8	3	10,680	10,530	1,775
4329 Guatemala	3[2]	7,200	1,310	18.2	3,830	24.6	3[2]	8,170	1,380	16.9	4,480	21.7	3	10,450	8,610	1,345
4247 Costa Rica	3[2]	5,830	1,100	18.9	3,060	25.8	3[2]	7,890	1,420	18.0	4,810	24.1	3	9,690	7,800	1,260
Desmodium sandwicense																
Spanish clover	5	7,130	1,240	17.4	4,050	21.6	5	10,500	1,800	17.1	6,160	22.2		–	8,815	1,520
Medicago sativa[3]																
Indian alfalfa	9	10,790	2,220	20.6	5,730	28.7	4	4,100	710	17.3	2,250	25.2		–	–	–
Williamsburg	9	10,530	2,250	21.4	5,850	27.5	4	4,570	750	16.4	2,300	23.3		–	–	–
Caliverde	9	9,610	2,020	21.0	5,430	26.5	4	4,230	700	16.5	2,360	22.1				

[1] The soil of the experimental site is Waimanalo silty clay, transitional Dark Magnesium Clay to Low Humic Latosol, and lies at 65 feet elevation. The annual rainfall is about 45 inches. The topsoil reaction is nearly pH 7, sticky when wet, lumpy and granular when dry. The subsoil is mottled gray-brown, indicating poor internal drainage. The availability of N, P, and K is quite low. Treatments were broadcast and disced in prior to planting: N at 57, P at 105, K at 220, B at 3, lime at 2000 pounds per acre. Alfalfa drilled in rows 8 inches apart, remaining crops drilled in 24-inch rows. Each variety grown in single plots, 0.15 acre in area. Yields are averages from duplicate subplots taken at random for each ratoon. Crops irrigated to optimum level, except during water-short periods, May to September in 1954 and 1955, when irrigation was inadequate and resulted in the death of the alfalfa. The drought periods resulted in reduced yields. All crops cut in the mature vegetative or early flowering stage, except the intortums, which during January to February of each year were harvested for the seed crop and thus showed a correspondingly reduced forage yield. Cleaned-seed yields ranged between 70 and 230 pounds per acre in each seed period.

[2] One seed crop was produced in the December–February period in addition to the forage yields shown.

[3] All alfalfa varieties declined severely in yield and stand and failed entirely after ratoon 13 at the age of 16 months. The alfalfa stand apparently failed because of unavailability of phosphorus aggravated by insufficient irrigation water.

TABLE 2. Seed and forage yield responses of established *Desmodium intortum* to molybdenum treatment, Waimanalo, Oahu, 1954–56[1]

	DRY MATTER YIELD, POUNDS PER ACRE							SEED YIELD, POUNDS PER ACRE		
	First Year		Second Year		Mean			First Year Only		
HAES NO.	Check	Mo	Check	Mo	Check	Mo	Increase Mo/Check	Check	Mo	Increase Mo/Check
							%			%
4331	7,287	8,269	9,298	9,654	8,293	8,962	8.1**	112	153	37
4329	7,456	8,372	9,488	10,445	8,472	9,409	11.1**	136	167	23
4247	8,659	8,976	10,467	10,680	9,563	9,828	2.8*	226	—	—
* LSD at 0.05 level of significance (Check vs. Mo)						265				
** LSD at 0.01 level of significance						416				
Mean					8,775	9,399	7.1			

[1] Molybdenum, 2 pounds per acre, was applied as a spray on 3-week-old regrowth intortum 1 year after planting. These desmodiums flower and seed once a year in the short-day period, December to February. Flowering delays and limits vegetative yields for the period. Vegetative growth prevails about 9 months each year. For cultural details, see table 1.

TABLE 3. Two-year yields of mixed intortum and pangolagrass on bauxitic stripsoil and on topsoil returned to stripsoil, Wailua, Kauai, 1958–60[1]

TREATMENT NO.	TREATMENT[2]		DRY MATTER					
	Symbol	Element and rate, pounds per acre (start of first year; second year as noted)	First year, pounds per acre per year		Second year, pounds per acre per year		Second year, pounds per acre per day	
			Stripsoil	Topsoil	Stripsoil	Topsoil	Stripsoil	Topsoil
A	Ck	None	830	2,000	1,080	3,870	3	11
B	NPK	N200, P300, K300	7,160*	13,260*	5,430*	13,050*	15*	36*
C	NP2K	P600	11,930*	13,340	8,620*	14,440	24*	37
D	NP2KL	Lime 5,000	12,660	14,060	10,710	13,460	30	37
E	NP2KL2	Lime 10,000	12,520	13,710	10,200	13,340	28	37
(F)	NP2KL2Mg	Mg25 (100 2nd year)	12,810	13,330	12,130	12,450	33	34
(N)	(F)BMoMnZn	B10, Mo2.5, Mn95, Zn25	13,500	14,370	13,270	12,770	36	35
Ka	(N), 2 yr.K3	K900 (2nd year)	—	—	15,200	17,360*	42	48*
Oa	(N), (2 yr.K3, (N)-L2Mn)	K900, (N)-(L2Mn 2nd year)	—	—	20,550*	18,320	56*	50
*Statistical significant response to treatment at 0.05 probability			NPK P2	NPK	NPK, P2, P2K3	NPK, K3		

[1] The soil of the experimental site is Kapaa silty clay, an Aluminous Ferruginous Latosol, with an annual rainfall of about 75 inches, and lies at about 700 feet elevation. The topsoil reaction is pH 4.8, and shifts to pH 5.8 and 6.5 when treated with 5,000 and 10,000 pounds lime per acre, respectively. The availability of all mineral nutrients is low. Topsoil returned to stripsoil is comparable to the native undisturbed soil of the area. The stripsoil is the soil material at a depth of 8 to 18 feet below the original surface which is exposed after the commercial aluminum ore has been removed. The stripsoil is devoid of organic matter and is very low in fertility but is physically a tractable and well-aerated soil. The native vegetation on the rounded ridges of the test site consists of mixed yellow foxtailgrass (*Setaria geniculata*), ricegrass (*Paspalum orbiculare*), and some glenwood grass (*Sacciolepsis contracta*), joee (*Stachytarpheta cayannensis*), and lantana (*Lantana camara*).

[2] Treatments were broadcast and disced in on well-tilled soil at the start of the test, and topdressed the second year when applied. Inoculated intortum and kaimi seed were broadcast and harrowed in. Pangolagrass was sprigged in at 3 × 10-foot intervals 10 weeks after the intortum seeding to assist the legume establishment. Only the check plots produced kaimi clover. Other treatments produced 80 to 90 percent intortum with the remainder being pangola, except where a high potassium rate temporarily resulted in pangola dominance for one or two ratoons. The test results show that sustained high production for topsoil requires initially P at 600, K at 1000 pounds per acre at a cost of $270. Also, stripsoil requires P at 1000, K at 1000 pounds per acre at a cost of $400. Annual retreatment of K at 200 pounds per acre, costing $20, is required where crops are removed.

TABLE 4. Two-year grazing results on mixed pangolagrass and intortum pasture for varying levels of lime and fertilizer on low wetlands, Camp Maui, Maui, 1958–60[1]

TREATMENT NO.	SOIL REACTION 1 YEAR AFTER TREATMENT	TREATMENT[2]			DRY MATTER, PER ACRE PER YEAR[3]		LEGUME IN DRY MATTER		LIVEWEIGHT GAINS[4]								
														Increase			
		Lime (as $CaCO_3$)	Fertilizer (F)	Cost	1	2			Gain per head per day 1	2	Gain per acre per year 1	2	Mean gain per acre per year	Per lime increment	Value at $0.20	For fertilizer	Value at $0.20
	pH	*pounds*		*dollars*	*pounds*	*pounds*	*percent*	*percent*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*dollars*	*pounds*	*dollars*
1	5.0	none	F	44.45	13,620	15,470	33	35	1.06	1.54	447	666	556	0	(111.20)	—	—
2	5.6	1,300	F	50.95	16,320	18,730	33	22	1.53	1.28	623	657	640	84	16.80	—	—
3	5.5	2,600	F	57.45	16,620	19,500	44	36	1.68	1.48	772	757	764	124	24.80	—	—
4	5.9	3,900	F	63.95	15,580	17,530	42	39	1.30	1.47	565	796	680	—84	—	—	—
5	6.3	5,200	F	70.45	17,040	26,010	44	29	1.52	1.30	643	749	696	16	3.20	410	82.00
6	6.2	5,200	none	26.00	11,800	7,200	34	32	1.38	0.34	477	94	286	—	—	0	(57.20)
Mean of all plots					15,160	17,400	38	32	1.41	1.24	588	613					
Mean effect of lime																	
Fertilized only, No. 1					13,620	15,470	33	35	1.06	1.54	447	666	556				
Limed and fertilized, Nos. 2 to 5					16,390	20,440	41	32	1.51	1.38	651	740	696				
Increase for lime, %					20	32	24	—9	42	—30	46	11	140				
Mean effect of fertilizer																	
Limed and fertilized, No. 5					17,040	26,010	44	32	1.52	1.30	643	749	696				
Limed only, No. 6					11,800	7,200	34	29	1.38	0.34	477	94	286				
Increase for fertilizer, %					44	261	29	10	10	282	35	697	143				

[1] Unpublished data, Hawaii Agricultural Experiment Station Project 108.

The experimental site, on a former World War II Marine Camp, consists of Pauwela silty clay, a Humic Ferruginous Latosol, with an annual rainfall of about 100 inches, and lies at about 1000 feet elevation. The topsoil has a reaction of pH 5.0, and is low in available P, K, and Ca. The native vegetation consists of boston fern (*Nephrolepsis exaltata*), various sedges (*Carex*), yellow foxtailgrass (*Setaria geniculata*), ricegrass (*Paspalum orbiculare*), hilograss (*Paspalum conjugatum*), and rattailgrass (*Sporobolus capensis*), with guava (*Psidium guajava*) being the dominant shrub. Level areas in the past were cropped to pineapple and sugar cane and abandoned in the 1930's.

[2] Treatments of N at 44, P at 84, K at 104, B at 3.5, and Mo at 2.5 pounds per acre and lime, made at the start only, were applied with a lime spreader and disced in on well-tilled soil free of weeds. Pangolagrass cuttings were planted in furrows at 6 × 3-foot intervals. A mixture of seeds of tropical and temperate legumes was drilled in 15-inch rows. After 6 months, only intortum 4247 (*Desmodium intortum*) and a few big trefoil (*Lotus uliginosus*) survived. The combined fertilizer cost is $44.45. The lime is dune sand from near Puunene valued at $10.00 per ton $CaCO_3$ equivalent. The cost figures given are "on-truck at pick-up point," and do not include hauling or field application.

[3] The dry matter yields are estimates based on incomplete plot yield data, and may be in error by up to 10 percent of the reported yields.

[4] Hereford steers weighing about 450 pounds at the start were grazed and sold each year. Weight gains on unimproved native pasture range from 10 to 20 pounds per acre per year.

TABLE 5. Some seed and forage yields over a 7-year period for fertilized mixed kaimi clover, dallisgrass, and native grass pasture in low wetlands, Halehaku School, Maui, 1951–58[1]

TREATMENT[2]		CLIPPED FORAGE YIELD						KAIMI SEED		INCREASE IN YIELD OVER BASIC TREATMENT	
		Second year			Seventh year (after 4 yr. grazing)			Third year (75 days)			
No.	Element and rate	Dry matter per acre per year	Protein in dry matter	Kaimi clover in dry matter	Dry matter per acre per year	Protein in dry matter	Kaimi clover in dry matter	Trash and seed per acre	Seed of kaimi per acre	Forage average 2 and 7 years	Kaimi seed
	pounds per acre	*pounds*	*percent*	*percent*	*pounds*	*percent*	*percent*	*pounds*	*pounds*	*percent*	*percent*
1.	check	2620	6.49	9.4	3130	5.74	2.4	132	11	9	−27
2.	P50	2900	6.84	11.1	3680	5.92	1.8	137	15	25	0
3.	P50, K150	2320	6.34	9.3	3880	6.08	4.7	143	19	18	26
(4).	PKMg25, B2.5 (Basic treatment)	2340	7.90	12.8	2920	6.32	4.2	136	15	Basic	Basic
5.	KMgB	2220	6.57	6.8	3310	5.71	3.3	125	10	5	−33
6.	PMgB	3350	7.07	17.1	3720	6.10	4.0	205	31	34	107
7.	PKB	3070	6.88	8.2	3740	6.09	3.0	133	7	29	−53
8.	PKMg	3440	6.26	13.8	3770	5.88	4.0	153	16	37	7
9.	(4) Mo2	4830**	10.26	31.3	4720**	6.93	7.7	351*	58	81	287
10.	(4) Zn20	3340	6.17	8.4	3670	6.08	3.7	161	16	33	7
(11).	(4) MoZn	5230	9.87	39.3	5730	6.21	10.7	373	66*	108	340
12.	Lime 4000	4520*	9.95	43.0	4950**	7.46	11.7	582**	112**	80	647
13.	(4) Lime	6430**	11.16	42.6	5660**	7.85	14.5	859**	176**	130	1073
14.	(11) Lime	6390	10.62	40.5	5270	7.60	12.4	692**	137**	122	813
15.	(11) Coral sand 4000	6250	10.63	40.0	6100	8.33	20.6	763**	161**	135	907
* Least significant difference at 0.05 probability		1590			1190			165	49	Lime, Mo, Basics	Lime, MoZn, Basics
** LSD at 0.01 probability		2110			1580			220	65		

[1] The experimental site is Haiku silty clay–Uaoa silt loam complex, a Humic Ferruginous Latosol, with an annual rainfall of about 80 inches, and lies at 650 feet elevation. Topsoil reaction is pH 5.0; when limed at 2 tons per acre, it rises to pH 6.0; very low availability of P, K. and Ca. The native grass cover is yellow foxtail-grass (*Setaria geniculata*), ricegrass (*Paspalum orbiculare*), and hilograss (*Paspalum conjugatum*), reverted from pineapple. Lightweight cattle gains range from 10 to 20 pounds per acre per year on native forage.

[2] Treatments made at the start only were applied broadcast on well-tilled land and disced in. Rates of burned lime and coral, from the same ocean beach, are based on $CaCO_3$ equivalents. Kaimi (*Desmodium canum*) and dallisgrass (*Paspalum dilatatum*) seed were broadcast and harrowed in. The yields, consisting mostly of native grasses, represent clipped forage, oven-dried. Treatments replicated 7 times, with samples composited for chemical analysis.

TABLE 6. Four-year performance of various grass and kaimi clover pastures on limed and fertilized low wetlands, Halehaku, Maui, 1955–58[1]

GRASS[2] MIXED WITH THE KAIMI CLOVER	ANNUAL PERFORMANCE SECOND YEAR FROM ESTABLISHMENT								FOUR-YEAR AVERAGE ANNUAL LIVEWEIGHT CATTLE GAINS ON LIMED AND FERTILIZED PASTURE			
	Dry matter yield per acre per year		Kaimi clover in dry matter		Protein in dry matter							
					Grass		Kaimi clover					
	Limed and fertilized	Check	Limed and fertilized	Check	Limed and fertilized	Check	Limed and fertilized	Check	Gain/head/day	Gain/acre/year		Value of gain at $0.20 per pound
	pounds	*pounds*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*pounds*	*pounds*	*percent*	*dollars*
Pangolagrass	9,500	1,490	31.6	1.5	8.26	5.05	15.4	—	1.63	720	137	144.00
Dallisgrass	10,600	2,250	35.9	3.8	9.46	7.44	16.16	—	1.64	630	120	126.00
Kikuyugrass	11,500	1,710	44.2	11.3	8.26	6.74	18.14	14.80	1.74	575	110	115.00
Native grasses	12,150	1,890	44.7	10.3	8.96	6.34	16.90	13.24	1.72	524	100	104.80
Mean	10,940	1,835	39.1	6.7	8.74	6.39	16.58	14.02	1.68	612	—	122.40
Increase for lime and fertilizer %	496	0	484	0	37	0	18	0				

[1] Unpublished data, Hawaii Agricultural Experiment Station Project 128.

The experimental site is presently classified Pauwela silty clay, a Humic Ferruginous Latosol (may be reclassified to Aluminous Ferruginous Latosol). The annual rainfall is about 75 inches and the elevation, 600 feet. The native vegetation consists of boston fern (*Nephrolepis exaltata*), sedges (*Carex*), yellow foxtailgrass (*Setaria geniculata*), hilograss (*Paspalum conjugatum*), and ricegrass (*Paspalum orbiculare*). Liveweight cattle gains range from 10 to 20 pounds per acre per year on such native forage.

[2] The site was tilled over a 6-month period. Burned coral equivalent to 6 tons $CaCO_3$, N35, P65, K130, B5, and Mo2 pounds per acre were broadcast and disced in. The total cost of materials was $101.50 per acre. The topsoil has a reaction of pH 4.6, and after liming pH 6.0. The seeds of kaimi (*Desmodium canum*) and dallisgrass (*Paspalum dilatatum*) were drilled in rows 15 inches apart. Cuttings of pangolagrass (*Digitaria decumbens*) and kikuyugrass (*Pennisetum clandestinum*) were sprigged in 3 × 3 feet apart. The native grasses volunteered mostly hilograss and ricegrass. Test grasses were in single 2-acre paddocks. Forage yields based on mowed strips prior to rotational grazings.

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