琉球の草地と飼料作物(畜産学科)

GRASSLANDS AND FORAGES IN THE RYUKYUS*

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ABSTRACT

Based on research work in the Ryukyu Islands between 1966-1969 and the senior author's evaluations in Taiwan, Hawaii, and Florida in the United States, significant improvements can be made in increasing forage for ruminants in the Ryukyus by (1) growing annual crops as winter or summer annuals on crop land presently not utilized to a maximum and (2) improving unproductive native pastures by subduing the present vegetation with herbicides and/or tillage and establishing Pangola grass (*Digitaria decumbens*).

Oats (*Avena sativa*) is the best supplementary annual crop for winter production ; corn (*Zea mays*) produced high yields in limited trials and needs further evaluation. Corn and the sorghum-sudangrass hybrids (*Sorghum bicolor* x *S. sudanense*) were superior for summer production, the sorghum hybrid being more resistant to typhoons because of regrowth from basal buds.

Pangola grass is the best perennial grass for pastures because of its palatability, high production, perenniality and adaptability to soils. Large scale plantings (220 ha.) are planned in the Ryukyus in 1969.

THERE were 18,312 beef cattle, 1204 dairy cattle, 51,162 goats, 13,067 horses, and 168,038 hogs in the Ryukyus, according to the 1965 census. The primary source of forage*** for cattle during the winter period is sugarcane tops. During the rest of the year native grasses provide most of the feed of ruminant livestock kept in barns. Pasture provides considerable feed for beef herds in the Yaeyama group of islands.

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*** Forages are a crop of which the tops, roots (sweet potatoes), or tubers (white potatoes) are pastured or grazed by livestock, harvested by hand or mechanically in a moist state. Forages may be (1) fed as green material, (2) dried and fed as hay, or (3) ensiled and fed as silage. Forages are generally in the grass family (*Gramineae*) or the legume family (*Leguminosae*). Other families are the cabbage (*Cruciferae*), sweet potato (*Convolvulaceae*) or sunflower (*Soloanceae*) family. Grasses are the primary source of feed for livestock on pasture.

The native species present in Ryukyan pastures are primarily Chigaya or Cogongrass (*Imperata cylindrica*) and Susukigrass (*Miscanthus sinensis*). These grasses are also present in the pastures in many subtropical and tropical Asian countries such as the Philippines, Taiwan, East Pakistan, and India. Generally, they are considered as "weedy" grasses wherever they grow. They are of lower nutritional quality, particularly as they become mature, than improved introduced species to be discussed in this article. These two grasses are utilized as pasture grasses and have fair nutritional quality in young stages in countries where they are present. Unfortunately, they mature quickly during the summer and lose palatability rapidly. Chigayagrass, particularly, is a poor forage when over one meter tall. Both are generally regarded as poor species by livestock management specialists.

The carrying capacity of pastures in the Ryukyus in determined to a considerable degree by the presence of these two undesirable native species. The improvement of pastures and areas containing these two species by establishing superior introduced species is necessary for the success of the livestock industry in the Ryukyus. Introduced species are generally (1) more palatable, (2) more nutritious especially as they approach maturity, and (3) more productive especially at higher levels of fertilizer, particularly nitrogen, than the Susuki and Chigayagrasses.

The senior author has studied experimental areas and observed practical farm operations in Tawian which has a sub-tropical climate similar to the Ryukyus. Similar studies were made on the islands of Kauai, Hawaii, and Oahu in the state of Hawaii which is likewise subtropical. Prior to leaving the mainland of the United States, Florida and Georgia (both in subtropical areas and in a similar latitude to the Ryukyus) were visited to determine which subtropical forages were being used by farmers and experiment stations. All except the third author visited the islands of Miyako, Ishigaki, and Okinawa to talk with experimentalists in the livestock branch of the Government of the Ryukyus and farmers and to determine the potentials of increased livestock production in the Ryukyus.

In the fall of 1966, experimental plantings of several winter-growing grasses and legumes were made at the Animal Husbandry Research Farm, University of the Ryukyus, Shuri, Okinawa, and harvested at various dates between January and May. Plots were seeded in rows one meter apart and well fertilized at planting with nitrogen (N), phosphorus (P) and potassium (K). In 1967, three experiments were established in the same general area in order to compare (1) production of several varieties of corn planted at various dates and (2) production of three sorghum-Sudangrass varieties compared to Sudangrass when harvested four times.

Based on the observational information obtained above and the experimental data obtained in 1967–68, the forages are categorized in an attempt to assess the potentials and use of forages (grasses and legumes primarily) in ruminant livestock production in the Ryukyus. Furthermore, recommednations based on the best available information are made in an effort to improve the establishment, acreage, and productivity of forage crops for ruminant livestock in the Ryukyus.

PRESNT AND POTENTIAL AREAS FOR FORAGES

It is likely that the area in the Ryukyu Islands presently devoted to the main crops of sugarcane, rice, sweet potatoes, pineapples and vegetable crops will remain in these crops. There is a possibility that some small areas may be used for annual forage crop production during the winter months following crops such as rice or vegetables. Wherever possible, such

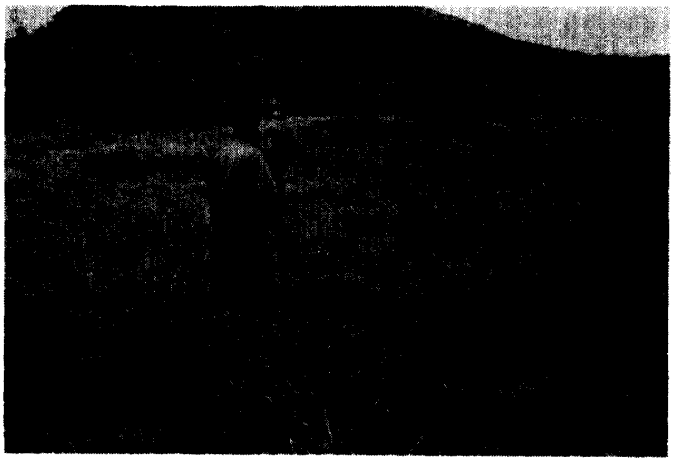
land should be utilzied to its full potential. Some annual grasses, legumes, or plants in the cabbage family will grow well during the cool, dry winter season if planted in October, November, or early December. A limited area of land is now devoted to Napiergrass which is excellently suited for high production.

The great potential for improvement is in the native pastures in the hilly areas on the islands of Okinawa, Miyako, Ishigaki and Iriomote, Figure 1. On most of these hills the elevation is less than 500 meters. Subtropical species to be discussed will grow well at the maximum elevations down to sea level.

Many of these hilly areas are now partly devoted to scattered small areas of sugarcane. Areas between the small sugarcane fields are primarily in Susuki or Chigayagrass. Improved grasses such as Pangolagrass or Napiergrass (discussed later) could be established in these areas to provide additional forage.

Similarly, areas on hills could be planted to the superior species mentioned. If fenced off by individual farmers or by a community, such areas could be used for pasture for growing beef cattle to be fattened later in confinement.

On Miyako, Ishigaki, and Iriomote islands, there are many large areas now in Susuki and Chigayagrass. These could also be planted to the better grasses to double the carrying capacity beef cattle per hectare if properly managed and fertilized.



Fig, 1. Hilly areas covered by Chigaya and Susukigrass offer great opportunities for re-establishment with pangolagrass for better pasture for livestock. Yaeyama, Ryukyus, January 1967.

I. FORAGES TO GROW IN THE RYUKYUS.

1. Tropical Perennials

Forage investigations in the subtropical and tropical Asiatic countries and in the United States indicate that perennials adapted to high temperatures are much more productive than species adapted to more temperate climates. In Okinawa, tropical perennial grasses produce about 85% of their yearly production between May 1 and November 1 and only 15% during the cooler, drier period from November 1 to May 2[22]. The higher summer temperatures (25 to 28°C in July, August, September) are more conducive to greater growth for these species than the cooler temperatures of winter (15 to 18°C in December, January and February).

A. Tropical perennials for intensive cutting by hand or machine and feeding green to livestock.

1) Tropical grasses

a. Napiergrass (*Pennisetum purpureum*) was introduced from Africa and is the most useful of all species for cutting and feeding green in the Ryukyus and Taiwan[19] It can also be used with good sources for making silage. At the Ryukyu Livestock Station near Shuri, Okinawa,[28], Napiergrass produced almost twice the yield of the next best perennial grass or Susukigrass. Napier is the best grass for level, productive well-fertilized land where the greatest yield per acre is desired, Figure 2.

Fig. 2. Napiergrass is the most productive and best grass for level land well fertilized with nitrogen. January 1967 near Ishigaki, Yaeyama, Ryukyus.

Napier gives excellent response to nitrogen. Data from Puerto Rico[30] near the United States show that the yields increased almost linearly as the rate of nitrogen increased from 0 to 40 *kg* per 10 *ares**. Increases continued as the rate increased from 40 and 160 kg per 10 *ares*.

Napiergrass should not be cut closer than about 15 *cm* or the yield will gradually decrease and the stand will thin out badly over several years[19].

Planting oats between rows of Napiergrass, a common practice in Tiwan[19] in early November is advised to improve the yield. Napiergrass grows slowly during winter and oats grow rapidly.

Napiergrass is erect and has a bunch habit of growth with no rhizomes or stolons. It should be planted in rows and cultivated and used where erosion is not a serious problem. It is propagated by stem cuttings.

b. Other tropical grasses.

(1) Paragrass (*Panicum purpurascens*), a native of Africa, is adapted to more poorly drained soils than Napiergrass[19,31] It has long creeping stolons which root at the nodes. It is propagated by stem cuttings since it produces no seed. Paragrass is also used for pasture in low areas but is coarser, stemmier, and less palatable than Pangolagrass.

(2) Pigeongrass (*Setaria sphacelata*) is a strong, bunchy grass from Africa. It is propagated by seed or cuttings. In Taiwan[19] it produced about three-fourths as much dry matter as Napiergrass. Grazing trials at the FAO station near Los Banos, Philippines, (personal visit, March 1967) show it is less palatable than Napiergrass. Research work needs to be conducted

* 10 *ares* = 0.10 *hectare*

on this grass before it can be recommended in Okinawa.

2) Tropical legumes

One of the main problems in the Ryukyus and in other tropical and subtropical areas is to find suitable perennial legumes to be grown alone or with grasses. Legumes are desirable in mixtures with grasses since they provide nitrogen and are generally palatable species. The lack of a good persistent, perennial legume is a problem in the United States as well as in Asiatic countries.[8,10,15,16,17,18,21,23,30]

a. Koa haole (*Leucaena glauca*) is a shrub-like legume which is found on soils having a high pH in many oriental countries[19] and Hawaii.[31] It is high in protein when young. Since it is essentially a woody tree, its stems are like tree branches when it is over 1 to 1 1/2 meters tall. It needs to be harvested before it gets one meter tall to reduce the amount of woody stems. Although Koa haole is not a very satisfactory legume, it is among the best perennial legumes for livestock use for the Ryukyus.

b. Alfalfa (*Medicago sativa*) is not a tropical legume but acts as a perennial. A stand of alfalfa at the Ryukyu Livestock Research Station of GRI near Shuri, Okinawa, was three years old[28] and in excellent condition during the winter of 1967. It produces most of its forage in the cooler part of the year—winter and early spring.

Data reported in Okinawa by Uchihara[29] show that alfalfa from Peru, Africa, or California (variety Caliverde) yielded between 5144 to 5255 *kg* green matter per 10 *are*. It is estimated this would be about 1050 *kg* dry matter per 10 *are*. Alfalfa has a protein content of about 20% and produces a good yield during the period from December to the latter part of June. Because of these reasons, its use should be expanded further by livestock farmers and more research should be conducted on this crop to improve yields during its optimum growth period of June to December.

Topdressing annually with phosphorus and especially potassium is necessary for high yields and long-lived stands of alfalfa[7]. If well fertilized and not cut until the first flowers start to appear, alfalfa should last for several years as a perennial legume grown alone. Alfalfa could be used as a valuable source of protein for chickens or other animals if dehydrated with equipment which is now present in some pineapple bran dehydrators in Okinawa.

B. Tropical perennials for pasture where less intensive management is practiced.

1) Tropical Grasses for Pasture.

a. Pangolagrass (*Digitaria decumbens*) is first choice for pastures in the Ryukyus based on its high palatability, good performance, and widespread use in Taiwan[19], Hawaii[11,20,31], Florida[9,13,21,27], Colombia, and Puerto Rico, Figures 3 and 9. Limited data from the Ryukyus Animal Husbandry Station of GRI near Shuri, Okinawa,[28], show Pangola yielded 11, 639 *kg* green matter per 10 are. Miyagi[22], (see above) reported a yield of 3396 *kg* green forage per 10 are at the Animal Husbandry Research Station at Shuri. This ranged from 1/2 to 2/3 of the production of Napiergrass in the same test. Eighty-six percent of this yield was produced from May 4 to November 4. In Taiwan, Pangolagrass produced 2200 *kg* dry matter per 10 are per year for a 2-year period[19]. In Florida, beef cattle on fertilized pasture gained 37.8 *kg* per 10 are on Pangolagrass compared to 22.4 *kg* on coastal Bermudagrass and 13.3 *kg* on native grass[9].

Pangolagrass is adapted to a wide range of soils. Data from Taiwan[19] show it performs well on soils of high and low acidity. Pangolagrass is of African origin. It was introduced into the Ryukyus about 1962, Taiwan in 1957[19], Hawaii about 1950[11], and Florida about 1930.

Fig. 3. Pangolagrass is the most productive and best pasture grass in the Ryukyus. It is the best grass to replace Chigaya and Susukigrass in areas as shown in Fig. 1. Photographed, January 1967 at GRI Station near Nago, Okinawa, Ryukyus.

This acceptance as a valuable pasture forage in a relatively short period of time indicates it has excellent qualities for pasture over a wide range of conditions. In a personal communication in January 1969, Mr. Yuzo Asato, Ishigaki, reports the planned use of 220 hectares on Iriomote Island in 1969[1] after successfully establishing this species on a more limited basis in pastures in 1967 and 1968.

Pangolagrass is a perennial which is propagated by runners or stolons. It grows to height of about one mater. If well fertilized, particularly with nitrogen at a rate of 30 *kg* or more per 10 *ares*, it produces a dense cover, suppresses weed growth, and produces high yields.

Several strains of Pangolagrass are available. Because of its resistance to virus, the A24 strain from Taiwan[19] should be the preferred source of this grass for further planting on the Ryukyus. The virus produces stunting, reduces yields, and kills plants, thereby reducing stands.

b. Bermudagrass (*Cynodon dactylon*), a native of India, is less valuable in the Ryukyus than Pangolagrass. Improved strains of Bermudagrass are grown on over 1,100,000 hectares in Georgia and adjacent states in the United States in more temperate areas where Pangolagrass will not survive the winters[4].

Bermudagrass forms an excellent sod, spreading by rhizomes and stolons. It is lower growing and less acceptable to livestock than Pangolagrass as indicated by animal performance in Florida[9]. In Taiwan[19], Coastal Bermudagrass from Georgia yielded about 80% as much dry matter per acre as Pangolagrass when fertilized with 10 *kg* N per 10 *are*. Some American varieties produce seed. Bermudagrass should likely be evaluated further in experiments for pasture under high rates of nitrogen fertilization.

c. Kikuyugrass (*Pennisetum clandestinum*) is inferior to Pangolagrass whenever it has been tried at elevations below 1000 meters[12]. Since most of the Ryukyus are below 500 meters in elevation, Pangolagrass is considered to be a better grass because of wider adaptation. In areas where cool temperatures prevail in winter as in areas in Iriomote, Kikuyugrass may be adapted[1]. Asato[1] notes that in Iriomote, "Kikuyugrass shows good growth during the period December to June but does not in the summer." This is in agreement with published results on Kikuyugrass in Hawaii[3,12] which show it is adaptable to cool temperatures whereas Pangolagrass is

more adaptable to higher temperatures.

Kikuyugrass is the most important pasture grass in Hawaii[12,2]. It is used in Hawaii[12] and Taiwan[19] at elevations above 1000 meters. It is low-growing and is propagated by stolons and rhizomes.

In trials at the Ryukyus Livestock Research Station near Shuri, Okinawa, Kikuyugrass yielded 75% as much as Pangolagrass[28], and didn't regrow as well. It deserves further trial under Ryukyuan conditions. At present, the data indicate Pangolagrass is superior.

2) Tropical Legumes for Pasture.

Growing a legume in association with a grass for pasture has several advantages. The legume (1) increases the protein content of the grass and itself has a high protein content and (2) supplies nitrogen for the mixture, reducing or eliminating the need for nitrogen fertilization.

Finding a suitable forage legume to grow with a grass under pasture, however, is difficult in tropical and subtropical countries. Generally, the grass is more resistant to disease and low soil fertility and crowds out the legume under grazing[16,19]. Several palatable legumes appear promising in Taiwan[19] and the Ryukyu islands when established in Pangolagrass. Considerable researeh on establishment and use is necessary, however, before the following legumes can be recommended in the Ryukyus.

a. Spanish clover (*Desmodium intortum*) appears at present to offer the greatest promise as a companion legume to Pangolagrass. Like most legumes, Spanish clover requires a soil with medium high pH for good growth (probably above 6.0).

Trials conducted in Florida[15], Hawaii[10], and Taiwan[19], show this legume can be maintained with Pangolagrass under grazing. The data in the table below[19] show the increase in protein when Spanish clover is added to Pangolagrass. After one year, 11% of the mixture was in Spanish clover. Florida and Hawaii report similar good results with this promising legume[15,10].

Table 1. Production of legumes and Pangolagrass in Taiwan.

Combination	annual *kg* per 10 *ares*		% legumes after 1 year
	Dry weight	Protein	
Pangola alone	1350	135	0
Pangola plus Spanish clover	1350	185	11
Pangola plus Rhodesian Kudzu	1230	165	1
Pangola plus *Centrosema*	1250	134	2

c. Centro (*Centrosema pubescens*) is a creeping legume showing promise in Taiwan, Hawaii, and Florida[19,11,16]. It is not as aggressive as Spanish clover in Hawaii or Taiwan.

c. Rhodesian Kudzu (*Glycine javonica*) is a slender, trailing legume which is slow to establish, drouth resistant, but not as productive or competitive as Spanish clover or Centro under Taiwan tests,[19] (Table 1).

d. Siratro (*Phaseolus atropurpureum*), introduced from Australia, is one of the newest legumes being tested. It looks promising in Florida[6,7] and at the FAO livestock station near Kao Shung, Taiwan[19] (and personal observations).

e. Stylo (*Stylosanthes gracilis*) has not been tried in the Ryukyus. It has shown primise in Taiwan[19], Florida[16,17] and Hawaii. It is slow to become established but relatively permanent with Pangolagrass when established.

2. Tropical Annuals

A. Summer-growing annual forage grasses.

1) Corn (*Zea mays*) is probably the best and most versatile of the summergrowing anuual grasses. It is the primary feed crop for livestock in the United States because of its high production, ease of culture, response to fertilizer and proper management practices, high digestibility, and ease of harvest. It produces high yields of forage and grain in the summer months in Taiwan and in the southern part of the United States, similar in climatic conditions to Okinawa.

When corn is used for silage, it should grow for a 3 to 5 month period, depending on the variety, before harvest. Because of its rapid growth, inexperienced operators may harvest the stalks and leaves after two or three months, sacrificing the great potential of corn to produce grain during the ear-filling period of 3 to 5 months after planting. Once corn is cut near the ground level, it will not regrow. When hervested for silage, the grain should be well formed on the cob in the early stage (small depressiou on tip of kernel). If cut before this stage, total yields will be reduced since maximum production of dry weight occurs when the grain is filling with carbohydrates. About 40% of the total dry weight of the crop should be in the grain, the remainder in the leaves, stalks and cob. Two-thirds of the feeding value of corn silage containing 40% grain is in the grain, one third being in the leaves, stalks and cob. Corn will require about 20 *kg* N per 10 *are* for good production of one crop.

Date obtained by the authors in 1967, Table 2 and Figure 4, show the high production of corn when planted in May or June harvested in August or late September to late October. Corn (average of 5 varieties) planted on May 23 and harvested on August 14 (probably a month too early for maximum yield) yielded an average of 2169 *kg* green material per 10 *are* (approximately 700 *kg* dry matter). Corn planted July 8 yielded from 2388 *kg* green material per 10 are when harvested September 28 (probably a month too early) to 6640 *kg* per 10 *are* when harvested on October 28 (the range in *kg* dry matter per 10 *are* would be approximately 700 to 2200). There was a noticeable difference in yield among varieties. Maximum yields were produced by the later-maturing varieties from Taiwan. They appeared to be well adapted to Okinawan conditions, probably because of a longer maturity period. The maximum yield of about 2200 *kg* dry matter per 10 *are* in a period of nearly 4 months shows the tremendously high potential of this crop for livestock feed.

Since about 1/4 of the silage was grain, Table 2, the high feeding value of this crop is again emphasized. Data in Table 3 show that, in the same location as reported in Table 2, corn growing for approximate 2-month periods produced 562, 344 and 161 *kg* dry matter per 10 *are* when planted on March 24, August 9 or September 28, respectively. These data indicate that corn produces the highest yield from a spring planting when ensuing temperatures and moisture become more favorable and least from a fall planting when lowering temperatures and discreasing moisture result in lower yields. Data in Table 2 show that Michigan hybrids 420, 430, and 570 spring planted on May 23 and harvested 3 months later produced less (1981 to 2232 *kg* green matter per 10 *ares*) than when summer planted on July 8 and harvested 3 months later (2660 to 3444 *kg*). Both planting dates produced high yields, however, indicating versatility of use of corn.

2) Sudangrass, the sorghums, and sorghum-Sudangrass hybrids are highly palatable grass crops which produce ratoons every 4 to 8 weeks. They are well adapted to high temperatures and will grow well between late April and November 1, when Napiergrass grows well. Planting should be in late April or early May on a well-prepared seedbed. At least 20 *kg*

Table 2. Green yield of ten hybrid corn varieties grown forage production in summer at the Animal Husbandry Research Farm, University of the Ryukyus, Shuri, Okinawa. 1967.

Variety	Planting date	Harvesting date	Days of growth	Plant Hegiht, *cm*	Green Yield Per 10 *ares*, *kg*			
					Grain	Cob	stalk	Total
Michigan 202	May 23	Aug. 14	83	165	667	460	1048	2175
〃 370	〃	〃	〃	187	919	445	942	2302
〃 420	〃	〃	〃	198	751	431	969	2151
〃 430	〃	〃	〃	201	717	309	955	1981
〃 770	〃	〃	〃	218	815	432	986	2232
Average				194	774	416	980	2169
Michigan 202	July 8	Sept 28	82	205	704	565	1029	2388
370	〃	Sept 30	82	208	916	702	1142	3081
420	〃	Oct 5	89	205	950	755	956	2661
430	〃	〃	89	201	678	802	1225	2705
570	〃	〃	89	206	1059	1000	1385	3444
Taiwan No. 5	〃	〃	89	244	1311	647	1545	3503
SYN 7	〃	〃	89	243	964	574	1675	3213
SYN 8	〃	〃	89	235	962	771	1538	3271
MIZ 63A	〃	〃	112	280	1301	967	4395	6663
Bop. Do	〃	〃	112	235	1020	1290	3330	5640
Average				226	996	8074	1854	3657

Table 3. Yields in kg. per 10 are of corn planted at three dates in 1967 and oats planted in late 1967 as measured in approximate 2-month periods for corn and a 3-month period for oats. Animal Husbandry Research Farm. University of the Ryukyus, Shuri, Okinawa.

Planting date	Corn, Taiwan variety			Oats Nov. 1
	Mar 24	Aug 9	Sept 28	
Harvesting date	May 27	Oct. 3	Dec. 9	Feb. 1 (68)
Days of growth	64	56	72	92
Green weight	4320	2570	1150	4090
Dry weight	561	344	161*	600

* typhoon on Oct 24–25

nitrogen per 10 *ares* will be required for every 4-months of growth.

Cutting or grazing should not be started until the growth is about one mater tall. Shorter growth may poison livestock because of prussic acid poisoning. Recommended cultural practices from Florida[8,18] served as the basis of experimental plantings made in Okinawa in 1967.[25]

a. Sorghum-Sudangrass hybrids are hybrids between sorghums (grown for grain or forage) and Sudangrass (grown for forage). Seed should not be replanted from a crop since the resulting crop will be of low vigor. *New hybrid seed must always be obtained* when a crop is planted. Seed can be obtained from the Texas Agricultural Experiment Station mentioned above, Northrup King and Company, Minneapolis, Minnesota, (Sordan), and Funk Seed

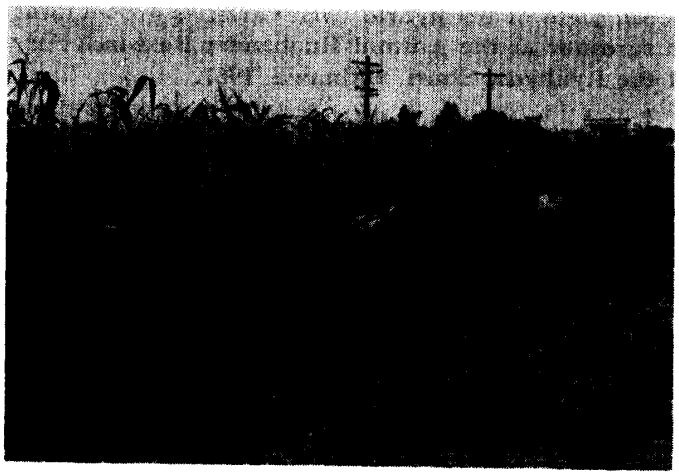


Fig. 4. Corn is probably the best and most versatile of the summer growing annual grasses. Planted July 8, 1967, being harvested October 5, 1967, 89 days later. Prodcution of Taiwan variety # 5 was 3503 green weight kg per 10 are, 37% being grain. Animal Husbandry Research Farm, Shuri, Okinawa, Ryukyus.

Company, Bloomington, Illinois (Lindsay 77F).

Cutting should be no closer than 15 *cm* or poor regrowth will result. Because of the large number of buds formed near the ground level when sorghum-Sudangrasses or Sudangrasses are cut at about a height of 15 to 20 *cm*, several ratoons are possible from this crop. Planting and cutting is as for Sudangrass.

Data in Table 4 show that the average yield for three varieties of sorghum-Sudangrass planted on April 26 and harvested 4 times in a 187-day period was 994 *kg* per 10 *ares*. The vigorous growth of the third harvest is shown in Figure 5. Sorghum-Sudangrass growing for a 99-day period produced an average of 5216 *kg* green matter per 10 *ares* or compared to two varieties of corn which produced 6653 and 5640 *kg* green matter per 10 *ares* in another experi-

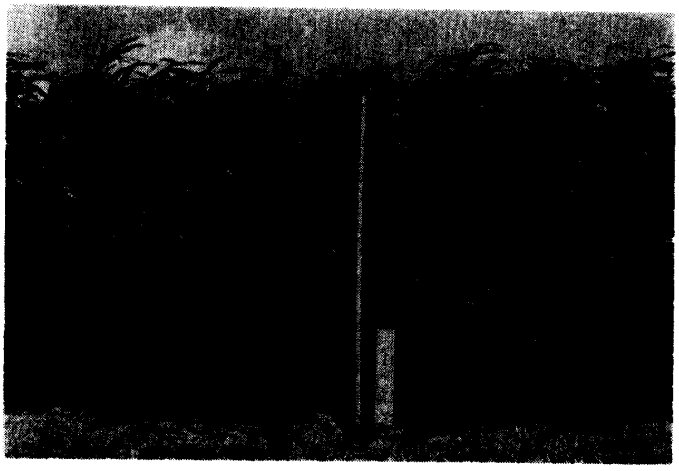


Fig. 5. Sorghum-Sudangrass yields equally as well in three ratoons as corn in one, making it one of the two best summer growing annual crops. It is finer-stemmed than corn but produces no grain. Third ratoon, Sept. 10,1967, 138 days after planting on April 26, Animal Husbandry Research Farm, Shuri, Okinawa Ryukyus.

ment, Table 2. Data are hard to compare because of different lengths of growing seasons, different sites, and because dry weights were not attained in the experiment on corn, Table 2. Both, however, produced high yields per 10 *ares*, and were probably similar in production of dry matter.

In comparison to Sudangrass, Table 4, three sorghum-Sudangrass hybrids produced about 45% more dry matter than Sudangrass (994 kg compared to 687 *kg* dry matter per 10 *ares*). This is similar to the greater yields obtained from sorghum-Sudangrass in southern United States when compared to Sudangrass.[3)]

b. Sudangrass (*Sorghum sudanense*) is similar to the sorghum-Sudangrass hybrids and, likewise, produces several ratoons. Cutting should be no closer than 5 *cm* for good regrowth. It should be seeded by (1) broadcasting the seed and covering with a harrow and roller or (2) drilling in rows about 30 *cm* apart. Greenleaf, Piper, and Sweet Sudangrass varieties are obtainable from the Texas Crop Improvement Association, College Station, Texas, U.S.A., and should be among the best varieties for the Ryukyus.

Data in Table 4 show that Piper Sudangrass is high yielding but considerably lower than the sorghum-Sudangrass varieties. Advantages of Sudangrass are that it can be cut or grazed closer, the plants are not hybrid so the seed can be replanted from seed produced in Okinawa.

c. Forage sorghum (*Sorghum vulgare*) produces only one crop with no ratoon. Its use is not encouraged. Rather than grow only one cutting, it would be more advisable to grow corn as a silage crop and utilize the grainproducing potential of corn.

B. Summer-growing annual forage legumes.

Thick-planted soybeans (*Glycine max*) or cowpeas (*Vigna sinensis*) would be the best choices. In general, they cannot be recommended unless a high protein feed is desired. Summer-growing annuals such as the sorghum-Sudangrasses or corn have a higher yield potential.

C. Winter-growing annual forage grasses.

These are cool-temperature grasses which grow well during November-April when Napier-

Table 4. Green and dry weight in kg per 10 are of 3 varieties of sorghum-Sudangrass and one variety of Sudangrass planted April 26, 1967, and given four successive harvests. Animal Husbandry Research Farm, University of the Ryukyus, shuri, Okinawa. Fertilized with 14 kg N, 6 kg K per 10 are at planting and 10 kg N and 4 *kg* P are after second harvest.

Variety and kind of grass	Weight	Date of harvest and accumulated days' growth				
		June 20	Aug. 3	Sept. 11	Oct. 30	Total
		55	99	138	187	187
Sordan	fresh	3434	1824	3852	1027	10,138
Sorghum-Sudangrass	dry	312	190	347	116	965
Yield Maker	fresh	3480	1884	4284	992	10,640
Sorghym-Sudangrass	dry	348	181	442	113	1054
Lindsay	fresh	3134	1992	4084	1004	10,146
Sorghum-Sudangrass	dry	299	175	380	109	962
Piper Sudangrass	fresh	2400	1627	3007	1034	8069
	dry	171	140	270	105	687

grass, sorghum-Sudangrasses, Sudangrasses, and Pangolagrass grow very slowly. As shown later, some of these can be planted by overseeding over a Pangolagrass sod or by planting in rows between Napiergrass.

1) Winter oats (*Avena sativa*) is the best supplementary feed for winter use. Oats are widely used in Taiwan[19] and Florida[5] for winter feed. Plantings made at the Animal Husbandry Research Farm near Shuri, Okinawa, in November and early December gave the best production of all crops when grown alone or in mixture with vetch, Tables 3 and 5 and Figure 6.

Oats can be planted (1) alone in rows 30 *cm* apart above the fertilizer, (2) between rows of Napiergrass, or (3) with winter vetch in alternate rows, Figure 6. Since oats grow to a height about 1 1/2 meters in the three winter months, they are well suited for hand harvesting.

Fig. 6. Winter oats, left, is the best winter forage for the Ryukyus, yielding more than rye, right, and other grasses. Woolypod vetch is excellent seeded alone or between oat rows. Planted December 2, 1966; Picture March 15, 1967. Animal Husbandry Research Farm, Shuri, Okinawa, Ryukyus.

2) Winter rye (*Secale cereale*) is only about one-half as productive as oats and more stemmy than winter oats, Table 5 and Figure 6. On very poor soils, it may be superior to oats. The earlier-heading date makes it less desirable for forage.

3) Italian Ryegrass (*Lolium multiflorum*), variety Flori la Rust Resistant, produced only about two-thirds as much dry forage, Table 5 and Figure 7, as oats, during the winter months. It would be more suitable for pasture than oats because of excellent regrowth if pastured closely. Broadcasting ryegrass over Pangolagrass in October for pasture would appear to be its best use. This practice is successful in Florida in the United States.

4) Corn (*Zea mays*) has not been evaluated adequately in the Ryukyus but looks promising for winter feed production, Figure 8. It produces high winter production in Central Taiwan and Florida. It should be tried in experimental plantings for green chopped material and silage. Corn requires a high amount of nitrogen, about 20 *kg* per 10 *ares* for one 4-month crop. Corn does not produce ratoons.

D. Winter-growing annual forage legumes.

These would be grown by sowing between alternate rows of oats in the case of vetch, Figure 6, or overseeding (broadcasting) on top of established Pangolagrass, Figure 3. Legumes

Table 5. Yields of winter annuals in the 1966–1967 winter growing season at the Animal Husbandry Research Farm University of the Ryukyus, Shuri, Okinawa. Ten *kg* N and P and K were used for 10 *ares*.

Species and Variety		*kg* per 10 *ares*	
		Fresh	Dry
Planted Nov. 16, 1966; harvested Feb. 23, 1967			
MSU 4n Allotetraploid Forage Rye		1330	233
MSU Allotetraploid Ryegrass		1420	250
MSU 4n Gator Rye x Allotetraploid		1920	353
MSU Allotetraploid Vetch		3750	435
Gator Rye		2340	393
Florad Oats		6390	1048
Planted Dec. 2, 1966; harvested Mar. 27, 1967			
Gator Rye		850	221
Auburn woolypod vetch		2140	265
	Total	2990	486
		2200	475
Florida Oats		1850	229
Auburn wooly-pod vetch	Total	4050	704
		890	231
Gator Rye		1800	259
Warrior vetch	Total	2690	490
		1930	417
Florad Oats		1450	209
Warrior vetch	Total	3380	626
Plnated Dec. 2, 1966; harvested Mar. 30, 1967.			
Woolypod Vetch		2220	351
Warrior Vetch		3110	498
Berseen Clover		1500	270
Florida Rust Resistant Ryegrass		2170	378
Floranna Sweet Clover		2110	523
Plannted Dec. 2, 1966; harvested April 15, 1967			
Yuichi Arrowleaf Clover		1060	225
Auburn Crimson Clover		1830	406
Ball Clover		1830	626
Israel Sweet Clover		1280	312
Berseem Clover		1220	376

Fig. 7. Annual ryegrass is an excellent pasture grass which can be oberseeded on Pangolagrass in October to be used for winter pasture. Planted December 1966; Photographed March 15, 1967, Animal Husbandry Research Farm, Shuri, Okinawa.

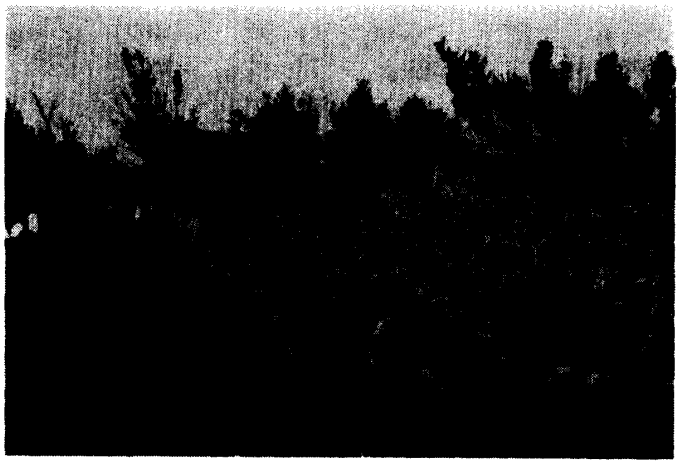


Fig. 8. Corn planted in October or early November should be evaluated further as a source of winter feed. Photographed January 30, 1967, in Miyako, Ryukyus.

overseeded on Pangolagrass produce considerable nitrogen for greater production of the Pangolargrass.

1) Common Vetch (*Vicia sativa*) variety Warrior was the most productive of the vetches in tests made in Okinawa in 1967, Table 5. Common vetch produced 50% greater yield by March 30 than did woolypod vetch, Table 5. It is the preferred legume to be grown in alternate rows with oats for winter feed.

Common vetch has comparatively weak, semi-viny stems which gives it a semi-prostrate growth.

2) Woolypod vetch (*Vicia dasycarpa*) is similar to common vetch. When sown on December 2, it produced yields nearly as high as those of common vetch, Table 5, Figure 6. This was also supported by reports from Taiwan[19]. It appears to be of excellent quality and is high in protein. Seed is avaieable from Taiwan Seed Service, Provincial Department of Agricul-

ture and Forestry, Shinshieh, Taichung, Hsien, Taiwan.

3) Ladino clover (*Trifolium repens*) has provided high quality forage in Okinawa. It has yielded well in Taiwan[9] and Florida[21] for winter production with Pangola grass. Yields in Taiwan[19] in 1961 were as follows:

Mixture		*Kg* per 10 *ares* (dry weight)
(1)	Berseem clover	150
	Pangolagrass	850
(2)	Ladino clover	1200
	Pangolagrass	850

The primary use of Ladino clover in Okinawa would be for overseeding a Pangolagrass sod in the fall to improve winter production.

4) Berseem clover (*Trifolium alexandrinum*) looked promising in 1967, as a winter feed, Table 5, in tests in Okinawa. When seeded on top of Pangolagrass, it is popular as a method of improving the yield of Pangolagrass in winter in Florida and, to a lesser extent, in Taiwan.[19]

5) Annual sweet clover (*Melilotus indica*), variety Floranna[14], has given good winter growth in trials in Okinawa in 1967, Table 5. It should produce its maximum growth in April and May. It grows to a height of 1 to 2 meters. Annual sweet clover may prove valuable for overseeding on Pangolagrass. It should be tested further in trials in Okinawa.

6) Ball clover (*Trifolium nigrescnes*) produced the highest yields of the five clovers allowed to grow until April 15, Table 5. It is questionable, however, if it would have outyielded the vetches and sweet clover harvested on March 30 if they had been allowed to continue growth.

Ball clover is grown successfully as a pasture crop in the southern part of the United States. It should be tested further in Okinawa because of its high production in these tests. Its best potential use is for overseeding on pasture grasses such as Pangolagrass.

7) Crimson clover (*Trifolium incarnatum*) yielded well by April 15 in the trials reported in Table 5, but less than Warrior Vetch or Floranna sweet clover harvested two weeks earlier. Although not the highest-yielding species, it should find a good use overseeded on top of Pangolagrass, now a common practice in Florida in the United States.

The large percentage of hard seed and its prolific seeding habit make Crimson clover the most important winter clover in subtropical United States. It should likewise become important in Okinawa which has subtropical conditions similar to those in Florida.

Although the trials reported in Table 5 were planted in November and December, it is likely that Crimson clover should be planted in September in Okinawa to obtain maximum yields during the winter season.

Note: All legumes must be inoculated prior to planting to enable them to add nitrogen to the soil. Inoculum is available from the Nitragin Company, 3101 West Custer Ave., Milwaukee, Wisconsin.

II. CAREFUL ESTABLISHMENT IS NECESSARY FOR GOOD STANDS

A. Napiergrass requires a well-prepared seedbed. Clean, well-tilled land is necessary for this crop planted in rows about a meter apart. The stems should be placed in the bottom of the furrow and fertilized with nitrogen, phosphorus, and potassium[7].

B. For annual grasses such as oats, rye, corn, Sudangrass, and sorghum-Sudangrass hybrids, the soil should be prepared carefully as described for Napiergrass above. Plants are established from seed with the fertilizer placed under the seed in rows 30 *cm* apart. Corn rows

should be 60 to 90 *cm* apart. Oats, ryegrass, and crimson clover can also be overseeded (broadcast) on top of established Pangolagrass with no tillage involved or broadcast on clean soil, harrowed in and compacted.

C. For alfalfa, clean land should be used as in A and B above, fertilized for grass, but with no nitrogen. When alfalfa is planted, adequate phosphorus and potassium should be used[7]. It should be broadcast, harrowed in with a spike-tooth harrow, compacted by rolling or sown about 1 to 2 *cm* deep in rows about 30 *cm* apart. It must be inoculated prior to planting so it can add nitrogen to the soil.

D. Pangolagrass planted carefully on small areas on clean land (information from Luh *et al*[19]) should become established rapidly, Figure 9.

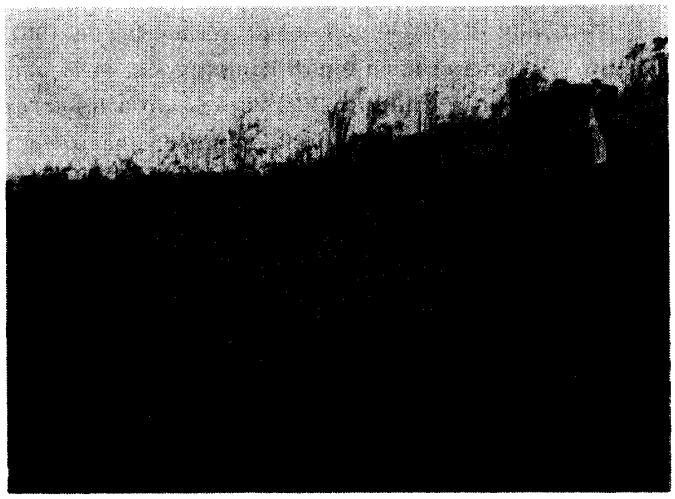


Fig. 9. Pangolagrass becomes established rapidly when planted one meter apart as shown here in Taiwan on a steep sidehill in January 1967.

1) Pangolagrass should be planted between March 1 and November 1. It grows best in hot weather. Planting in April or early May will likely give the best establishment.

2) A good seedbed should be prepared by plowing or with a hoe as for other crops. The field should be harrowed. The furrows should be made 15 *cm* deep with a plow or hoe. Fertilizer should be mixed as follows or as indicated by soil test by Chinzei *et al*[7]:

Ammonium sulfate (20% N)	— 3 parts
Superphosphate (16% P_2O_5)	— 4 parts
Potassium chloride (60% K_2O)	— 1 part

The fertilizer should be spread in the bottom of the furrow at the rate of 0.4 *kg* for each 10 meters of row when rows are one meter apart or 0.2 *kg* when 50 *cm* apart.

3) Pangolagrass should be planted by hand in rows one meter apart[19]. The fertilizer should be covered with 6 to 8 *cm* of soil. The Pangola cuttings should normally be 15 to 20 *cm* long and be cut so there are at least three nodes per cutting. The cutting is held by the top and placed in the bottom of the furrow at a 45-degree angle and covered with 7 to 9 *cm* of soil. Two nodes should be covered and one should be above ground. The middle node should be just below the surface of the ground and the lower one buried 6 to 8 *cm* deep.

E. How to plant Pangolagrass mechanically on large area.

Broadcasting of Pangolagrass cuttings is used for larger areas. It is the standard method in Florida[9] in the United States. The land should be free of weeds and clean as for hand

planting. Seedling pieces should be cut 8 to 10 *cm* long. The seedlings should be distributed so there is at least one piece for every 100 square centimeters. The pieces are harrowed into the soil with a disk so pieces are covered. The area should be compacted with a roller if possible. Weeding is not needed if fertilizer is added[7] as specified at a rate of 50 *kg* 20% ammonium sulfate, 30 *kg* 16% superphosphate, and 20 *kg* of 60% potassium chloride per 10 *ares*.

F. How to plant Pangolagrass on stony land[19].

Hole planting should be used where the land is so stony it cannot be cultivated. The holes are made 30 *cm* in diameter with 60 *cm* between holes. The holes should be 15 *cm* deep with 40 grams of fertilizer placed in the bottom of the hole and covered with 8 *cm* of soil. Four to 5 seedlings are placed in the hole with the tops toward the center. After seedlings are well established, weeds are removed and fertilizer is applied at the rate of 40 *kg* per 10 *are* in the areas between holes[7].

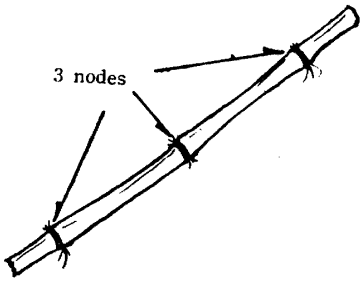


Fig. 10-a Pangola grass cutting showing three nodes

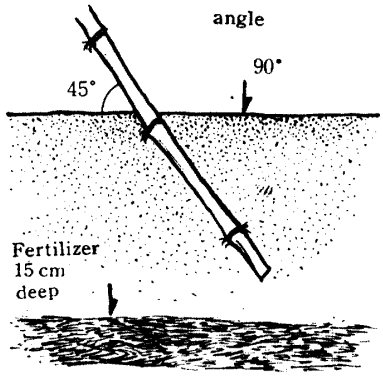


Fig. 10-b Proper way to plant Pangola grass cutting

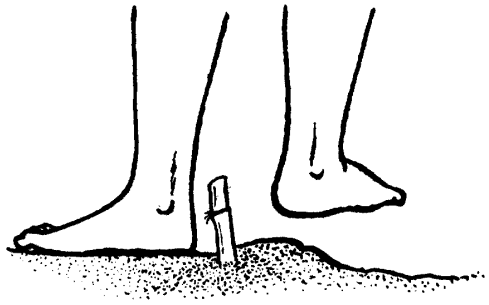


Fig. 10-c Soil should be packed around Pangolagrass cutting

The soil should be compacted over the cutting with the feet immediately to get it started and prevent drying of the soil. Packing should be adequate so that the cutting can not be pulled out easily by hand.

G. How to plant grass on uncleared land having trees and grass[24]. To kill trees and shrubs, 1 to 2 *kg* of 2,4,5-T herbicide are used as a spray per 10 *ares*. The trees may be destroyed by cutting. The area can be burned in 2 to 3 months to reduce grass growth. Repeat spraying may be necessary. If grass growth is heavy a month after burning, it may be necessary to spray with 1 *kg* dowpon per 10 *ares*. (Dowpon (dalapon) grass killer is obtainable from the Dow Chemical Company, Midland, Michigan, or in Tokyo, Japan). After 2 months, Pangolagrass can be established by fertilizing and planting in rows one meter apart as in method

in II D above. The rows may be made with a plow and the cuttings put in the plow furrow. The cutting is placed in the open furrow, fertilized, and then covered with another furrow slice or planted by hand in a checker-board pattern 1 meter apart.

III. SOUND MANAGEMENT OF PANGOLAGRASS IS NECESSARY AFTER PLANTING

A. Grass should be protected until established. This is especially necessary where the soil was not well prepared. Animals should not graze Pangolagrass until it has covered the ground and the growth is 25 to 35 *cm* tall. This will generally require a period of 3 to 4 months.

B. Weeds should be removed early when 2 to 6 *cm* high. When weeded too late, weeds cannot be separated from the planted grass. 2,4-D herbicide obtainable in Tokyo at a cost of 20 cents (U.S.) per 10 *ares* will kill most broad-leaved weeds. Once established, Pangolagrass will control weed growth if well fertilized.

C. Pangola should be cut when 30 to 40 *cm* high. When cut too late, the nutritive value declines rapidly. For a large area, cutting should start when the grass is 30 *cm* high. The whole area can then be cut before the grass is 40 *cm* high. Excess grass can be cut before it blossoms and put in a silo.

D. Grass should be fertilized with nitrogen after cutting. *Nitrogen, especially, is necessary for high yields and stands free of weeds. Fresh barnyard manure, liquid manure, or chemical nitrogen fertilizer should be applied after each cutting,* **5** *to* **6** *times a year.* At least 30 *kg* per 10 *ares* are required per year. This would be 6 *kg* N per 10 *ares* per application (30 *kg* ammonium sulfate). Annual applications of phosphorus and potassium are necessary for high yields. Thirty *kg* of superphosphate and 20 *kg* of potassium chloride per 10 *ares*[7] are advised. For greater winter production, nitrogen should be applied on Pangolagrass in October. Nitogen is more beneficial if applied in October for winter growth than if applied in December[30].

IV. IMPROVED FORAGES AND PASTURES NEED HIGH AMOUNTS OF NITROGEN.

Napiergrass must be heavily fertilized in order to utilize effectively the small acreages on which it is planted. The fields should be near to the feeding area. Maximum fertilization with N, P and K will profitable. Forty *kg* N per 10 *ares* is not excessive per year. Napier should be about a meter tall when cut but can grow up to two metrs before cutting. It should be remembered, however, that as a grass grows taller, it matures and decreases in digestibility, resulting in decreased animal acceptance and productivity.

Pangolagrass should be cut or grazed by livestock when it reaches a height of 40 *cm*. With adequate nitrogen fertilizer, Pangolagrass can endure frequent defoliation. *Thirty kg per* **10** *ares is a minimum for good yields of Pangolagrass.*

V. HOW TO START LEGUMES IN ESTABLISHED STANDS

The information presented here was obtained by the senior author after viewing legume establishement practices in Florida, Hawaii, and Taiwan. These practices should work in the Ryukyus but additional research is necessary to be sure of the best methods of establishment. Suggestions for practical establishement and use are:

1) The area should be overgrazed to a height of 4 to 6 *cm* and/or

2) Strips 30 *cm* wide should be sprayed in rows 2 meters apart with 1 *kg* Dowpon per 10 *ares*. Legume seed should be sown within 2 to 3 weeks.

3) Legumes must be inoculated with proper *Rhizobia* bacteria immediately before planting.

4) Seed should be broadcast on the surface or incorporated to a depth or 1–2 *cm* with a spade or any machine such as a cultivator to loosen the soil. Cattle should graze for a week or two to trample the seed in the ground. Seeding in October or November when grass growth is slowing down is likely to result in better stands than seeding in spring just before grasses start growing rapidly.

5) The area over the seeded row should be fertilized with phosphorus and potassium[7].

6) There should be not grazing or 4 to 6 weeks after planting and then not too heavily.

7) Rotational grazing should be practiced. Rotational grazing is the practice of intensively grazing to a height of 5 to 8 *cm*, removing the cattle, and then returning them to the same pasture in 30 to 40 days in summer and 60 to 75 days in winter. Three to four pastures are advisable for rotational grazing.

VI. HOW TO START LEGUMES IN NEW CLEANLY-TILLED FIELDS.

1) Rows of Pangolagrass should be alternated with legumes seeded in one meter rows. The legumes seed should be planted 1 to 2 *cm* deep and above the fertilizer. The soil should be compacted over the row.

2) The legume should be fertilized with phosphorus and potassium in a band under the seed.

3) Once established, rotational grazing should be practiced as in V-7 above.

VII. KEYS FOR HIGH YIELDS ON ESTABLISHED OF MOST IMPORTANT PERENNIAL GRASSES.

A. Fertilizer should be applied 5 to 6 times per year for high yields of Napiergrass. Forty *kg* nitrogen per 10 *ares* annually should be used. Liquid manure helps to supply nitrogen but will generally not add sufficient amounts of this element. Thirty *kg* of 16% superphosphate and 20 *kg* of 60% potassium chloride per 10 *ares* per year are necessary[7].

B. Napiergrass should be cut no closer than 15 *cm* or the stand will not last long. It should be fertilized with nitrogen after cutting as in A. above.

C. Pangolagrass should be grazed rotationally every 30 to 40 days in summer, and every 60 to 75 days in winter. Fertilizing with 30 *kg* per 10 *ares* per year applied in portions after each rotational grazing will result in high yields.

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琉球の草地と飼料作物

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1965年の統計によれば，琉球の家畜頭数は肉牛18,312頭，乳牛1,204頭，山羊51,162頭，馬13,067頭である。冬期の主な粗飼料はキビ稍頭部で，その他の時期には，反芻家畜は主に畜舎で在来野草を与えている。八重山群島では肉牛は主として放牧でまかなわれている。

琉球の放牧地における在来野草はチガヤ (*Imperata cylindrica*) とススキ (*Miscanthus sinensis*) が主である。これらの野草はフィリピン，台湾，東パキスタン，印度などの亜熱帯や熱帯地方の多くの国の放牧地に発育しているものである。これらの草が生えている所では一般に雑草として考えられている。チガヤとススキは本論で述べてある導入牧草より栄養価が低く，特に成熟期にその傾向が強い。これらの草が生育している国々では放牧草として利用され，生育の初期にはかなりの栄養価がある。しかし，これらの草は夏の間に急速に成熟して嗜好性を失うものである。特にチガヤは1 *m* 以上になると劣等な粗飼料となる。一般に，この二つの野草は畜産専門の人々から劣等な品種の草として認められている。

琉球の放牧地の牧養力は，これら二つの望ましくない在来野草のために制限を受けている。優良な導入牧草によって，この雑草が生えている放牧地を改良することは琉球の畜産を成功させるために必要である。導入品種はチガヤ，ススキより嗜好性がよく，成熟期においてもより栄養価値が高く，施肥，特に窒素肥料の多肥に対して強く反応するものであ。

著者の一人 Tesar は琉球と同じ亜熱帯気候に属する台湾の試験場と一般農家の実情を調査した。同様な調査を亜熱帯のハワイ州オアフ島，ハワイ島，カワイ島についても行なった。アメリカ本土を出

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発する前に琉球と同じ緯度にある亜熱帯に属するフロリダとジョウジアを訪ね，どのような亜熱帯牧草が試験場や農家で利用されているかを調査した。また，著者等は琉球の畜産試験場の専門家や農家の方々と懇談し，畜産の発展の可能性を確かめるために沖縄本島と宮古島および石垣島を訪ねた。

1966年の秋に冬作イネ科牧草とマメ科牧草の栽培試験を琉球大学附属農業試験場で行なった。そして1月から5月にかけてそれを収獲した。試験は1m間隔に条播し，窒素，燐酸，加里は充分に施肥した。1967年にはトーモロコシの播種期別の生産性の比較調査を実施すると共に，ソルガムースーダングラス（Sorghum-Sudangrass）の三品種について，4回刈した時の生産性についての試験も行なった。

飼料作物の分類は前述の亜熱帯地方の国々での観察的な知見と1967-68年に得られた実験データーを基にし，それに琉球における飼料作物の利用法と将来性などを評価して行なった。さらに琉球の反芻家畜に対する草地造成法や飼料作物の生産性の向上に最も有効と思われる事柄についての勧告もなされている。