CHINESE - AMERICAN

JOINT COMMISSION ON RURAL RECONSTRUCTION

Animal Industry Series No. 6

GRASSLAND POTENTIAL AND CURRENT DEVELOPMENT ON TAIWAN

By

T. H. Luh, Forage Crop Assistant Specialist,
C. Huang, Forage Crop Specialist,
and
Howard W. Ream, Chief, Animal Industry Division,
Joint Commission on Rural Reconstruction

TAIPEI, TAIWAN, CHINA

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FOREWORD

Much has been written about the merits of grass. Perhaps the most vivid description of the value of grass to mankind ever penned is contained in an article by the late Senator John Ingalls of the United States which appeared in the Kansas Magazine in 1872 and is quoted as follows:

"Grass is the Forgiveness of Nature—her constant benediction. Fields trampled with battle, saturated with blood, torn with the ruts of cannon grow green again with grass, and carnage is forgotten. Streets abandoned by traffic become grass-grown like rural lanes and are obliterated. Forests decay, harvests perish, flowers vanish but grass is immortal. Sown by the winds by wandering birds, it softens the rude outline of the world. Its tenacious fibers hold the earth in its place and prevent its soluble components from washing into the wasting sea. It invades the solitude of deserts, climbs the inaccessible slopes and forbidding pinnacles of mountains, modifies climates and determines the history, character and destiny of nations.

Unobstrusive and patient, it has immortal vigor and aggression. Banished from the thoroughfare and the field it bides its time to return and when vigilance is relaxed, or the dynasty has perished, it silently resumes the throne from which it has been expelled but which it never abdicates. It bears no blazonry of bloom to charm the sense with fragrance or splendor, but its homely hue is more enchanting than the lily or the rose. It yields no fruit in earth or air, and yet, should its harvest fail for a single year, famine would depopulate the world."

Grass has not been appreciated for these values to any great extent as yet in Taiwan. However, the recent development of improved high producing forages in this country has brought about true appreciation of grass and its potential among a few farmers. These farmers have ably managed improved areas of forage and are amply demonstrating its value to others. As a result, considerable interest is evident recently on grassland development and the consequent utilization of these lands for livestock production in many sections of Taiwan. Like any successful undertaking, this one started in a small way in the minds of a few men who visualized the potential that existed for including improved forages in plans for increasing the food production potential of this country. Largely through the foresight and vision of JCRR Commissioners R. H. Davis and T. H. Shen and Secretary-General of JCRR, Dr. Y. S. Tsiang, impetus was given to the production of forage crops with the initiation of an observation program and several grazing farm projects in 1953. Numerous introductions of improved forages were made at this time and the early work was guided by H. F. Chu of the Plant Industry Division, JCRR, and T. H. Luh, then of the Taiwan Agricultural Research Institute. Encouragement to the program was given by Dr. Olaf S. Aamodt, former chief of the Forage Crops Division, Agricultural Research Service, U. S. Department of Agriculture, who visited Taiwan in 1956 and was the International Cooperation Administration's Washington Consultant and Advisor to the First Far East Seed Improvement Conference, which was held in Taipei that year. Through Dr. Aamodt's efforts, forage crops received considerable attention and discussion at this conference. Likewise, he urged the Chinese Government to begin immediately to develop this great food production potential and to thus demonstrate the possibilities for utilizing land in this way to other countries in Asia. Subsequently, Mr. John Hercus, United Nations Food and Agricultural Organization Forage Crop Consultant studied the grassland potential of Taiwan for three months in 1959 and gave sound advice and encouragement to develop this resource to its fullest. The program has been accelerated since 1957 and many individuals and organizations have assisted in conducting field trials and investigations and in helping farmers with the planting of improved forages. Among these have been the Provincial Department of Agriculture and Forestry, Provincial, County and Township Farmers' Associations, the Provincial Livestock Research Institute and the District Agricultural Improvement Stations, particularly those at Hwalien and Taitung, the Taiwan Agricultural Research Institute, the Provincial College of Agriculture at Taichung, the Voluntary Assistance Committee for Retired Servicemen and many others. Within JCRR, invaluable assistance has been given by the Plant Industry and Agricultural Extension Divisions and especially by be field workers of the Liaison Office of Mountain Resources Development.

Howard W. Ream
Chief, Animal Inustry Division

GRASSLAND POTENTIAL AND CURRENT DEVELOPMENT ON TAIWAN

T. H. LUH, C. HUANG and H. W. REAM

Taiwan, a province of the Republic of China, is one of the most densely populated countries in the world. There are nearly 11,000,000 people living on approximately 8,887,000 acres (3,576,000 hectares). The populace is increasing at the rate of 3.5 per cent per year. The country must therefore utilize all of this land to maximum advantage in order to meet the food needs of this greatly expanding population.

PRESENT LAND AREA AND UTILIZATION

Only about 29 per cent of the land is cultivable land, of which 16 per cent is classed as paddy, and 12 per cent dry farming, with about 1 per cent in farm woodland and windbreaks. This area has, for the most part, been developed and managed as efficiently as land anywhere. Crop yields per unit area are among the highest in the world. The general index of agricultural production has increased from 39.8 in 1946 to 133.4 in 1960. Unfortunately there is little opportunity to expand the area. Small parcels of land can possibly be reclaimed from the sea and some land can be bench-terraced in the foothills. Further development of irrigation facilities offers the greatest opportunity for increased over-all crop production. But the increases from all of these possibilities can only be expected to increase total food production a small amount percentagewise.

Of the remaining land area, about 32 per cent is above 1,000 meters in elevation and is mostly shallow soil, or exceptionally rocky land on extremely steep slopes, or is covered with arrow bamboo which would require excessive expense to eradicate. Most of this land is only suitable for forestry and some of the steepest areas which cannot sustain tree growth should be maintained as watershed protection areas.

The remaining 39 per cent comprises the foothill and tableland areas between 100 and 1,000 meters elevation. The slopes are often quite steep but much of the land is suitable for raising adapted grasses and legumes.

More detailed information relative to grassland development possibilities is included in data from a so-called "Marginal Land Survey" which was completed in 1959.

POTENTIAL AREAS FOR GRASSLAND DEVELOPMENT IN FOOTHILL AND TABLE LAND AREAS

According to this survey of 1,400,000 hectares of land having an elevation of 1,000 meters or less, over 70 percent is submarginal for cultivated crops. Most of this is

Class VII land (based on a classification similar to the Land Capability Classification used in the U. S.) which totals about 900,000 hectares. Over half of this or more than 500,000 hectares has inadequate protective cover. About 150,000 hectares of the latter is cultivated at the present time, and another 115,000 hectares is now idle, chiefly abandoned tea, citronella, or sisal plantations or land in a sparse cover of weeds and grass. There is also approximately 250,000 hectares of land which has only a scattered stand of trees and which at the present time affords little protection from erosion. It is estimated that 100,000 hectares of the land now cultivated, 92,000 hectares of the idle land, and one-half or 125,000 hectares of the thinly forested lands could be developed for forage production. This is a total of 317,000 hectares and would constitute the principal area where early grassland and livestock development should take place.

LIMITED POSSIBILITIES FOR DEVELOPMENT IN MOUNTAIN AREAS

Future expansion may later take place at elevations above 1,000 meters. While there are 1,132,771 hectares of land at elevations over 1,000 meters, most of this is extremely steep slopes, is exceptionally rocky or has very shallow soil, or is covered with dense stands of arrow bamboo which would require excessive expense to clear. Likewise, much of this land is inaccessible. About 1 per cent or 10,000 hectares may be suitable and accessible for grassland development. Thus, the total potential area for forage production in Taiwan may be about 327,000 hectares. Planted to good species of grasses and legumes and with good fertilization and management practices, this area should be capable of supporting 1,000,000 mature cattle (or equivalent in animal units of other forage consuming livestock) or more than three times the present cattle population.

The map (Fig. 1) shows the areas on Taiwan best adapted to early forage development. These are designated according to suitability from the standpoint of soils, rainfall, topography and location with respect to markets:

MOST FAVORABLE

a. Linko and Taoyuan Table Lands

The soils on these tablelands are reddish-brown lateritic soils developed on gravel terraces which were uplifted to form a discontinuous belt of land. The coarse underlying material affords easy downward percolation of surface moisture and provides adequate drainage for crop growth during the wet season. However, these areas suffer some from drought during dry seasons. The pH averages less than 5.0 and additions of some limestone to correct this extreme acid condition is desirable. These soils respond well to fertilizer applications and with good managemement produce high yields of adapted grasses and legumes. Sufficient demonstrations have

POTENTIAL AREAS FOR GRASSLAND DEVELOPMENT

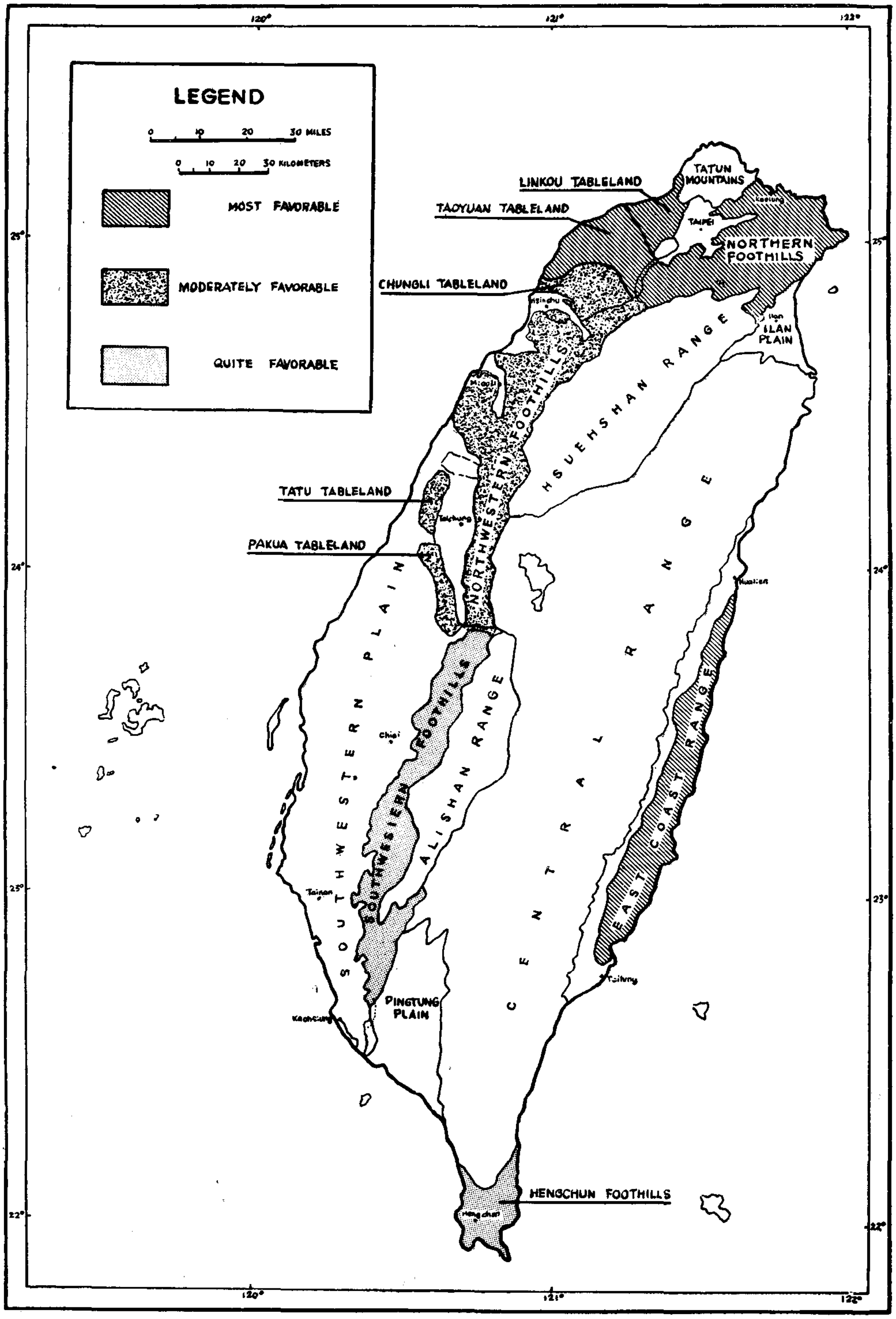


Fig. 1. Potential areas for grassland development

been established in the Taoyuan tableland and many farmers are interested in securing land to develop forages in this area. Little has been done on the Linko tableland and some demonstrations are needed to show what can be done with good forages in this area.

b. Northern Foothills and Tatun Mountains

The soils are largely yellow soils, particularly on the less steep slopes below 1,000 meters which are the slopes best adapted to grassland development. They are chiefly derived from sandstone and shale, and are mainly reddish or yellowish-brown loams and clay loams. They are uniformly acid in reaction but not as strongly acid as most of the reddish-brown lateritic soils. The soils respond to good fertility treatment and with the well distributed rainfall characteristic of the area, are capable of producing very high forage yields. Some of the areas above 1,000 meters elevations may be too wet for favorable livestock production. (Fig. 2) Few farmers have thus far planted forages in this area and demonstrations should be established to acquaint landowners with the great potential that exists for development.

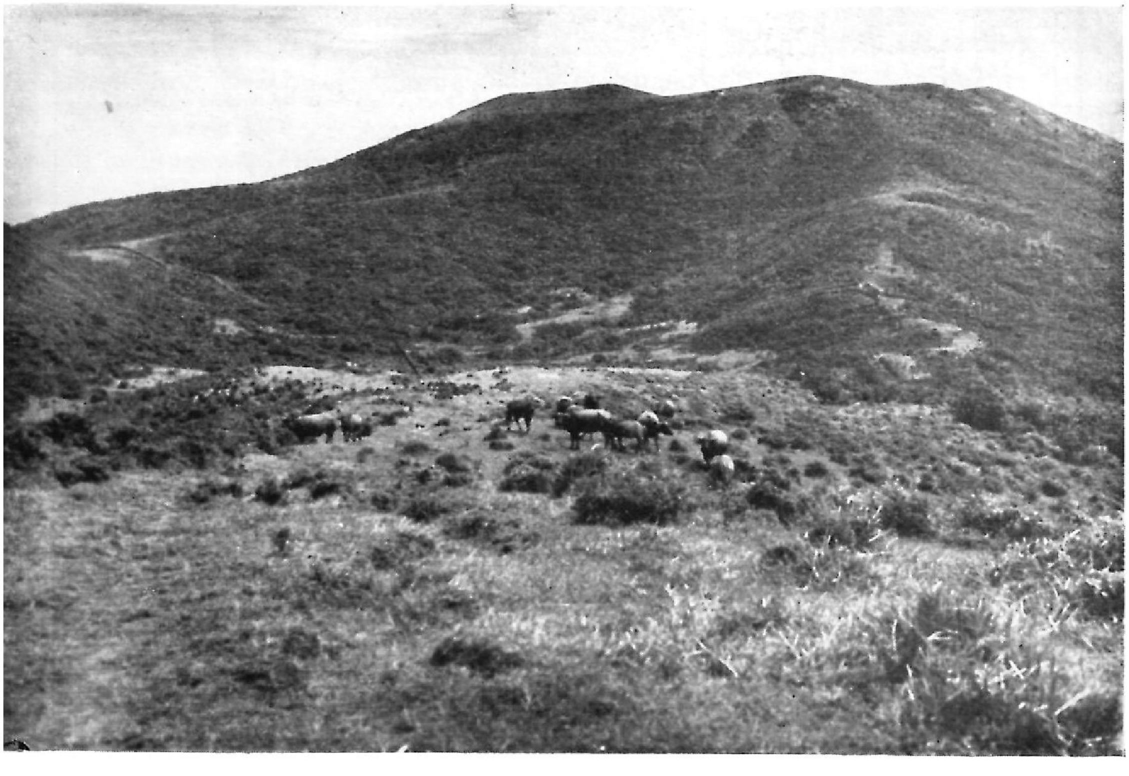


Fig. 2. Large areas of similar undeveloped, practicially waste land can be developed with improved forages in the Northern foothills area.

c. East Coast Range

The soils are very similar to those of the northern foothills with some areas of reddish-brown lateritic soils in a narrow band along the southeast coast and interspersed with the dominant yellow soils in the interior. With year round growing temperatures and well distributed rainfall as well as responsive soils, this is perhaps the best area in Taiwan for forage development.

These three sub-areas are most favorable because they all have well distributed rainfall and suitable temperatures and have soils that are capable of producing abundant forages. Likewise, the land is generally accessible to roads and other means of transportation. Sub-areas a and b are also located close to metropolitan Taipei where markets for livestock products, particularly dairy products are readily available.

MODERATELY FAVORABLE

a. Chungli, Tatu and Pakua Tablelands

The soils are reddish-brown lateoritic soils the same as on the Linko and Taoyuan Tablelands. However, the area is not as favorable for forage production since rainfall is not as well distributed and prolonged periods of dry weather often occur from September to February. This makes it necessary to preserve forage in the form of silage in order to feed cattle during these periods. (Fig. 3)

b. Northwestern Foothills

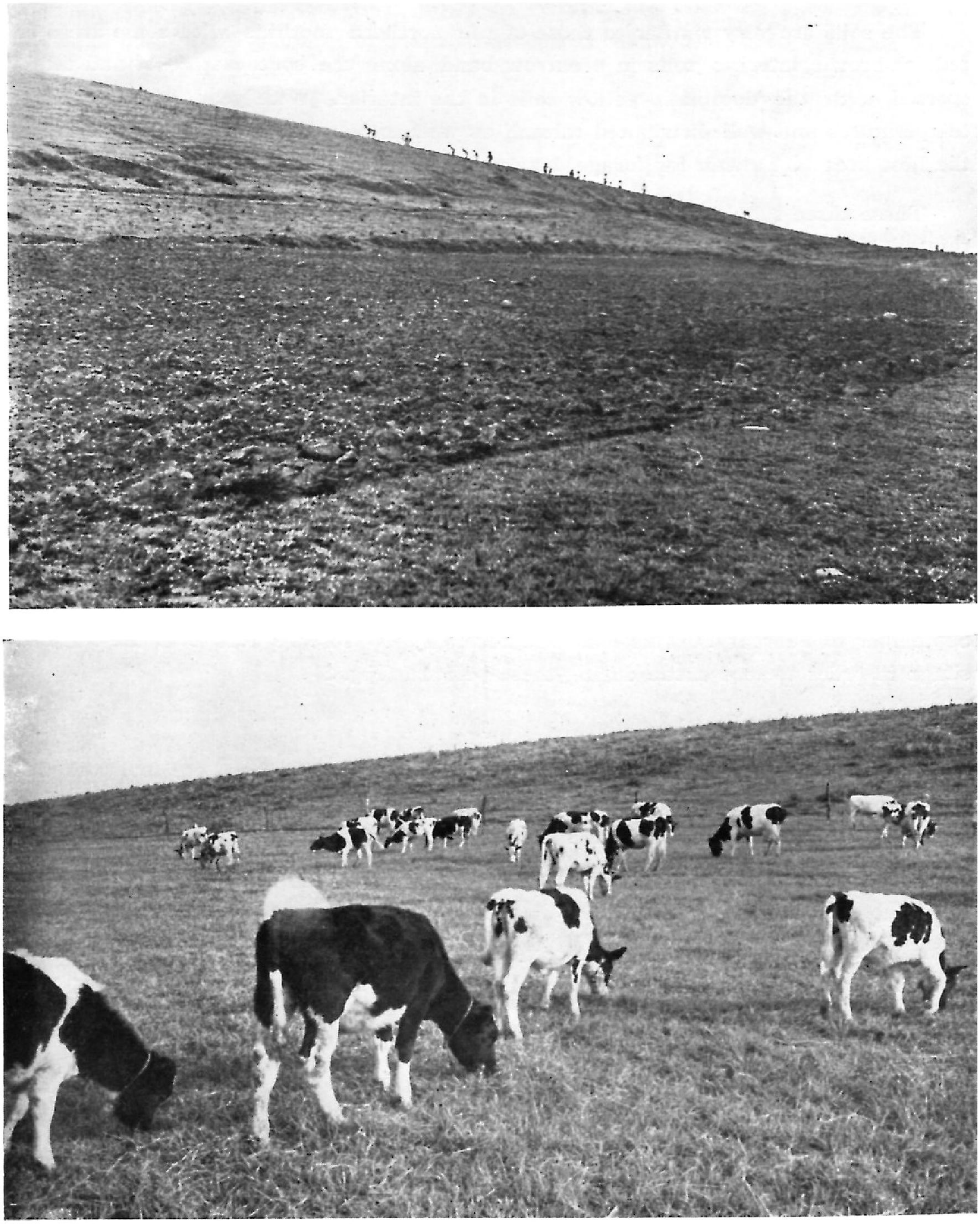
The soils are similar to those of the Northern Foothills, but here too, poor distribution of rainfall limits the growth of forage in the winter months and makes it necessary to harvest surplus forage during seasons of favorable growth and store it for feeding cattle during the dry periods.

These two areas are classed as moderately favorable because of less favorable climatic conditions and a little greater distance from good markets in metropolitan Taipei. It is estimated that total forage production is only about 70 to 80 per cent of of the most favorable areas.

QUITE FAVORABLE

Southwestern and Hengchun Foothills

Soils in these two areas are generally yellowish-brown soils similar to those of the Northern and Northwestern Foothills with the exception of small areas of yellowish-red soils. The latter soils are found along the coast and are derived from calcarous material of elevated coral reefs. These areas are neutral in reaction and in general quite productive. (Fig. 4)



A

B

Fig. 3. Before (A) and after (B) planting hillside on the Chungli Tableland to Pangola, Holstein cows are grazing on the pasture 6 months after slope in (A) was planted and after one cutting of green forage had already been made.

Fig. 4. An excellent pangola pasture which has been developed on steep land in the Southwestern foothills area.

Forage production in these areas is estimated at only about 60 to 70 per cent of that of the most favorable areas. A prolonged dry season from mid-October until early May is the reason for this lower production. Farmers must put up silage or hay to feed cattle for five or six months, thus increasing the cost of production. Accesibility to markets is also a limiting factor, particularly in the Hengchun Foothills where dairying is not feasible because of the long distance even to local markets. Here as in other inaccessible areas, beef cattle production will be the chief livestock enterprise.

OTHER AREAS

Accessible scattered areas can be found on the less steep slopes in the Central Alishan and Hseuhshan ranges and in the Tatun Mountains where forage crop production will be feasible. Forage production will undoubtedly be better on the lower slopes and at lower elevations, because of the longer growing season. Freezing temperatures for three or four months will retard the growth of even temperate-zone legumes and grasses in the high mountain areas (above 2,000 meters) and result in lower production. However, the greatest deterrent to early development of these areas is their inaccessibility. (Fig. 5)

Fig. 5. Scattered valleys and less steep slopes at the base of mountains are suitable for frorage production in the Central, Alishan, and Hseuhshan ranges provided they are accessible.

Some development is also feasible on rain dependent paddy lands in the plain areas. Here where the second rice crop is oftentimes damaged or is a complete failure, grasses and legumes may be fitted into the cropping system to great advantage. The utilization of the forage produced to feed several cows on each of the small farms will not only diversify the farm operation and increase income but will also increase crop production as a whole on the farm. The beneficial effects of the organic matter supplied by legumes and grasses when plowed under in the crop rotation and the added manure from the cows will result in a marked increase in rice and other crop yields on these semi-dryland soils.

Forages can also be produced to advantage on (1) some of the gravelly river bottoms and stony lands that are too dry or otherwise unsuited to crop production, (2) the slopes of bench terraces and paddy fields, (3) the banks of irrigation ditches, reservoirs, and railroads and roadsides, (4) areas adjacent to runways on airports and miscellaneous lands on military reservations and (5) graveyards which occupy considerable area on the island.

Grassland in the Taiwan Economy—Cheap Feed for Livestock

Forages are the cheapest feed that can be grown for livestock particularly ruminants such as cattle and goats. On Taiwan it is particularly important that draft cattle, dairy cattle and goats be fed predominantly on forages so as not to compete for grains and concentrates with grain consuming livestock, such as hogs and poultry, or directly with humans for cereal food crops. Protein feeds are in very short supply and at present large quantities of concentrates are being fed to dairy cows on Taiwan. An example of the saving in protein feed and in feed costs that could be made by feeding good forages to dairy cattle is shown in the following study:

A survey of dairy farmers in Southern Taiwan in 1960 indicated that they fed an average of about 40 kilograms (kg.) of sugar cane tops and 6.5 kg. of concentrates per day. To feed a balanced ration to dairy cows with good quality fresh Pangola grass or other equally nutritious grasses would require very little protein concentrate for cows producing 10 kg. of milk or less, which is more than these cows were producing. Assuming a liberal feeding of 1½ kg. of concentrates with all the green grass, a cow will eat, the cost of feeding can be reduced materially as shown in the following table:

Comparative Daily Cost of Feeding Dairy Cows at Present and With Good Quality Forage

	Cost per day—NT dollars*			
	Roughage	Concentrates	Per Cow	Difference Per Cow Per Day
1. Present Ration 40 kg. sugarcane tops @$ 0.20/kg. & 6½ kg. concentrates @$ 3.00 kg.	8.0	19.5	27.5	
2. Pangola grass 50 kg. @$ 0.08/kg. & 1½ kg. concentrate @$ 3.00/kg.	4.0	4.5	8.5	19.0**

* New Taiwan dollars—40=US$ 1.00.

** The NT$ 0.08 per kilogram of green forage is based on an average annual Pangola grass establishment and maintenance cost of NT$ 2,000 plus annual interest of 18 per cent on land valued at NT$ 20,000 or NT$ 3,600 or a total annual per hectare cost of NT$ 5,800. With an average yield of 100,000 kg. of green forage per hectare, the forage cost is NT$ 0.058 per kg. to which is added NT$ 0.022 per kg. for harvesting and transporting the forage or a total cost of NT$ 0.08 per kg.

In addition to the saving of NT$ 19.00 in feed costs, a total of 5 kg. per day of concentrate was saved per cow. In one lactation period of 300 days, this is a saving of 1,500 kg. of concentrates or enough to feed 4 hogs to a market weight of 90 kg.

Taiwan has about 420,000 cattle of all kinds and about 140,000 goats. Feeding them better forage will not only improve production, whether it be milk, meat mohair or draft power, but should also result in some saving of concentrates.

SOIL CONSERVATION A MUST IN TAIWAN

Several a sastrous heavy rains and floods during the past two years with resultant erosion scars on the hillsides and general land deterioration have driven home the fact that better land utilization and soil conservation measures are a "must". Tropical and sub-tropical grasses that are not only productive but also "protective" have been developed recently. These provide one of the most effective tools for soil conservation and at the same time make it possible for farmers to receive maximum returns from the land. (Fig. 6)

Fig. 6. Disastrous erosion can be stopped and at the same time farmers can receive economical returns from forages and livestock on hillsides such as this.

GRASSLAND CAN HELP IMPROVE TAIWAN'S ECONOMY

To meet even the present requirements in Taiwan for dairy products, hides, tallow, meat and other livestock products from forage consuming livestock would require considerable expansion in cattle and goat raising. Imports of livestock and dairy products represent a substantial sum. The amounts in US dollars for the main livestock and dairy products imported from 1952 to 1959 are shown in Table 1. These amount to an average of over $ 10,000,000 annually.

Table 1. Importation of Livestock Products into Taiwan 1952-1959

Unit—US$

Item	1952	1953	1954	1955	1956
Beef Tallow	1,291,928	1,571,863	661,312	2,424,209	2,977,217
Hide & Leather	1,776,976	1,208,405	1,446,806	1,476,400	1,486,069
Wool	1,514,909	3,214,000	2,745,465	3,098,858	1,772,949
Dairy Products	1,987,261	2,999,940	1,299,600	2,005,266	1,848,085
U. S. Aid Relief Dairy Products	11,608	311,715	425,519	3,705,018	6,239,817
Breeding Stock	12,592	5,169	4,157	2,884	2,450
TOTAL	6,595,274	9,311,092	6,582,859	12,712,635	14,326,587

Item	1957	1958	1959	Average per Year
Beef Tallow	2,819,193	2,462,285	3,001,036	2,151,130
Hide & Leather	1,302,259	1,232,998	1,265,198	1,399,388
Wool	1,942,857	1,336,001	2,616,320	2,280,169
Dairy Products	2,011,599	2,274,191	1,854,025	2,034,993
U. S. Aid Relief Dairy Products	2,116,429	1,827,805	3,537,873	2,271,973
Breeding Stock	13,442	156,279	4,680	25,207
TOTAL	10,205,779	9,289,559	12,279,132	10,162,865

Remarks:
1. Figures in this table are based on "The Statistics of Import Exchange Settlements, ICA Project and Non-Project Procurements and Import with Self-Provided Exchange" for the years of 1952 through 1959, published by the Bank of Taiwan.
2. Figure of the U. S. Aid available relief dairy products in this table are based on statistics made available by Mr. Y. H. Young, Rural Health Division, Joint Commission on Rural Reconstruction.

Much of this foreign exchange can be saved in the future particularly through stepped up production of dairy and beef cattle. Cattle production programs recently started in Taiwan call for rapid increases in dairy cattle numbers through the upgrading of native-Sindhi crossbred cows using semen of Holstein or Jersey western breeds. For this purpose, frozen semen has been air lifted from the United States. Similarly farmers are being encouraged to cross native cows with Santa Gertrudis semen from the Philippines and to raise the offspring for beef.

With rising standards of living on Taiwan per capita consumption of dairy products and meat can be expected to increase materially in the future. Improvement in income and diets of people in surrounding countries will also result in greater demand for these products in trade channels. Taiwan could, with the development of her grassland potential, export considerable livestock and livestock products, particularly beef, in the future to nearby countries. Such development will greatly improve the income of many farmers as well as the general economy of Taiwan.

GRASSLAND DEVELOPMENT A NEW UNDERTAKING

Grasses have previously received little attention by the Chinese farmers. Compared to crop improvement and culture, which has been developed through the centuries to the extent that per unit area yields are among the highest in the world, grassland development has only recently begun to receive cursory attention. Farmers have looked on grass as something for their cattle to graze on along the roadsides or in waste places, as something to be dug up on the hillsides, as a source of material for fuel or as thatching material for the roofs of their houses.

Some work was done with grasses and legumes by the Japanese during their occupation. They introduced many temperate zone grasses and legumes and attempted to grow alfalfa as early as 1910. Guinea grass was introduced from the Philippines in 1906. For the most part, this work was confined to the livestock stations and only in the past 10 to 15 years have tropical grasses such as Guinea and Napier been planted on farms, and then only to a very limited extent.

The Joint Commission on Rural Reconstruction in cooperation with the Provincial Department of Agriculture and Forestry started observations on forage and cover crops on a more extensive scale than ever before in late 1953. These early observations served to eliminate many of the temperate zone grasses and legumes from consideration in the program for lands below 1,000 meters in elevation. In 1957, an accelerated program was started and particular emphasis was placed on tropical and sub-tropical legumes. During the past four years, observation nurseries have been established at 22 locations on the island, ranging in elevation from sea level to 2,200 meters. A total of 205 grasses and 230 legumes have been included. From these observations and subsequent preliminary yield and other trials, some promising species and varieties have been found which are now being recommended to farmers and others for specific purposes.

THE IMPORTANT FORAGE CROPS FOR TAIWAN

All of the high yielding, most desirable forage species of Taiwan have been introduced. Native species are generally low yielding and have survived on the low fertility soils found wherever grass is allowed to persist on the island. No doubt more productive native species which may have been present have failed to survive and disappeared.

GRASSES

A. For Lowland and Foothihill Areas

1. *Pangola Grass* (*Digitaria decumbens Stenf.*)

This grass is a native of Africa and was first introduced to Taiwan in 1957. It is a perennial, grows to a height of about one meter, spreads rapidly by surface runners, and soon produces a dense cover of relatively fine leaved vegetation.

Pangola grass is the most outstanding and has been the most productive of all the forages tested on Taiwan for general use in areas from sea level to about 1,000 meters. During the height of the growing season on good soil some of the runners (stolons) grew more than three feet in a week's time. When adequately fertilized, it out yields most other varieties, has a higher protein content, and is likewise a very palatable grass. It also produces a dense cover which suppresses and keeps out most weeds. While it is very prolific, there is little danger of it becoming a serious weed in cultivated fields because it produces little if any viable seed and has no rhizomes. The top growth can be easily controlled by cultivation.

Strain differences have been noted in Pangola. Of seven strains introduced to date, one (A 24) brought to Taiwan from the Philippines has proved superior. The other strains all looked very promising when first introduced but after the first year are attacked by what appears to be leaf hoppers. These cause a severe stunting of the plant and drastically reduce production. In some cases the plants are killed and stands thin out. The Philippine strain has been almost entirely resistant to this insect. (Fig. 7)

2. *Para Grass* (*Panicum purpurascens* (*Raddi*)

Likewise a native of Africa, this grass is a straggling decumbent perennial, sending out long, rather coarse, creeping stolons which root at the nodes. It grows to a height of about 1 meter, has trailing culms often 2 to 6 meters long with blades 10 to 15 mm wide.

Para grass is a very productive grass and compares favorably in yield with Pangola on wet sites. It is exceptionally well adapted to wet, poorly drained sites and heavy soils in heavy rainfall areas. Like Pangola, it produces no seeds and has no rhizomes which would make it a pest. It also does best at elevations up to 1,000 meters. Three strains have been introduced and a strain from Thailand (A 52) is the leafiest and appears most productive.

Compared to Pangola, however, Para grass is very coarse and stemmy and is relished much less by livestock. Analyses made in Hawaii indicate that on the average it contains only 6.4 per cent crude protein on a dry weight basis as compared to 9.9 per cent for Pangola. Observations are that after several years stands tend to thin out and become weedy.

3. *Bermuda Grass* (*Cynodon dactylon*(*L*) *Pers.*)

Originally from India, this grass has been highly developed in the United States particularly by Dr. Glenn Burton at the U. S. D. A. Station at Tifton, Georgia. Two improved varieties from this station, Coastal (A 42) and Suwanee (A 43) have been very productive particularly on lighter sandy soils, and on saline or alkaline soils. Several turf varieties for lawns and golf course greens have been tested and a strain collected in the Philippines (A 59), and two USDA strains PI No. 224147 (A 75), and No. 224694 (A 98) are most promising for this purpose.

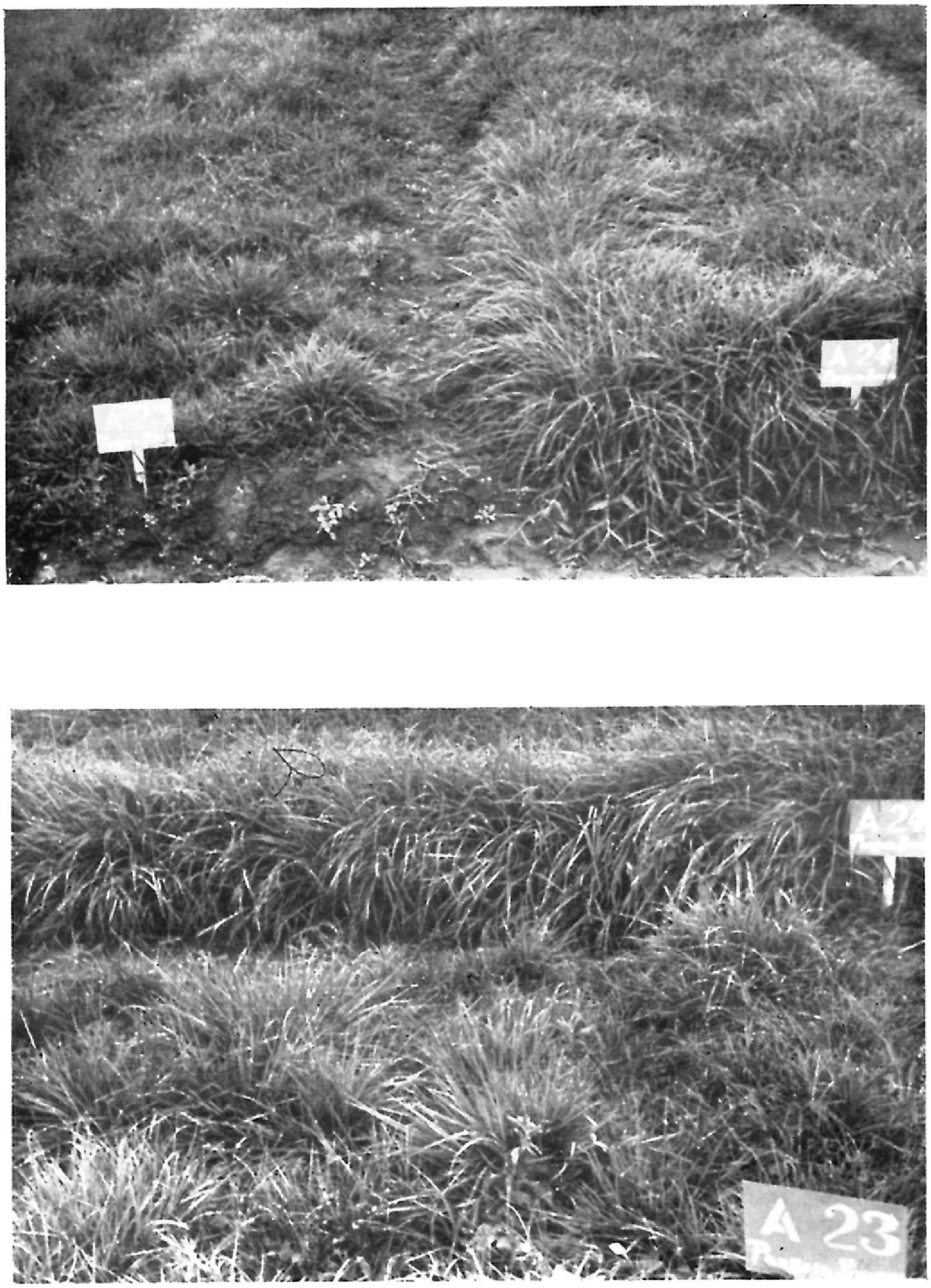


Fig. 7. Strain differences have been noted in Pangola grass (A24) a strain introduced from the Philippines is the only strain resistant to a "stunting disease". Comparable growth of a susceptible strain (A23) is shown above.

Bermuda is a very good turf forming grass that spreads and is propagated by stolons or surface runners and by underground rootstocks or rhizomes. It spreads rapidly particularly when cultivated. It produces a dense sod and withstands quite heavy grazing when managed properly. However, on heavier soils in Taiwan, it does not keep weeds out of the stand as well as Pangola. Coastal is dark green in color and Suwanee is a lighter yellowish green. The latter produces better on sandy soils.

4. *Napier Grass* (*Pennisetum purpureum Schum*)

Napier grass, a native of tropical Africa, is a robust, erect, leafy, tufted, branching perennial with a growth habit similar to sugar cane. It is best adapted to better soils but with adequate fertilization does well on poorer soils. Unless planted in rows and cultivated it, will become sod-bound and weedy and decline in productivity in several years. Consequently, it is best used only on level land where ersosion is not a problem.

Napier grass has been used for many years on Taiwan as a cut forage, or soiling crop, for feeding cattle. Several strains have been tested and in comparison with Pangola grass using levels of nitrogen up to about 200 kg. of Nper hectare has been no more productive than the latter. Greater waste is also evident when compared to Pangola, particularly the coarse stems that are not consumed by cattle. The cost of production is also higher since cultivation is necessary with Napier but not with Pangola. However, the yield potential with extremely high rates of nitrogen is undoubtedly much greater than with Pangola. Consequently if suitable level land is available, and especially if land is scarce, Napier should be planted and high rates of fertilizer used. Recently several new strains have been obtained, and among these a hybrid (P. purpureum × P. typhoides) from India appears very promising. It is much leafier and less stemmy than other strains, but has not been tested sufficiently as yet.

5. *South African Pigeon Grass* (*Setaria sphacelata* (*Schumach*) *Staph*)

This is another tropical African grass and is a robust bunch type perennial, with rather smooth leaves. The leaves reach a height of about 1 meter and seed heads often extend to 2 meters. It is propagated either by seed or by cuttings. It is a prolific seed producer and since considerable variability exists in the species, there is opportunity for an effective breeding program to improve it for forage purposes.

This is among the recently introduced species and several strains appear particularly promising, namely: (A68) from the Philippines, the Kazungula strain (A89) from South Africa and (PI 19912) from Australia (A 114). Of these the Kazungula strain is the leafiest, most succulent late maturing and appears most, productive. In comparative tests with Napier and Guinea grass fertilized at the rate of 90 kg. of N per hectare during a 7 month period, (A68) produced as much green forage, about ¾ as much dry matter and nearly as much crude protein as Napier. Likewise it produced over twice as much green forage and over 1½ times as much dry matter and crude protein as Guinea. This grass is recommended for more extensive trial wherever Napier can be grown since cattle relish it and there is not as much waste when fed as there is with Napier.

6. *Alabang X* (*Andropogon nodosus* (*Willem*) *Nash*)

This grass was introduced into the Philippines from India and was brought to Taiwan in 1957 where it has been productive only in extreme southern Taiwan. Here it yields nearly as well as Pangola and is recommended for more widespread use in the Hengchun Foothills. It is a decumbent freely branching perennial which attains a height of about 1 to 1½ meters. It is a heavy seed producer and can be propagated either from seed or by cuttings.

B. For Elevations Above 1,000 Meters

The previous six grasses are all adapted to elevations below 1,000 meters while the following are best adapted to elevations above or for use in Nrrthern Taiwan in the winter months:

1. *Kikuyu Grass* (*Pennisetum cladestinum Hochst. ex Chiov.*)

Kikuyu grass is another perennial African grass which spreads extensively by rhizomes and stolons and normally attains a height of 60 to 70 cm. It is a very nutritious and palatable pasture grass, and will withstand very close grazing. It is very drought resistant and produces a very dense sod which seldom permits invasion by weeds.

Trial plantings of this grass have been made for road stabilization in the mountains at elevations ranging from 1,000 to 2,700 meters. It has been very effective in binding and holding the soil on some very steep roadside cuts and fills. Plantings for pasture purposes in this same area have been very productive and Kikuyu is recommended as the best pasture grass here.

2. *Rye Grass* (*Lolium multiflorum, Lam.*)

Two varieties, common and Italian, are very useful winter annuals for overseeding on grass stands in Northern Taiwan in the winter months. Seeded in November, they provide an abundance of forage from early February until early May when they die out. This is a period when Pangola is not very productive because of the cold weather.

Both of these and perennial Rye grass (Lolium perenne L.) are well adapted to elevations above 1,500 meters for year round production and are recommended for inclusion in seeding mixtures with other grasses and legumes in these locations.

3. *Winter Oats (Avena sativa L.)*

Winter oats is a very valuable winter forage for Northern Taiwan. It can be planted in rice paddies alone or with Astragalus, Lana Vetch or Papago peas or may be overseeded in Pangola using similar mixtures. It can also be grown in cultivated fields or pastures at elevations up to 2,000 meters. If cut when in the "boot stage" (when flower heads are beginning to form but before they emerge) as many as three to five harvests can be made. Among 17 varieties tested Florad (B 39) and Commercial Japanese variety (B 16) have been the best. (Fig. 8)

Fig. 8. Winter Oats is a valuable winter forage for Northern Taiwan Pictured is Florad a new variety recently introdued.

C. Other Grasses

1. *Bahia Grass* (*Paspalum notatum Flugge*)

This is a very dense, sod forming grass which is quite productive under low levels of fertility. It seldom grows taller than 40 to 50 cm. and is a good grass for use on airports adjacent to runways and for special soil conservation purposes. Likewise, it is recommended for steep, gravelly or rocky hillsides where soils are poor and droughty and where Pangola may not provide a dense enough cover.

In comparative yield trials on productive soils, it produced only about ⅔ as much dry matter and crude protein per hectare as Pangola, but on poorer sites will possibly yield more.

2. Temperate zone grasses such as Orchard (*Dactylis glomerata L.*), Tall Fescue (*Festuca arundinacea Schreb*) and Harding (*Phalaris tuberosa var. stenoptera* (Huck) Hitch.) are adapted to elevations above 1,500 meters and are recommended in mixtures with Ladino clover, big trefoil and rye grass.

LEGUMES

The universal problem in tropical and sub-tropical areas remains that of finding suitable productive forage legumes and particularly legumes that will grow in association with grasses. No great progress has been made in Taiwan to date in the solution of this problem. However, there are several legumes which appear promising, at elevations up to 1,000 meters. Before they can be used on a widespread basis they must be tested more thoroughly and many aspects of how to properly incorporate and manage them in grass stands must be worked out. The most promising of these are:

I. Intortum clover (*Desmodium intortum*)

This is a very palatable legume, that seems to grow best on soils with moderate to high fertility level and where rainfall is moderate but well distributed. In Taiwan it seems to grow best in eastern and central Taiwan at elevations up to about 1000 meters, particularly where the soils are not too acid. Several trials are underway to determine if it can be satisfactorily grown in mixtures with Pangola grass. Results to date are promising but further observations are needed to determine whether this legume can persist for a number of years in the dense stand of Pangola grass.

Strain differences are evident in the three strains under observation. All appear different and have different growth characteristics. A strain introduced from the Philippines (C50) and which probably originated in Guatemala, appears more productive and covers the ground better than a strain introduced from Hawaii (C18). Both of these will be tested further along with several other, strains recently introduced.

2. *Centro* (*Centrosema pubescens*)

Centro is a creeping legume that is very promising as a forage plant for southern and central Taiwan at elevations up to 800 meters. It is more drought resistant and will tolerate lower temperatures than will tropical Kudzu. It is being raised extensively for hog and poultry feed at the Provincial Livestock Research Institute at Hsinhua and makes a particularly good hog pasture. Yield determinations are being made and more information regarding its productivity will be available soon. Like most legumes, it is difficult to established but once a stand is obtained affords an excellent ground cover and appears quite productive. For this reason, it is also being used extensively as a cover crop and for mulch production in citrus orchards.

Trials are underway to determine how well it grows with Pangola grass but early results indicate that it does not compete as well as (*Desmodium intortum*).

3. *Tropical Kudzu* (*Pueaaria phaseoloides Bent.*)

Tropical Kudzu is better adapted to southern Taiwan at elevations below 500 meters. In northern Taiwan it loses all of its leaves in the winter months and has difficulty recovering productiveness in the spring. In the south, it grows very dense and produces an abundance of seeds. It will undoubtedly find a place as a legume for limited grazing during the rainy season with the maximum growth held in reserve as carry over in the dry season. It may also be grown in combination with Napier or Guinea grass but it does not recover rapidly enough after cutting to compete with Pangola grass.

Four strains have been tested and no differences have been noted in them.

4. *Stylo* (*Stylosanthes gracilis*, *H. B. K.*)

Limited observations indicate, particularly in southern Taiwan, this legume has possibilities for forage production at lower elevations. While it is rather slow in establishing itself, Stylo is very productive after the first year and appears to be very drought resistant. It becomes rather coarse and woody as it matures and studies are needed to determine the best stage at which to cut it for forage. No tests have been made as yet with Stylo in combination with grasses. (Fig. 9)

5. *Rhodesian Kudzu* (*Glycine javanica L.*)

This is a relatively slender, climbing perennial legume which has shown much promise in areas up to about 1,500 meters. Like other tropical legumes, it is slow to establish itself but once established, it produces a large quantity of herbage. Trials in combination with Pangola grass indicate that it is not as competitive or as productive as (*Desmodium intortum*) or Centro. It is a fairly drought resistant legume and withstands mild frosts. Therefore, its range of adaptation will extend up to around 1,500 meters or slightly higher.

Fig. 9. Stylo—(Stylosanthes gracilis) a promising legume for Southern and Central Taiwan.

A number of strains have been introduced and it is one of the few tropical legumes that exhibits wide variability in date of maturity, leafiness, tillering habit and general productivity. Because of this, it lends itself to a future breeding program and no doubt better types suitable to Taiwan conditions can be obtained.

6. *Ladino Clover* (*Trifolium repens L.*)

This is one of the most palatable and desirable perennial legumes for pastures. Unfortunately, it is not adapted to lower elevations in Taiwan except as a winter legume in northern Taiwan for overseeding on Pangola. However, seed must be imported and it is questionable whether this practice is economical since the Ladino dies out when the heavy rains and hot weather begin in early May.

At elevations above 1,000 meters, Ladino is recommended as a legume in mixtures with orchard grass, tall Fescue andrye grass. Preliminary observations indicate that it may also be seeded with Kikuyu grass. However, acid soils must be limed if Ladino is to survive and be productive. This may limit its use since in the high mountains limestone is often not available and if transported long distances is very expensive.

7. *Winter Annual Legumes*

A number of winter annual legumes have been tested and are recommended for use in overseeding in grass stands, particularly Pangola, or as winter forages in combination with winter oats and ryegrass in northern Taiwan. Of these *Wooly Pod vetch* (*Vicia dasycarpa*) has been most outstanding in trials for the past two years. It makes rapid early growth and if seeded in late November or early December will provide considerable forage by late January or early February. Several additional cuttings can be made or the area can be grazed until mid-April when the plants mature or are killed by hot, wet weather. Successful stands have been established by overseeding on Pangola grass and also by broadcasting in rice paddies about two weeks before the crop is harvested. Lana is the variety that has been used. (Fig. 10) *Papago peas* (*Pisum arvense*), *Berseem clover* (*Trifolium alexandrinum*), *Subterranean clover* (*T. subterraneum*), *Ladino clover* (*T. repens*) are other promising legumes for this purpose. *Chinese milk vetch* (*Astragalus sinicus*) can also be used

Fig. 10. Lana Vetch (Vicia dasycarpa) which was overseeded in an established stand of Pangola grass

for the same purpose but is better adapted on wet sites. It is an excellent green manure legume for paddy soils as are Lana Wooly pod vetch and Papago peas. All of these legumes can also be used at higher elevations for winter forage or as cover crops.

7. Summer Annual Legumes

Alyce clover (*Alysicarpus vaginalis*) has been used successfully as a summer annual legume for overseeding on Pangola. Where managed properly in pastures in southern Taiwan, it has reseeded itself for the past three years. It appears to be adapted to areas up to 1,000 meters in elevation. *Hairy indigo* (*Indigofera hirsuta*) also shows some promise for this purpose. Recent introductions which look good in the observation nursery but have not been tested sufficiently are (*Phaseolus atropurpureus D.C.*), (*Phaseolus lathyroides L.*), (*Stylosanthes sundaica Taub.*) and (*Lotononis bainesii Bak.*).

8. Other Legumes

(*Leucaena glauca* (*L*) *Benth*) is a native shrubby legume that is found in southern Taiwan at elevations up to about 900 meters. If cut or grazed before it reaches a height of more than 1 meter, it is a nutritious forage comparable to alfalfa. However, it contains a toxic substance that causes animals to lose their hair, but there is little danger if fed to cattle or goats if it is mixed about half and half with grasses.

A number of varieties of cowpeas (*Vigna sinensis* (*L*) *Endl ex. Hask.*) have been tested among which the Victor and Groit varieties are best for forage purpose. These and *Velvet Beans* (*Stizolobium deeringianum Bert.*) are used mainly as green manure and as green feed in the summer for hogs and poultry on cultivated land.

PRELIMINARY STUDIES INDICATE SUPERIORITY OF TROPICAL AND SUB-TROPICAL FORAGES IN TAIWAN

Most of the early forage crop investigations in Taiwan involved introduction and testing of many temperate zone legumes and grasses. Considerable time and effort was spent in trying to grow alfalfa in all parts of the island. While it is possible to grow alfalfa in the Far East, the problem here is the same as in other sub-tropical and tropical countries—that of finding some way to grow this legume without the costly weeding required to maintain stands. Alfalfa has been a disappointment in most of the areas in Taiwan, because of its inability to survive heavy rainfall and high temperatures during certain periods and to compete with weeds. Cost of production has been reported to be about NT$ 800 to 1,200 (US$ 20 to US$ 30) or more per metric ton of dry hay equivalent. There are a few locations at elevations of 1,500 meters and above, where alfalfa may have promise. However, here the soils are extremely acid, and sources of limestone are not available close by. The prohibitive cost of transporting limestone to these inaccessible areas rules out the use of alfalfa, for the present. Work, however, is being continued to find more suitable methods of seeding alfalfa and other legumes and production techniques to make it possible to raise these legumes at a reasonable cost in these high mountain areas.

LEUCAENA GLAUCA OUTYIELDS ALFALFA

Leucaena glauca, a shrub like, legume grows wild in central and southern Taiwan and in chemical composition is very comparable to alfalfa. A test of its yielding ability in comparison to Indian alfalfa was conducted at the Taiwan Sugar Corporation Hog Farm in Central Taiwan in 1958 and 1959 with the following results:

Table 2. Yield in Kilograms per Hectare of Leucaena Glauca and Indian Alfalfa

	1958			1959		
	Fresh Wt.	Dry Wt.	Crude Protein	Fresh Wt.	Dry Wt.	Crude Protein
Leucaena glauca	34,960	10,338	2,531	43,836	9,260	2,491
Indian alfalfa	33,942	8,767	2,172	12,730	3,259	834
Difference for Leucaena glauca	1,018	1,571	359	31,106	6,001	1,657

The *Leucaena glauca* was planted from seed in rows 40 cm apart and cut when it reached a height of 1 meter. The alfalfa seed was broadcast and cuttings were made when in the one-tenth bloom stage. Both were planted in November 1957 on soil that had been limed to a pH of 7.0 and had 500 kg. of 18% superphosphate and 200 kg. of potassium chloride incorporated in the top 15 cm. A similar amount of fertilizer was applied as a top-dressing in eary 1959. Leuceana glauca increased in yield in the second year whereas alfalfa decreased drastically in production. In fact, by November 1959 less than a 10% stand of alfalfa remained in each of the four replicated plots and the experiment was discontinued. *Leucaena glauca* produced 7,572 kg. of dry matter and 2,016 kg. more of crude protein per hectare than the Indian alfalfa in the two year period. All of the woody stems of *Leucaena glauca* were discarded and not included in the yield determinations.

PANGOLA HAS PROVEN TO BE THE MOST OUTSTANDING GRASS FOR GENERAL USE ON TAIWAN

Early observations in the nurseries indicated that Pangola was one of the fastest growing, leafiest and most succulent of the grasses tested. It was placed in yield trials with other promising perennial grasses at the Provincial Livestock Research Institute at Hsinhua in early 1958. Here rainfall averages 1,750 mm (70 inches) annually but there is virtually no rain from mid October to early April. The average annual temperature is 23.1°C with an average for the summer months of 28.2°C and for the winter months of 18.9°C. The soil is an acid yellow sandy loan. The grasses in this test were planted in early 1958 and the first cutting was made on June 27. Four cuttings were made the first year and five the second. Comparison of yields of seven grasses for the two year period were as follows:

Table 3. Yield Comparison of Seven Tropical Grasses
Dry Weight in Kilograms per Hectare

Variety	1st year	2nd year	Average annual production for 2 years
Pangola grass (A24)	24,074	18,323	21,199
Pangola grass (A23)	22,814	—	—
Para grass (A1)	24,743	16,119	20,431
Coastal Bermuda (A42)	18,845	17,619	18,232
Suwanee Bermuda (A43)	16,600	18,859	17,730
Rhodes grass (A2)	20,322	15,106	17,714
Alabang X(A29)	16,964	12,982	14,973

The plots were fertilized at planting at the rate of 250 kg. of ammonium sulphate, 400 kg. of 18% superphosphate and 150 kg. of potassium chloride per hectare. A top dressing at the rate of 100 kg. of ammonium sulphate per hectare was made following each cutting. Thus, the first year, each plot received elemental nitrogen (N) at the rate of 130 kg. per hectare and the next year, at the rate of 100 kg. of N per hectare (20 kg. of N per cutting for five cuttings).

Pangola (A24) was superior to the other six grasses in the two years of this test. Pangola (A23) was nearly as productive the first year but was so badly damaged by insects or disease in the second year that no yields were taken. Paragrass was equally as productive as Pangola (A24) the first year but declined materially the next year in productivity. This was due to invasion by weeds, which was not the case with Pangola grass.

At Hwalien, in eastern Taiwan, where rainfall is quite evenly distributed throughout the entire year, Pangola (A24) planted November 29, 1957, produced 197,400 kg. of green forage in six cuttings made between April 25, 1958 and February 27, 1959. During this same period, Para grass produced 186,900 kg. African blue grass (Digitaria pentzii) 150,400 kg. and Rhodes grass 139,500 kg. No air dried yields were obtained, but if fed green at the rate of 50 kg. per head per day, this production of Pangola would be sufficient to support more than nine mature cows on each hectare of land for an entire year.

PANGOLA GRASS GROWS ON ACID SOIL

Pangola grass apparently grows under a wide range of pH and does not respond to applications of ground limestone. In a preliminary test at the Provincial Livestock

Research Institute, Hsinhua, the following results were obtained with two strains of Pangola grass (A23) and (A24).

Table 4. Effect of Limestone on Pangola Grass Yields

Kilograms of Ground Limestone per Ha.	Yield in Kilograms per Hectare			
	Pangola A23		Pangola A24	
	Green Wt.	Dry Wt.	Green Wt.	Dry Wt.
none	67,000	17,044	65,825	16,315
2,000	67,775	16,390	65,325	16,027
4,000	65,600	16,572	66,625	16,511
6,000	65,450	16,079	63,425	16,155

The two strains of Pangola were planted on May 24, 1958 on a yellow, sandy soil with an original pH of 5.4. The first cutting was made on July 4, 1958 with three subsequent cuttings, the last of which was made on Novembr 21, 1958. The data indicates no response to applications of ground limestone up to 6,000 kg. per hectare. While the data is limited to but one year numerous field observations indicate no response from applications of as high as 10,000 kg. of very finely ground limestone per hectare.

PANGOLA CAN WITHSTAND FREQUENT CUTTING IF WELL FERTILIZED

A test was conducted at the Provincial Livestork Research Institute, Hsinhua to determine the effect of frequency of cutting Pangola grass with different levels of nitrogen.

Height of cutting Pangola grass were 20 cm., 40 cm., and 60 cm. with 3 nitrogen levels, i. e. 50, 100 and 200 kg. per ha. The soil was a sandy loam of low fertility. Phosphate and potash were supplied in sufficient amounts to all plots so they were not limiting factors. Cuttings were started on June 18, 1960 and the last cutting was made in October 1960. The data is presented in the following table in terms of kilograms per hectare per day. Table 5.

The data indicates that the optimum cutting stage for Pangola grass seems to be whenever it attains a height of about 40 cm. (16 inches). With adequate nitrogen fertilizer, Pangola grass apparently can endure frequent cutting. The lower levels of 50 and 100 kg. of elemental N per season did not seem to be sufficient on this soil since the stands were beginning to thin out and numerous weeds were invading the plots, even those cut at 60 cm, following the last cutting. Since this data is only for one season, additional studies are needed particularly to measure the residual effects of cutting and fertilizer treatments.

Table 5. Effect of Frequency of Cutting and Nitrogen Applications on Yield of Pangola Grass

Treatment		Yield in Kilograms per hectare per day			Days to recover	Number of cutting
Height cm.	N. Kg/Ha.	Fresh wt.	Dry matter	Crude protein		
20	50	226.30	33.47	4,096	28	3
20	100	375.00	55.43	11,175	21	4
20	200	521.00	70.08	15,317	21	4
40	50	326.30	53.84	6,526	33	3
40	100	455.00	62.47	8,418	33	3
40	200	636.00	84.52	15,391	27	3
60	50	379.50	75.33	3,795	27	2
60	100	551.00	100.60	7,604	37	2
60	200	485.50	88.26	6,300	40	3

MIXTURES OF LEGUMES WITH PANGOLA SHOW PROMISE

The most desirable forage combination is a mixture of grasses and legumes. Since legumes usually contain more protein, calcium and phosphorous, a grass-legume combination is generally richer in these nutrients than grass alone. The protein content of the grass itself may be increased by virtue of its association with a legume. The cost of producing forage may also be reduced materially by growing a grass-legume mixture, since much of the required nitrogen may be supplied by the legume. The major problem in tropical areas however is to find suitable legumes which will compete with the agressive tropical grasses and persist for several years.

Trials have been started in Taiwan to determine whether some of the more promising legumes can be grown with Pangola grass. Results of a study made at Hwalien on a loam soil show some promise for the first year's results. Three legumes were planted in alternate 50 cm. rows with Pangola grass on Aug. 3, 1960. Four cuttings were made between then and June 15, 1961 with the following results:

Table 6. Yields of Pangola-Legume Combinations

Combination	Yield Kilogram per Hectare			Percent legumes by dry weight	
	Green Wt.	Dry matter	Crude prottein	1st cutting Oct. 1960	4th cutting June 1961
Pangola grass alone	82,715	13,507	1,348	—	—
Pangola grass & Desmodium intortum	81,997	13,456	1,837	32.0	10.6
Pangola grass & Centrosema pubescens	70,721	12,518	1,340	49.0	1.5
Pangola grass & Glycine javanica	68,150	12,325	1,656	12.0	0.9

There was little difference in dry matter production among the various combinations. However, the legume-grass mixtures produced considerably more crude protein per hectare than the Pangola grass alone with the exception of the Centrosema-Pangola mixture which was about the same as Pangola alone. The Desmodium intortum-Pangola mixture produced the largest amount of crude protein per hectare and this legume has persisted in the mixture better than the other legumes. (Fig. 9) This can be seen from the percentage of legumes by weight that remained at the time of the fourth cutting. Desmodium intortum made up 10.6 percent of the mixture by weight on June 15, 1961 as compared to 1.5 percent for Centrosema pubescens and only 0.9 per cent for Glycine javanica.

Fig. 11 Intortum Clover (Desmodium intortum) in a mixture with Pangola grass. Picture taken in April 1961 prior to the third cutting, Note high percentage of D. Intortum persisting in the stand.

While this data is only tentative and the study should be continued over a period of years to determine the persistence of these legumes, these results justify a recommendation of planting Desmodium intortum in alternate rows with Pangola grass in Northern and Eastern Taiwan. Since planting methods are similar for both, no additional costs are involved and more protein per hectare can be produced the first year. This practice is one which farmers can easily follow to the advantage.

Another method of improving yields of Pangola grass is that of incorporating annual legumes in existing sods. Such a test was conducted at Hwalien on a loam soil. Berseem and Ladino clover were seeded with and without Italian ryegrass on an established Pangola grass pasture on December 15, 1961. The plots were ungrazed until April 11, 1961 when the following yields of green forage, dry matter and crude protein per hectare were harvested.

Table 7. Yields of Clovers and Ryegrass Overseeded on Pangola

Combination	Yield in Kilograms per Hectare		
	Green Wt.	Dry Matter	CrudeProtein
1. Italian ryegrass	8,410	843.8	211.0
Pangola grass	6,020	741.0	84.5
Total	14,430	1,584.8	295.5
2. Berseem clover	18,300	1,464.0	428.0
Pangola grass	7,160	859.0	98.0
Total	25,460	2,323.0	526.0
3. Ladino clover	13,520	1,244.0	398.8
Pangola grass	7,050	846.0	66.4
Total	20,570	2,090.0	495.2
4. Berseem clover	9,660	773.0	180.9
Italian ryegrass	5,230	538.7.0	135.0
Pangola grass	5,400	648.0	74.1
Total	20,290	1,959.7	390.0
5. Ladino clover	1,710	157.3	50.4
Italian ryegrass	7,100	733.4	183.4
Pangola grass	7,670	920.4	104.9
Total	16,480	1,811.1	338.7

Both Berseem and Ladino clovers appear promising for overseeding on established stands of Pangola grass during the winter months in Eastern and Northern Taiwan. In Eastern Taiwan, ryegrass appears too aggressive to include in such mixtures since its inclusion in the mixture materially reduced the yield of both Berseem and Ladino clover as well as the total crude protein produced by the mixture.

TALL GRASSES PRODUCTIYE ON LEVEL LAND

Napier grass (A26) and *Setaria sphacelata* (A68) a new introduction appear to be productive grasses for use where erosion is not a problem. They are tall growing, bunchy grasses and do not cover the ground well and since they usually must be cultivated frequently, they should be grown only on level, non-erosible land.

A test conducted on the Taiwan Sugar Corporation Hog Farm indicates that both of these grasses are more productive than Guinea grass. Six cuttings were made between March 1960 and March 1961. The plots were fertilized with 500 kg. of Ammonium phosphate (16–20–0) on March 15, 1960 and a similar amount was applied on February 1, 1961. One year's results are shown in Table 8.

Table 8. Yields of Setaria Sphacelata, Napier and Guinea grass

Variety	Yield in Kilograms Per Hectare		
	Fresh wt.	Dry Matter	Crude Protein
South African Pigeon grass (A68) (Setaria sphacelata)	224,510	35,662	3,338
Napier grass (Pennisetum purpureum) (A26)	227,430	49,170	4,166
Napier grass (Hawaiian strain) (A25) (Pennisetum purpureum)	192,470	36,429	3,436
Guinea grass (Panicum maxium) (A27)	121,140	23,996	2,294

Both (A68) and (A26) were much more productive than Guinea grass. While dry matter and crude protein yields of Napier grass were higher than *Setaria sphacelata* (A68) the former included an estimated 20 per cent of coarse items which would not be consumed by the cattle. Consequently (A68) is considered equally as good a grass as Napier on the basis of this first year's test. In addition, several new strains of *Setaria sphacelata* appear even more leafy and productive than the (A68) strain. New strains of Napier also need further testing before final conclusions relative to the merits of these two grasses can be drawn.

WINTER ANNUALS ARE PROMISING IN NORTH AND EAST

Pangola grass grows very slowly during the winter months in Northern and Eastern Taiwan and yields of forage decline materially. The planting in fields, or overseeding of winter annuals on Pangola grass, stands appears to be an effective means of "bridging this gap" in forage production during this cold period. Lana Wooly-pod vetch (*Vicia dasycarpa*) and Chinese milk vetch (*Astragalus sinicus*) have been very productive for this purpose. Lana vetch is best on uplands and Chinese milk vetch on lowland paddy fields or on very wet upland soils. A trial was conducted using these two legumes in combination with winter oats and ryegrass on a prepared seedbed at the First Dairy Farm, near Yingo in Northern Taiwan. The soil was a red lateritic clay loam, typical of the Taoyuan tableland area. Plots were seeded on November 4, 1960 and four cuttings were made, the first on December 20, 1960, with subsequent cuttings on February 13, April 10, and May 13, 1961. Results are shown in Table 9.

Lana vetch was much more productive than Chinese milk vetch on this dry upland soil. The combination of winter oats, Lana vetch and Italian ryegrass is a very good mixture for supplementary forage since each component of the mixture provides succulent forage in a definite succession. Winter oats begins growth rapidly and supplies the majority of the forage in the first cutting. Lana vetch is most productive in the second cutting and Italian ryegrass which starts slower, furnishes abundant feed in the last two cuttings.

Table 9. Yields of Winter Annuals in Northern Taiwan

Mixture	Yield in Kilograms per Hectare		
	Fresh wt.	Dry matter	Crude protein
1. Oats, Japanese commercial	9,300	864.7	268.8
Lana vetch	11,700	1,478.0	479.0
Italian ryegrass	14,400	1,452.0	379.4
Total	35,400	3,794.7	1,127.2
2. Oats, Japanese commercial	15,600	1,594.0	354.6
Astragalus sinicus	3,800	383.0	103.0
Italian ryegrass	20,500	1,973.0	502.0
Total	39,900	3,950.0	959.6

This combination was overseeded successfully on existing Pangola grass stands in numerous field trials in Northern and Eastern Taiwan in the 1960–1961 winter season. (Fig. 10) This mixture is now recommend to farmers as an effective supplementary winter season seeding.

Fig. 12 Winter Oats, Lana Vetch and Ryegrass mixture for winter Forage in Northern Taiwan.

WINTER OATS A GOOD SUPPLEMENTARY FEED FOR NORTH AND EAST

Farmers have planted winter oats in their paddy fields in Northern Taiwan for many years to provide feed for their water buffalo, particularly in the early spring when they are working hard in preparing paddy fields for planting. With the development of greater interest in dairying in this area, winter oats is playing an important role in supplying succulent feed for dairy cows from January to April. Successful seedings have been made in established Pangola and Napier grass stands as well as on prepared seedbeds. One of the problems has been to find the best adapted, highest yielding variety. Tests were conducted for this purpose at the National Taiwan University Farm, Taipei and at the District Agricultural Improvement Station Livestock Farm at Hwalien during the winter of 1960–1961. Following are the results of these tests:

Table 10. Winter Oats Variety Yield Test

Variety	Yield of Dry Matter in Kilograms per Hectare	
	Taipei	Hualien
Florad (B39)	6,842*	—
Floriland (B38)	5,647*	—
Palestine (B25)	5,962	4,499
Indian (B20)	5,916	4,976
Indian (B19)	5,500	3,732
Diamant (B41)	5,324*	—
Seminole (B37)	5,202*	—
Indian (B21)	5,109	4,771
Indian (B22)	4,899	4,952
U. S. commercial (B.9)	4,078	4,228
Kakoshima (B23)	3.753	4,532

* Insufficient seed available for duplicating trial at Hualien.

Florad, a new variety developed at the Florida Agricultural Experiment Station in the U. S. was most outstanding in the test at Taipei. Observations of row plantings at Hwalien also showed this to be a very promising variety.

CURRENT STAGE OF GRASSLAND DEVELOPMENT ON TAIWAN

Taiwan farmers are beginning to see the advantages of forages and are taking an interest in feeding them to hogs and poultry as well as developing grassland areas on sloping land. With the introduction and sucessful performance of many tropical and subtropical grasses and legumes since 1957 many demonstrations have been established jointly by the Joint Commission on Rural Reconstruction and the Provincial Department of Agriculture and Forestry with the cooperation of the

Hsien Government and Farmers Association Agricultural Extension workers. Most of these have been established on relatively poor soils not suitable for crop production such as the rocky slope shown in Fig. 13. As a result of these demonstrations over 1000 hectares (2500 acres) have been planted since 1958. During 1960 approximately 600 hectares (1500 acres) were planted to improved forages, chiefly Pangola grass. About 200 hectares (500 acres) of this was planted by paddy farmers in very small tracts of 0.2 of a hectare (½ acre) to 1 hectare (2.5 acres) on dryland or sloping unproductive land adjacent to their rice fields. These farmers are utilizing the forage to feed cattle and thus have added another enterprise to their farm business. Likewise the manure produced is used on rice fields to improve the organic matter supply and increase yields. This development is spreading in northern Taiwan and in the past year over 100 farmers have purchased dairy cows. Undoubtedly this will be the nucleus of the future dairy industry on Taiwan.

Some indication of the economic feasibility of adding dairying to these farms having some dryland suitable for growing forages, can be gained from a field survey made of dairy farms and crop farms in Yuan Mei Township of Taoyuan Prefecture in Northern Taiwan. The study was conducted in 1959 by Dr. S. C. Hsieh and Mr. Y. T. Wang of the Rural Economics Division of JCRR. A total of 16 crop farms with comparable amounts of arable land, 8 of which had dairy enterprises and 8 without, were selected for the study. The farms were very similar in most respects, except livestock numbers and investment in the dairy enterprise, as shown in the following table:

Table 11. Land, Labor, Livestock and Capital Investment of 16 Crop Farms with and without Dairy Enterprises, Northern Taiwan, 1959

Item	Average per Farm	
	8 Farms without Dairying	8 Farms with Dairying
Cultivated Land area (hectares)	2.26	2.43
Family size (persons)	11.0	11.0
Farm workers (man equivalent)	2.7	2.8
Livestock raised:		
Cattle—head—	1.0	0.9
Hogs —head—	6.8	9.5
Poultry—head—	61.0	72.0
Dairy cows—head—	0	2.8
Buildings and implements NT$	15,117	20,686
Fixed capital investment in dairy enterprise. (mainly cows, special buildings and equipment) NT$	0	53,383

A

B

Fig 13. Rocky Slope before (A) and after (B) planting to Pangola grass. Unproductive slopes such as this can produce large amounts of milk and meat with good forages.

The farms with dairying had slightly more hogs, poultry, and investment in buildings and implements in addition to the investment in the dairy enterprise. The annual production costs per dairy cow including labor, feeds purchased and self supplied, medicine and dairy cow and building depreciation was NT$10,518. The barnyard manure produced was worth NT$1,136 and the value of a calf produced averaged NT$411 or a total value for by products of NT$1,547 leaving a net production cost of NT$8,971.

DAIRY FARMS SHOW GREATER ECONOMIC RETURNS

The comparison of economic factors on these farms are shown in table 12 and indicate that substantially more total as well as cash farm income was obtained on those farms that diversified with a dairy enterprise.

The total input and cash input were greater on the dairy farms because of the heavy investment required for expensive dairy cows and some additional buildings and equipment. Nevertheless the total cash returns per dollar cash input were nearly 30% higher, $1.89 as compared to $1.49, on the farms without a dairy enterprise. Less fertilizer was used and less hired labor employed on the dairy farms. However, about 21 per cent more labor was used on the dairy farms and family labor was better utilized throughout the year. (Fig. 14)

Fig. 14. Dairying is an enterprise that lends itself well to small farms, where family labor can be effectively utilized. Here a Chinese girl is feeding a Jersey cow winter oats forage while the rest of the family looks on.

Table 12. Comparison of Input-Output Relationship Between Crop Farms with and Without Dairy Enterprise, Northern Taiwan 1959

Item	Crop Farm Without Dairy		Crop Farm With Dairy	
	Amount NT$	%	Amount NT$	%
Total income:				
Crop production	28,920	100	37,716	130
Livestock production	12,310	100	14,770	120
Dairy production*	—	—	30,641	—
Total (A)	42,230	100	83,127	202
Cash income:				
Crop production	7,966	100	8,269	104
Livestock production	11,088	100	12,563	113
Milk production	—	—	20,010	—
Total (B)	19,054	100	40,842	214
Total input:				
Labour	11,969	100	14,268	119
Working capital	14,257	100	36,145	254
Fixed capital (flow service)	1,357	100	6,737	496
Total (C)	27,583	100	57,150	207
Cash input (D)	12,749	100	21,630	170
Fertilizers:				
Self-supplied	1,223	100	2,208	181
Purchased	4,577	100	3,918	86
Total	5,800	100	6,126	106
Feeds:				
Self-supplied	2,929	100	14,319	489
Purchased	4,287	100	13,690	319
Total	7,216	100	28,009	388
Labour:				
Seif-supplied	8,540	100	11,265	132
Hired	3,429	100	3,003	88
Total	11,969	100	14,268	119
Tota lincome/Total input A/C	149		145	
Cash income/Cash input B/D	149		189	

* Including milk, production of calves and increased value of dairy cows.

YIELD OF PADDY RICE INCREASED ON DAIRY FARMS

Since large amounts of barnyard manure were produced by cows on the dairy farms more compost manures were used. Even though an average of 214 kg. or one third less commercial fertillizer was used on the dairy farms, paddy rice yields were 20% greater. These and other differences are shown as follows:

Table 13. Yield of Paddy Rice and Use of Fertilizer on Farms With and Without Dairy Enterprises

Item	Average per Farm	
	8 Farms Without Dairying	8 Farms With Dairying
Yield of paddy rice per crop kg/ha.	3,031	3,626
Fertilizer used:		
Chemical fertilizer kg/ha.	653	439
Compost manures kg/ha.	1,966	5,373
Total value NT$	1,466	1,356
Percentage distribution of fertilizers used:		
Chemical fertilizers	89	65
Compost manures	11	35

Forage crops play an important role in the dairy enterprise and on some of the farms on which they are included in the crop rotation additional increases in crop yields can be expected in the future from the beneficial effects of the additional organic matter and nitrogen supplied.

PLANTING PANGOLA GRASS IN TAIWAN

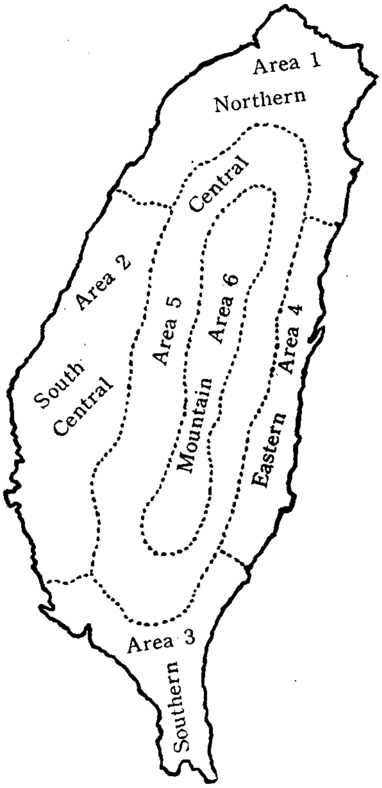
Field plantings of Pangola grass have been made in all parts of Taiwan at elevations below 1,000 meters under a wide variety of soil and climatic conditions. Experience has demonstrated certain specific recommendation and techniques for making such plantings. These are presented on the following pages.

What Variety to Plant

Nine varieties or strains of Pangola grass have been tested on Taiwan and all are susceptible to insect and disease damage except (A24), a strain which was introduced from the Philippines. This strain has been resistant to attacks of insects and is the only one recommended for planting in Taiwan at present.

When to Plant

Pangola grass grows best in hot, wet weather. The best time to plant is in the rainy season. If irrigated Pangola can be planted at any time lower elevations in Southern Taiwan. In Northern Taiwan and at elevations between 500 and 1,000 meters in the southern and central parts it is best not to plant Pangola grass between December and February because of the cold weather. At this time, the growth is very slow and it takes a long time to cover the ground. The recommended time for planting Pangola grass on dry land in different sections of Taiwan is as follows:



Area 1—Northern—March 1—November 1
Area 2—South-Central—May 1—Sept. 15
Area 3—Southern—June 1—Sept. 1
Area 4—Eastern—Any month when soil is moist enough
Area 5—Central—April 15—Sept. 15
Area 6—Mountain—Do not plant Pangola grass at elevations above 1,000 meters.

HOW TO PLANT

Select good vigorous runners from a newly planted field or cut stems from an older field. Discard the tender top leaves and dry withered parts. Plant as soon after cutting as possible. Pangola grass does not produce seeds, so stem cuttings or runners are planted.

Three methods of planting Pangola grass have been use successfully in Taiwan as follows:

1. *Row Planting:*

This is the most widely used method and the rows are normally spaced one (1) meter apart. However, where enough planting material is available and labor is plentiful, rows 30 to 50 cm apart are recommended since the plants will spread and cover the ground more rapidly. The latter spacing is also recommended where erosion is a problem, and under these conditions the rows should also be planted on the contour. (Fig. 15)

Fig. 15. Pangola grass two weeks after planting in rows one meter apart.

Prepare a good seed bed

The land should be prepared by plowing or with a hoe the same as for planting other crops. Then harrow the field to level it. Make furrows 15 cm deep with a plow or hoe. Mix the fertilizer well as follows:

Ammonium sulphate	3 parts
Calcium superphosphate	4 parts
Potassium chloride	1 part

Spread the fertilizer in the bottom of the furrow at therate of 0.4 kg. for each 10 meters of row where the rows are 1 meter apart and 0.2 kg. per 10 meters of row where the rows are 50 cm. apart.

Plant Properly

Cover the fertilizer with 6 to 8 cm of soil. Cut the planting material so there are three nodes on each cutting. (Fig. 16)

Normally these will be about 15 to 20 cm long. Hold the top of the cutting and place the remainder in the furrow at a 45° angle and cover with 7 to 9 cm of soil. Two nodes should be covered with soil and one should be above the ground. The middle node should be just below the surface of the ground and the lower one buried 6 to 8 cm deep. (Fig. 17.)

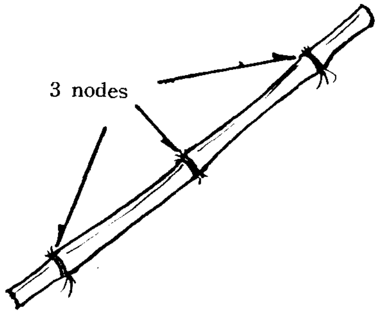


Fig. 16. Pangola grass cutting showing three nodes

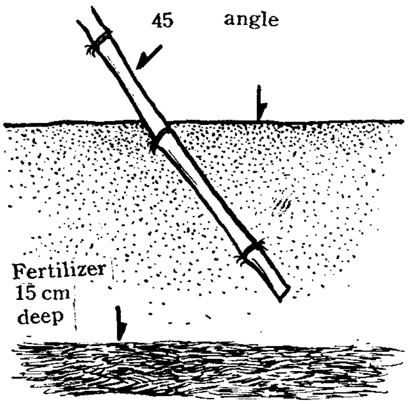


Fig. 17. Proper way to plant Pangola grass cutting

Pack the soil over the seedlings with the foot immediately after planting. This is particularly important since it presses the air out of the soil and prevents the cutting from drying out. The soil should be packed so firmly around the cutting that when pulled lightly with the hand, it cannot be easily pulled out. (Fig. 18.)

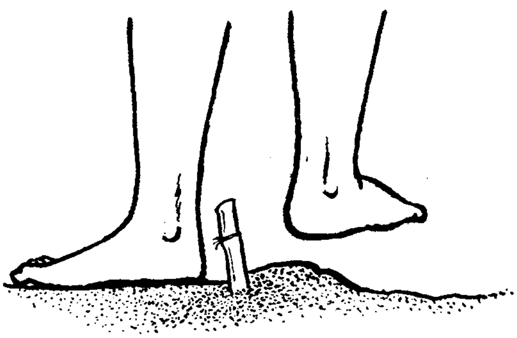


Fig. 18. Soil should be packed around Pangola grass cutting

2. *Broadcasting:*

Pangola grass can also be planted by broadcasting. When using this method, the land should be relatively free of weeds. Weeds should be taken off the land before plowing. Prepare the land the same as in the row planting method. Cut the seedling into pieces 8 to 10 cm long. Spread the seedlings on the ground so there is at least one cutting for cach 10 sq. cm. Disk-harrow them in to the soil, using any tool that will cover most of the cuttings with several centimeters of soil. Pack the soil with a roller if possible. When grasses are planted by this method on a weed free seed bed, no further weeding is needed provided adequate fertilizer is used.

3. *Hole Planting*

Hole planting is a method that can be tried in places where the land is so stony that it cannot be cultivated.

Make holes 30 cm in diameter with an undisturbed are a of 60 cm between. Remove stones and weeds from the hole as well as the roots of shrubs or trees. Dig the holes 15 cm deep. Apply the same fertilizer mixture used in the row planting method at the rate of 40 grams in each hole. Apply fertilizer at the bottom of the pit and cover with 8 cm of dirt. Plant 4–5 seedlings in the hole with the tops of the plants slanting toward the center. After the seedlings are well established, weed the plants and the area between holes, and apply the same fertilizer mixture at the rate of 400 kg. per ha, in the area between holes.

Do not make the soil surface of the row or hole lower than the surrounding land, otherwise excessive water will stay in the furrow, which will affect the growth of the seedlings.

PLANTING ON SLOPES WHERE TALL GRASSES OCCUPY THE LAND

There are many waste areas in Taiwan that are covered with tall growing grass, particularly *Erianthus Formosanus* or are covered with *Miscantus japonicus*. These must be suppressed before Pangola can be established. Several trials have been conducted in which these tall grasses were cut, Pangola planted in between, and cutting of the tall grasses continued until the Pangola was established. This was compared with clean cultivation in which the tall grass stalks and roots were dug and removed and Pangola planted immediately. The latter method was found to be best and least expensive. Also where Pangola was planted between tall grass, it was difficult to regulate the grazing since the cattle preferred the succulent Pangola and left the *Erianthus* and *Miscanthus* to grow up only to eventually damage the Pangola by excessive shading.

MANAGING PANGOLA GRASS

Sound management is essential after planting. The following points should be followed:

1. *Protect grass until it is established:*

Do not let animals graze on the recently planted grass until it has entirely covered the ground and the upright growth reaches a height of 25 to 35 cm.

2. *Weed early:*

Start weeding when the weeds just start to germinate. When weeded too late, weeds can not be separated from the planted grass, When weeds grow too long, they will take most of the nutritive elements from the soil and result in a loss in fertility. Once established and properly fertilized, Pangola grass is able to suppress weed growth and will usually be free of any troublesome weeds.

3. *Cut at the proper time:*

Pangola grass should be cut at 30–40 cm high. When cut too late, the nutritive elements will be reduced and the regrowth slowed down. If you have a large area, begin cutting when grass is 20 cm high. Then the whole area can be cut before the grass reaches 40 cm. (Fig. 19) Cut excess grass before it blossoms and put it in a silo.

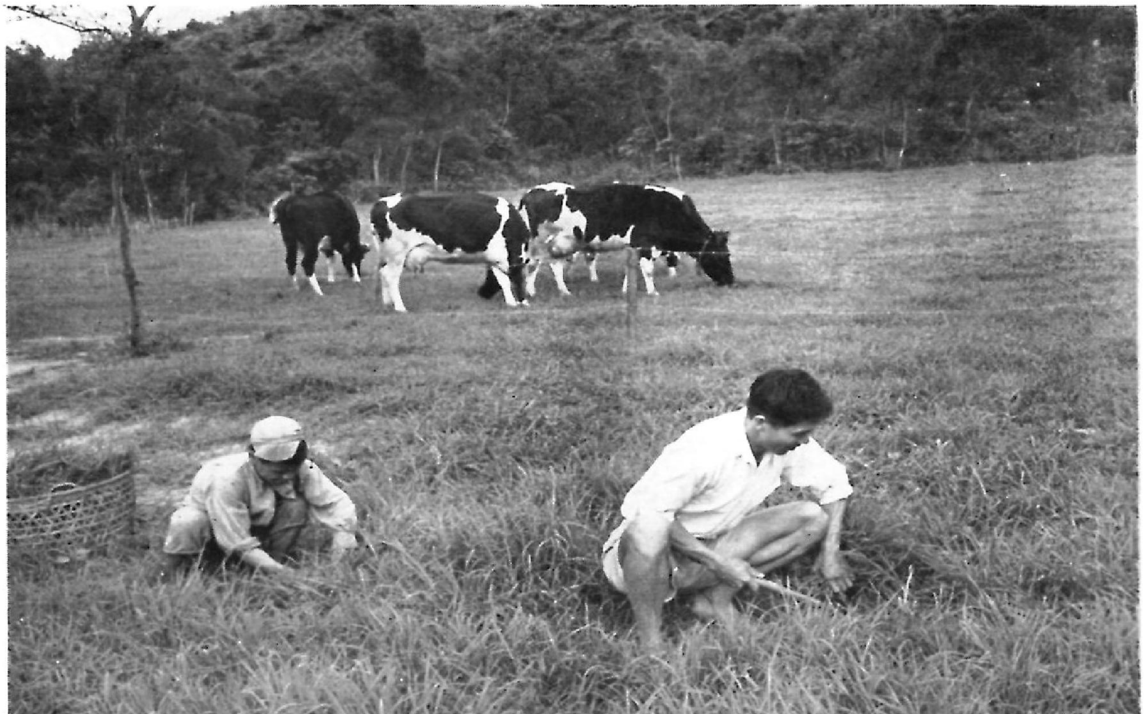


Fig. 19. Pangola grass is usually cut, hauled and fed green on small farms. When the weather is not too wet it may also be grazed. Cut when 30 to 40 cm high as shown in this picture, it is a very succulent and nutritious forage.

4. *Fertilize right after cutting:*

If no fertilizer is applied after cutting, the growth of the grass will be reduced. Apply fresh barnyard manure or nitrogen chemical fertilizer after each cutting or several times a year to improve the growth and to replace the lost nutrients taken away from the soil. On acid soils use calcium cyanamide at the rate of 100 to 200 kg. per ha. after each cutting or use up to 800 or 1,000 kg in two or more applications each year. Urea may also be used in place of calcium cyanamide on acid soils but at about half the rate.

Well Managed Grassland will Pay-Off

Grass is a crop that will pay big dividends if managed properly. If given a chance to grow up to 30 or 40 cm. after each cutting or grazing and if supplied with adequate fertilizer Pangola grass will undoubtedly remain productive for many years. "Be good to your grass and it will be good to you" is a slogan for every grassland farmer on Taiwan. If this adage is followed results such as those shown in Figure 20 can be obtained by every farmer in Taiwan.

While the grassland program is very new and much additional research is needed to answer many unsolved problems much can be accomplished in the meantime if Taiwan farmers will apply the principles outlined in this technical bulletin immediately.

Fig. 20. Cows grazing on improved Pangola grass at Kenting at the extreme southern tip of Taiwan. When propery grazed and fertilized as is this pasture, it can support as many as 2 to 4 cows per acre for a 12 month period.