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9. ABSTRACT

Brief descriptions of four types of economically important species of legumes used for food, green manuring, and forages in the tropics and subtropics. This is a companion to technical bulletins nos. 12 and 13. These descriptions include information on climatic and soil adaptation of each species, on cultural practices for effective production, and on their usefulness in farming systems. In addition to the legumes, similar information is provided for the major perennial forage grasses adapted to the tropics and subtropics. The intent of this report is to provide enough knowledge about each species to facilitate selection of those that appear best suited to particular situations, climates, and soil conditions.

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Characteristics of Economically Important Food and Forage Legumes and Forage Grasses for the Tropics and Subtropics

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Characteristics of Economically Important Food and Forage Legumes and Forage Grasses for the Tropics and Subtropics

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March 1975
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This Technical Bulletin No. 14 collects brief descriptions of four (4) types of economically important species of legumes used for food, green manuring, and forages in the tropics and subtropics. It is a companion to technical bulletins no. 12 and no. 13. These descriptions include information on climatic and soil adaptation of each species, on cultural practices for effective production, and on their usefulness in farming systems. In addition to the legumes, similar information is provided for the major perennial forage grasses adapted to the tropics and subtropics.

This type of information has previously been difficult to find, since publication has been widely dispersed in many places. The intent is to provide enough knowledge about each species to facilitate selection of those that appear best suited to particular situations, climates, and soil conditions.

For further information on selected species, queries may be addressed to this office. Additional copies of this technical bulletin may be requested from this office, or through the AID Mission, or the Regional Bureaus.

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I. Grown for protein feeds

1. Beans -- Phaseolus vulgaris. Prefers moderate rainfall, well-drained, fertile soils.

2. Field and Garden peas -- Pisum arvense. Prefers cooler growing season, moderate rainfall, neutral well-drained soils, medium fertility.

3. Cowpeas -- Vigna unguiculata. Prefers tropical humid climate, tolerate acid soils if well-drained, responds to fertility.

4. Chickpeas -- Cicer arietinum. Prefers cooler growing season, moderate rainfall, medium texture, well-drained soils.

5. Lentils -- Lens culinaris (L. esculenta). Prefers cooler growing season, moderate rainfall, well-drained soils of medium texture.

6. Pigeon peas -- Cajanus cajan. Tolerates some drought on deep soils, prefers well-drained fertile soils.

7. Mung beans -- Vigna radiatus. Adapted to warm humid regions, prefers fairly deep, well-drained soils.

8. Broad beans -- Vicia faba. Prefers cooler growing season, moderate rainfall, well-drained soils, tolerates some soil salinity.

II. Grown for oil and protein

9. Groundnuts -- Arachis hypogaea. Prefers moderate rainfall, and dry weather when ripening, well-drained, sandy loams.

10. Soybeans -- Glycine max. Prefers climatic conditions similar to those for maize, well-drained, fertile soils.

Note: Within each of these species there are many varieties that may differ widely in growth habits, and adaptation to soil and climatic conditions. Growers are advised to select varieties that have been locally tested and found to be productive. For regions of limited rainfall, the varieties with short growing periods are more likely to mature seed before soil moisture is exhausted.

The growing of one of these crops will normally increase the residual soil nitrogen by 40 or more lbs. per acre (44 kg/ha), for the benefit of the following crop.

Food grain legumes are important staple food crops in virtually all countries of the tropics and subtropics. They are present in most food stores and markets as dry grain; and usually there are several kinds sold in response to buyers' demands. While each type or species of food grain legume has its own distinctive flavor and cooking qualities, from a nutritional point of view, they are interchangeable. All food grain legumes are rich in protein, and also in lysine and tryptophan, which are essential amino acids in such protein that are deficient in cereal grains, root crops, plantain and other widely used starchy foods. Thus, food grain legumes not only satisfy food preferences, but they play a vital role in providing a better balance in human diets, where the supply of animal proteins (meat, milk, eggs, fish) is deficient.

The limited production of food grain legumes for market as dry grain may be traced to relative low yields. There has been little application of modern plant breeding, improved cultural practices, and field testing to identify those materials and practices that will result in higher yields. It appears probable and feasible to achieve 2 to 3-fold increases in yields of adapted food grain legumes in virtually all regions, that would make them equal or superior in farm value to the cereals that have received most attention in application of modern technology.

The additional unique quality of food grain legumes, not possessed by other staple food crops, is the fact that such legumes do not require nitrogen fertilizers. In fact, a vigorous crop of any of the food grain legumes may be expected to contribute 40 or more lbs/acre (44 kg/ha) of residual soil nitrogen, for the benefit of the following crop. Thus, the cereal grain crop that follows a food grain legume in the farming system may be increased 25 to 50% in yield, because of the residual soil nitrogen that is available. The leguminous crops have the unique capability of fixing large amounts of nitrogen when the seed has been inoculated with compatible strains of root-nodule bacteria (strain suitable to the legume species). The nitrogen fixed from soil air, is used by the legume to produce its own high protein content, and also the residual fixed nitrogen compounds in the soil and root system of the legume plants. The exploitation of this distinctive characteristic of legumes has received comparatively little attention. However, it is feasible for exploitation by all crop farmers and could have far reaching effects on profitability of agriculture when well understood and widely applied.

For further information on legumes see Technical Series Bulletin No. 12, "The Contribution of Legumes to Continuously Productive Agricultural Systems for the Tropics and Sub-Tropics".

Common Name	Botanical Name	Whole Seed Chemical Composition in Per Cent			
		Protein	Carbo-hydrate	Fat (Oil)	Minerals (Ash)
Beans	Phaseolus vulgaris	21.7	60.9	1.5	3.6
Peas	Pisum arvense	22.3	62.0	1.1	3.6
Cowpeas	Vigna unguiculata	23.1	61.4	1.4	3.3
Chickpeas	Cicer arietinum	19.6	63.5	3.7	3.2
Lentils	Lens culinaris	24.9	61.1	1.2	2.9
Pigeon peas	Cajanus cajan	19.5	65.5	1.3	3.8
Mung beans	Vigna radiatus	23.5	61.8	0.9	4.0
Broad beans	Vicia faba	26.2	59.4	1.3	3.0
Groundnuts	Arachis hypogaea	23.2	23.0	44.8	2.5
Meal, after oil extraction		46.6	30.2	6.3	5.4
Soybean	Glycine max	33.7	33.9	17.9	5.0
Meal, after oil extraction		45.7	31.4	1.3	6.1

NOTE: The average protein content of cereal grains is less than half that of these grain legumes. Cereal proteins also are seriously deficient in lysine and tryptophan, which are amino acids that are highly essential in human diets.

1. Field (Garden) beans - *Phaseolus vulgaris*

This type of beans is native to the Americas, but the crop is widely grown around the world in the tropics and subtropics, and as a warm season crop in the temperate zone. The crop is one of the most important food grain legumes (pulses) in the world. Beans are high in total protein, 20 - 25%, and thus serve to balance human diets based on starchy foods such as cereal grains, root crops, plantain, etc. They serve as "extenders" of the scarce animal and fish proteins. Beans are comparatively rich in lysine and tryptophan which are essential amino acids for human diets, but are deficient in starchy food crops. However, beans are widely popular as foods because they are easily grown, and store well, as well as because the food flavor is desired. Dried beans constitute a staple foodstuff for which markets exist in virtually all countries.

An important requirement for profitable production is to increase crop yields. The yields of beans in developed countries are approximately two- and three-fold as great as those commonly achieved in the less developed countries of the tropics and subtropics. It is believed that improved cultural practices, including the planting of improved varieties that are high yielding and resistant to pests, will substantially increase yields. It is important also to grow beans where they are adapted to the soil and climatic conditions. A significant factor that has not been adequately recognized, is that a vigorous crop of beans will leave residual soil nitrogen in the amount of 40 or more lbs./acre (44 kg/ha.) for the benefit of following crops. This potential is realized only where the seed is well inoculated with nodule-forming bacteria.

Description: This is an annual crop, either bushy or twining, three leaflets, flowers white to purple on short stalks, pods slender and somewhat curved, seeds globular to oblong, seed coat color being a varietal characteristic. The commonest seed form is kidney shaped, but color may be white, pinto, red, black, etc.

Climatic Adaptation: Beans require warm weather for the growing season, which may vary from 90 days for early maturing types to 140 days for later types. Excessive heat interferes with seed setting, and low temperatures are unfavorable for growth. Moderate rainfall is favorable in early growth, but dry weather favors good ripening. Beans are moderately drought tolerant.

Soil Adaptation: Beans prefer well drained loamy soils, neutral or mildly alkaline. Phosphate is the nutrient most often deficient in tropical soils.

Culture: The crop should be planted when rains begin in the warm season. Phosphate fertilizer should be applied in bands just below the plant row. If the soil is deficient in calcium, magnesium or sulfur, these elements should be present in the fertilizer. Nitrogen is not needed if seed is well inoculated. If "trace" elements (one or more of zinc, molybderum, boron, copper, iron, manganese) they may be mixed in very small amounts

with the fertilizer. The crop is planted in rows (50 - 60 cm. apart) at a rate of 40 - 50 lbs./acre (44 - 55 kg/ha.), just deep enough for contact with moist soil for prompt germination. Early weed control i essential.

Harvest should be prompt to avoid loss of beans by shattering. The seec should be dried on flat surfaces to about 10% moisture to ensure safe storage without molding.

2. Peas (field and garden types) - *Pisum arvense*

Peas probably originated in the highlands of Ethiopia, but their culture spread in pre-historic times to the Mediterranean region and thence to the developing world. In the tropics and subtropics, peas are an important crop at higher altitudes, and elsewhere during cooler seasons where rainfall is adequate. The crop is important as a cool season crop in India and Burma, in the countries bordering Lake Victoria in East Africa, in Morocco, Zaire (Congo), and in the highlands of Colombia, Ecuador and Peru. Average yields of peas in these countries are only one-half to one-third those of the developed temperate zone countries. There are significant opportunities for greatly improving yields in the tropics and subtropics to make peas important cash crops in regions where the crop is adapted, and to substantially improve the productivity of land when peas are included in farming systems.

Peas constitute a major staple foodstuff in the markets of the tropics and subtropics, either as whole dry peas or split peas. They are high in protein, about 25%, palatable and nutritious. They serve to balance the low protein cereal grains, root crops, plantain, etc. that predominate in human diets of LDCs. They are a supplement to the limited supplies of animal proteins (meat, milk, eggs, fish). Peas also are excellent sources of minerals and certain vitamins.

The principal constraint in making wider use of peas in agricultural production is the relatively low yield. Yet there is good evidence that yields may be increased several-fold by general application of existing knowledge. This would include growing peas where they are adapted to climate and soil, selection of productive varieties, effective use of mineral fertilizers, and appropriate cultural practices. Such higher yields would make peas an important contributor to cash income, and an asset in maintaining soil productivity.

An immediate benefit from growing peas is their contribution to soil nitrogen. When seed is inoculated with compatible nodule-forming bacteria, a strongly growing crop will leave 40 or more lbs./acre (44 kg/ha.) of residual nitrogen in the soil to benefit the following non-leguminous crop. No nitrogen fertilizer is needed for peas, and the use of various other legumes may largely eliminate any need to purchase nitrogen fertilizer for all crops.

Description: The pea is a cool-season annual, with twining or half-bush growth habit, reaching heights of one to two meters (depending on variety). The entire plant is glabrous (whitish coating), with little or no branching, and pinnate leaves terminating in a tendril. Flowers are large, showy, white or purple. Pods are flattish containing a few to many seeds; seeds may be round or wrinkled with seed coats green, yellow or brown. Split peas from which the seed coat has been removed are either yellow or green. The tap root system is branched and penetrates rather deeply in permeable soils.

Climatic Adaptation: Peas are best adapted to relative cool seasons, combined with moderate rainfall. The crop tolerates some frost, but suffers from high temperatures. It is not injured by limited rainfall in later growth stages.

Soil Adaptation: Prefers loamy soils, not strongly acid, well supplied with calcium. Deep soils with good water-holding capacity, but not waterlogged, support higher yields. Peas are rich in minerals, and any soil deficiencies in phosphate, potassium, calcium, magnesium or sulfur should be corrected by fertilization. No nitrogen fertilizer is needed.

Culture: Peas should be planted at the beginning of the favorable growth season, on a well prepared seed bed. Fertilizers are most effectively used by placement in a shallow furrow under the intended plant row, along with some animal manure if available, and covered lightly with soil before dropping the seed. Seeding rate is 30 to 60 lbs./acre (35 - 65 kg/ha.) in rows 30 to 40 cm. apart, to provide one plant per 10 cm. of row. Shallow planting is preferred for easy emergence of sprouts. Early control of weeds is essential. The pods all ripen at one time, and these may be airdried before threshing. Threshed seed should be dried to about 10% moisture content to insure safe storage without molding.

3. Cowpeas - Vigna unguiculata (V. sinensis)

Cowpeas are native to Africa. They are grown for market as dry food grain legumes in various countries, and very widely used as subsistence foods throughout much of the African continent. They are grown also in warm climates in other tropical and subtropical regions, where regional types and varieties have become established.

Cowpeas have a high protein content (20 - 25%) and are palatable and nutritious foods. They fill an important role in human diets wherever grown, as protein supplements to such starchy foods as the cereals, root crops, plantain, etc. The crop is used as a fresh vegetable (full grown green seeds), and as a dry grain. In the form of dry grain, cowpeas constitute a staple commodity in markets and trade.

The exploitation of the inherent values of cowpeas has been constrained by generally low yields. A comparison of average yields in producing countries shows that production may be increased several fold by selection of adapted varieties that are resistant to pests, by effective cultural practices and prudent use of fertilizers, together with prompt harvest and drying to produce a salable crop. A very important indirect benefit from growing cowpeas is their contribution to residual soil nitrogen. A vigorous crop of cowpeas will supply enough soil nitrogen to increase yields of the following crop of a cereal by 25 to 50%, and thus reducing dependence on fertilizer nitrogen. Cowpeas may be a significant component of a balanced crop rotation, to provide a marketable crop and to maintain soil productivity.

Description: The cowpea is a warm season annual herbaceous legume. The plants of different varieties may be half-bush to viny in growth habit, with shiny smooth tri-foliate leaves. The plant is indeterminate, and typically continues to blossom and produce seed for an extended period. The flowers are white or purple, borne in pairs on short stalks; the pods are smooth, 15-25 cm. long, cylindrical and somewhat curved. The seeds are kidney shaped, and seed coats of different varieties range from white with blackeyes, to solid colors of brown, clay, maroon, purplish or nearly black. The varietal seed sizes and colors make it possible to choose types for which there is greater market demand. Varieties generally breed true, so that maintenance of pure seed is not difficult.

Climatic Adaptation: Requires warm weather, and moderate rainfall. Better adapted to abundant rainfall than most other food grain legumes. May be adjusted to regions of short rainy season by choosing early maturing varieties. Intolerant of cold.

Soil Adaptation: Adapted to a wide range of soils from sandy to heavy loams, acid soils, and various levels of fertility. Intolerant of poor soil drainage. Responds to phosphate fertilizers, and to correction of soil deficiencies in calcium, magnesium and sulfur, these occur. Nitrogen fertilizers are unnecessary for good growth.

Culture: Choose varieties that have been field tested and found productive under local conditions. Plant on well prepared seedbed, in rows at 30 lbs/acre (33 kg/ha.), when soils are moist. Phosphates, and such other mineral fertilizers as may be necessary, as well as animal manures, should be placed in shallow furrows and lightly covered with soil before placement of seed. Early control of weeds is necessary. The ripe pods should be harvested promptly, and the seed well dried to about 10% moisture to insure safe storage without molding. Certain varieties do not shatter seed from ripe pods and are preferred for commercial production.

4. Chickpeas - Cicer arietinum

(Garbanzo) Chickpeas occupy an important role in the agriculture of the Mediterranean region, the Near East and the Indian subcontinent. They are grown in the cool season with winter type of rainfall, and are an important crop in various regions of Africa, the Far East and Latin America where a cool humid season occurs. The culture of the crop has received little attention in terms of modern applied science and technology, with the result that average yields are unnecessarily low. Nevertheless, chickpeas are prized as a staple food crop, and are sold very widely in stores and markets in many countries. Chickpeas are rich in protein, and are palatable and nutritious. They are used in human diets to supplement starchy foods (cereals, root crops, etc.), where they may partially replace animal proteins (meat, milk, eggs, fish).

A principal constraint on greater use of chickpeas in farming systems, is the relative low yields. Evidence is accumulating that greatly improved yields are feasible, that would make the crop much more profitable. The use of high yielding varieties adapted to local soils and climate, that are also resistant to insect pests and diseases, combined with effective cultural practices, and prudent use of mineral fertilizers, should greatly increase yields of grain. In addition, a vigorous crop of chickpeas will leave residual soil nitrogen, that will greatly benefit the following non-leguminous crop of cereals or other crops. Chickpeas have the potential of not only becoming a major income producer for the cultivator, but also a means of contributing to more sustained soil productivity.

Description: The chickpea is an erect, herbaceous, pubescent annual, 45 - 60 cm. in height. The plant is well branched, with pinnate leaves, each having 10 to 20 leaflets. The flowers are borne singly on short stalks, white or tinted in color. Pods are short, pubescent, containing one to two seeds each. Seeds are rather large, 1/2 to 1 cm. wide, wrinkled with a point on one end, and the color of different varieties may be white or pinkish, red or black. The small blackseeded types seem to be associated with earliness and tolerance to adverse soil and climatic conditions, and the white type with higher yields. However, plant breeders indicated that various combinations of seed and plant characteristics are possible. The chickpea has a tap root, rather well branched but does not penetrate deeply.

Climatic Adaptation: Thrives in cool seasons with winter type rainfall. Evades heat by maturing with onset of hot weather. Moderate rainfall preferred. Tolerates cool weather and light frost.

Soil Adaptation: Grows well on a wide variety of soils but does not tolerate poorly drained soils, nor soil salinity. Relatively high requirement for phosphates, and moderate supplies of soil calcium magnesium and sulfur. Nitrogen fertilizer is not needed if seed is inoculated with compatible strains of nodule bacteria.

Culture: Grown primarily for dry seed for home consumption and for market. Plant at beginning of rainy season (or after danger of heavy frost is past), on well prepared seed bed, with application of mineral fertilizers and/or animal manure placed in shallow furrow and lightly covered with soil before planting seed. Use only high yielding varieties, field tested in the region where crop is to be grown. Plant in rows 25 - 30 cm. apart at rate of 40 - 60 lbs/acre (45 - 65 kg/ha.), at depths no greater than necessary to place seed moist soil for prompt germination. Early weed control is necessary. Harvest promptly when seeds are ripe; thresh and dry seed to about 10% moisture content to avoid molding in storage.

6. Lentils - [illegible]

Lentils are an ancient food crop in the Mediterranean and [illegible] regions, widely grown as a cool season (winter) annual, where cool seasons coincide with moderate rainfall. In the higher altitudes of tropical Africa, Latin America, and Asia, lentils have become important. India and Pakistan are important producers.

Lentils are a high-protein foodstuff, averaging 24-25% protein and [illegible] carbohydrates. The protein is well supplied with lysine and tryptophan, which are two amino acids essential to human diets, but generally deficient in cereal grains, root crops and plantains that predominate in tropical and subtropical regions. Lentils are easily cooked, quite digestible, and popular as a foodstuff. The dry seed (grain) is widely marketed throughout the tropical and subtropical regions of the world. As a protein food, lentils are interchangeable with other food grain legumes, and the volume of each that is marketed, generally depends on price.

Lentils have not been fully exploited as a cash crop because of generally low yields. There is clear evidence that yields may be increased three- and four-fold by application of available knowledge. Use should be made of improved varieties with higher yielding ability, resistant to pests, that have been field tested in the region and found to be superior. The application of appropriate cultural practices, and prudent use of fertilizers should substantially increase yields and make lentils far more attractive as a cash crop.

In common with other food grain legumes, lentils are important for nitrogen fixation. When plants are well inoculated with compatible strains of nodule-forming bacteria, a vigorous crop may be expected to contribute 40 or more lbs/acre (45 kg/ha.) of soil nitrogen that will benefit the following non-legume crops. This is equivalent to about 200 lbs. per acre (220 kg/ha.) of sulfate of ammonia fertilizer. The inclusion of high yielding lentils in the farming system should increase cash income, and also enhance the continuing productivity of the land on which it is grown.

Description: Lentils are short season, erect, cool season annuals, reaching heights of 30 to 60 cm. The stem is branched; leaves are pinnate with four to seven pairs of leaflets, each leaf ending in a tendril. The single flowers are borne on short stalks, and may be white, lilac or light blue. Pods are short with one or two lens shaped seeds. Varietal seed colors may be green, reddish green or brown. There are large and small seeded types, the larger type having 13,000 seeds per kilo, and the smaller type having about 26,000. Lentils have a branched root system, that penetrates 30 to 60 inches into the soil. Earlier strains require 70 days from planting to maturity, and the later strains require 110 days.

Climatic Adaptation: Prefers cooler weather and thus grown as a winter annual where rains occur in the cool season. In harsher climates, plant after danger of damaging frosts is past, to mature a crop before onset of heat and drought.

Soil Adaptation: Lentils prefer soils of moderate fertility, with substantial waterholding capacity. Sensitive to soil salinity. Responds to phosphates, and to other mineral fertilizers where these are deficient (calcium, magnesium, sulfur). Being a legume, lentils do not require nitrogen fertilizers.

Culture: Plant only high yielding varieties, field tested under local conditions and found to be superior. Well prepared seed beds should have fertilizers and manure placed in bands in shallow furrows and covered lightly with soil before seeding. Plant in rows about 30 cm. apart, at seeding rate of 5 - 8 lbs/acre (6 - 9 kg/ha.), and depths of 2½ - 3½ cm. Lentils do not compete strongly with weeds, and early weed control is essential. The ripe crop should be harvested promptly, threshed, and the seed dried to about 10% moisture to avoid molding in storage.

6. Pigeon pea - Cajanus cajan

Pigeon peas are grown widely in the tropics and subtropics, for the dry seed, as green beans, and as livestock feed. Principal centers of production include India, Pakistan and Burma in South Asia, Uganda and Malawi in Africa, the West Indies and Venezuela. Average grain yields for these countries range from 370 to 1130 kg. per hectare. However, yields of 1800 to 2000 kg. are reported under good management.

The crop is handled in many ways in various regions; as a long-season (six months) warm season annual; intercropped with sorghum, maize or cotton for harvest after the main crop matures; or as a perennial in gardens for two or more crops. The greatest potential as a cash crop is culture as an annual using varieties that mature within six months.

Dry pigeon peas are a well established foodstuff, marketed in stores throughout the tropics and subtropics. They are high in protein, 22 to 25%, and rich in carbohydrates and minerals. Theyserve to balance the low protein cereal grains, root crops and plantain that predominate in human diets in the tropics and subtropics. They also supplement the limited supplies of animal proteins (meat, milk, eggs and fish).

The principal constraint in growing pigeon peas as a major crop is low yields. As noted above, it is feasible to increase yields several fold. This requires planting adapted, high yielding varieties, effective use of mineral fertilizers to correct soil deficiencies and meet the crops nutrient needs, and the adoption of cultural practices to make the most effective use of the land.

The pigeon pea is an effective contributor to soil nitrogen. When seed is inoculated with compatible strains of root nodule bacteria, the crop will leave 50 or more lbs/acre (55 kg/ha.) of residual soil nitrogen to benefit the following crop. The greater the pigeon pea yield, the greater the residual soil nitrogen. The actual value of the pigeon pea may be determined by adding the cash value of dry peas to the value of the increased yield of the following non-legume crop.

Description: The pigeon pea is a much-branched annual (or short-lived perennial) that grows two to four meters tall, depending on variety. The plants are mostly pubescent, with trifoliate leaves, and flowers borne in leaf axils. Flower color may be yellow or red. The pods are five to eight cm. long, with four to seven seeds per pod. The seeds are rounded with one edge flattened, usually brown, with a white spot at attachment to the pod. Pigeon peas are very deeply rooted, and thus tolerate prolonged dry periods between rains. There are a great many varieties with wide differences in adaptation, yields, length of growing season, resistance to pests, and other traits.

Climate Adaptation: Prefers warm weather and moderate rainfall. However, after early establishment it survives periods of limited rainfall. Also, the plant remains alive in cool seasons and resumes activity when warm weather recurs. Highest yields come from sustained growth.

Soil Adaptation: Pigeon peas grow well on a wide range of soils, but yield best on fertile loams, that are deep and well drained. It is reputed to have strong feeding power on less fertile soils. It tolerates some soil salinity and alkali, often found in dry regions. On deep soils, pigeon peas tolerate prolonged drought.

Culture: Despite the crop's tolerance of lower soil fertility, higher yields require the use of mineral fertilizers to correct soil deficiencies. Phosphate is generally needed, but other deficiencies may need correction, including potassium, calcium, magnesium, and sulfu When grown as a major crop, pigeon peas should be planted on a well prepared seedbed, at the beginning of a favorable growth period. The most effective use of fertilizer is to place it in shallow furrows under the intended plant row, along with animal dung if available, and covered lightly with soil before placement of seed. Seedling plants will receive prompt benefit. Early weed control is essential despite the strong growth habit of the pigeon pea. The better commercial varieties mature a crop of seed in a short period, so that a single harvest may suffice. Other varieties will require repeated picking as pods ripen. The pods should be threshed when dry, and the seed further (sun) dried to about 10% moisture to insure storage without molding.

7. Mung beans - Vigna radiata (V. aureus, V. mungo)

Mung beans are grown most abundantly in South Asia, including India and Pakistan, but also are grown in Africa and tropical America. There are two types, belonging to the same species -- the "black gram", or "urd" with mostly black seeds, and the green or "golden gram" with green or greenish yellow seeds. They are grown for food (dry beans and sprouts), for green manure (soil improvement), and as forage for livestock. Mung beans frequently are grown as a second crop following rice or cotton where rainfall is adequate.

Mung beans are high in protein (24 to 25%), and are useful in human diets to supplement the low protein starchy foods -- cereal grains, root crops, plantain, etc. The protein is rich in lysine and tryptophan, which are essential amino acids for human diets, that are deficient in most other food crops. Mung beans are useful also to supplement the limited supplies of animal proteins (meat, milk, eggs, fish), particularly for less affluent population groups. Mung beans are a standard staple foodstuff in most urban markets.

Mung beans have not been fully exploited in regions where they are well adapted, because of low yields. However, there is evidence from field tests that yields may be greatly improved by the application of present knowledge. The feasible increases of two- to three-fold would make mung beans a profitable cash crop in farming systems. To increase yields, the most productive varieties for the region should be planted to exploit their yielding ability and resistance to pests. The effective use of fertilizers -- phosphate, calcium, magnesium, potassium and sulfur, should be designed to correct soil deficiencies. The application of cultural practices to enhance yields may be greatly improved.

A highly important benefit of including mung beans in farming systems, is their contribution to nitrogen supplies, without purchase of nitrogen fertilizer. A vigorous crop of mung beans will contribute 40 or more lbs/acre (44 kg/ha.) of residual soil nitrogen for the benefit of the following crop. The inclusion of productive crops of mung beans in farming systems should substantially increase cash income, as well as enhance the continuing productivity of the land.

Description: The mung bean is a warm-season annual, 30 to 100 cm. tall (depending on variety), with an erect, spreading growth habit. The trifoliate leaves are quite hairy. Flowers are borne in clusters on short stalks; pods are slender, cylindrical 4 - 10 cm. long, with 8 - 12 seeds each. Seeds are roundish, often with square ends, quite small -- 20,000 - 25,000 per kilo. Seed color may be black, brown, green or golden, depending on variety. The plant has a tap root, comparatively well branched and deep, thus permitting exploitation of soil moisture to considerable depth. Some varieties mature in six to eight weeks, but others have much longer life periods. Yields up to 2000 kg./ha. have been reported for longer season varieties.

Climatic Adaptation: Mung beans require warm weather. They may be grown in seasons of limited rainfall by exploiting soil moisture accumulated during previous rainy periods, or after growth of an irrigated crop such as rice. Varieties differ in their response to length of day, and should be selected to match the day length of the season when the crop is to be grown.

Soil Adaptation: Mung beans prefer fairly deep and fertile soils. Since the crop has a high requirement for mineral nutrients (phosphate, potassium, calcium, magnesium, sulfur), fertilizers should be used to correct soil deficiencies. No nitrogen is needed when the seed is inoculated with compatible root-nodule forming bacteria.

Culture: Mung beans should be planted promptly when land is available, to more fully utilize the soil moisture. The seedbed should be well prepared, and fertilizer applied in bands under the intended plant rows, by placement in a shallow furrow and then lightly covered with soil, before seeding. Since seeds are small, they should be planted shallow -- about 2 - 3 cm. deep, to permit easy emergence. Where the previous crop has been well fertilized, it may not be necessary to apply more fertilizer for mung beans. Since the goal is greatly improved yields, reliance should not be placed on traditional culture which does not exploit the potentiality of mung beans. Row planting, about 50 cm. apart, with one plant per 4 - 5 cm. of row, is recommended. Since mung beans are not strongly competitive with weeds, early weed control is essential. The crop should be harvested promptly when ripe to avoid seed shattering, threshed, and (sun) dried to about 10% moisture to assure safe storage without molding.

8. Broad beans - Vicia faba

Broadbeans are grown in cool seasons with moderate to good rainfa particularly in the Mediterranean and Near East regions, and at higher altitudes in tropical climates. They are major food grain legumes under such conditions, including such diverse areas as Egypt, Ethiopia Turkey, Morocco, Tunisia, Brazil, Ecuador, Peru, and Mexico. Reported national grain yields vary from 330 to 2100 kg/ha., partly because of relative suitability of climate, but much to the differences in application of available knowledge about the crop. There appear to be grea opportunities to increase yields where climate and soil are favorable, as indicated by local field experiments. Broadbeans are rich in prote (25%), highly palatable and nutritious as foods, both as green shelled beans, and the ripe beans. They are important food supplements to cere grains (maize, sorghum, etc.) and to root and tuber crops. They are well supplied with lysine and tryptophan which are amino acids that are deficient in cereal grains and roots.

The potential values of broadbeans as a profitable cash crop and as a nutritious food have largely been unexploited because of relatively low yields. Yield increases of three- to four-fold are feasible by small cultivators by application of present knowledge. High-yielding varieties that have been field tested under local conditions should be grown. Such varieties are more resistant to insect pests and diseases. Attention must be given to correction of soil deficiencies particularly to phosphate, but also to potassium, calcium, magnesium and sulfur. Any deficiencies in "trace" elements needed in small amounts (zinc, boron, molydenum, manganese, copper, iron) may be corrected by adding them to fertilizer as needed. Improved cultural practices should be used. Animal manures usually provide sufficient "trace" elements.

In addition to much higher yields, a vigorous crop of broadbeans will contribute 40 or more lbs/acre (44 kg/ha.) of residual soil nitrogen for the benefit of the following non-leguminous crop. The broadbean needs no nitrogen fertilizer for its own growth, and the residual soil nitrogen is a clear bonus.

Description: The broadbean is a hardy cool-season annual, with erect growth. The plant has a single stem, 30 to 190cm. tall (depending on variety) very leafy, each leaf with one to three pairs of smooth leaflets. Flowers are borne in axils of leaves, dull white with purplish blotch. The pods are large and thick, 15 - 40 cm. long, with large seeds strongly flattened, varying in color -- green, brown, purplish or black. There are 1100 to 1650 seeds per kilo, but size is constant within each variety. The tap root is well branched, with only moderate soil penetration, which accounts for the crop's dependence on well distributed rainfall.

Climatic Adaptation: The crop is sensitive to high temperatures, particularly during blooming and pod development, and suffers from disease at such temperatures. Growth is most vigorous during cool weather, as at higher altitudes in the tropics, and the mild winters of subtropics.

Soil Adaptation: Prefers soils of moderate to good fertility, well drained, with high water holding capacity. Moderately tolerant of soil salinity.

Culture: Plant on well prepared seedbed, with use of necessary fertilizer to correct soil deficiencies. Phosphate is the basic need, but no nitrogen is needed when seed has been inoculated with compatible nodule-forming bacteria. Fertilizers, and/or manures may be placed in a shallow furrow and covered lightly with soil, and seed placed thereon. Seed at depth of 5 - 8 cm., in rows 75-100 cm. apart, at seeding rate to provide one plant per 15 - 25 cm. of row. Early weed control is necessary. Ripe pods should be harvested promptly, threshed, and (sun) dried to 10% moisture to insure safe storage without molding.

9. Groundnuts - Arachis hypogaea (Peanuts)

Groundnuts are believed to have originated in the area now occupied by Brazil, and to have spread rapidly through the tropical and temperate zones following European discovery of the new world. Within the tropics and subtropics groundnuts are an important crop in India, Indonesia, Burma, Thailand, a dozen countries of Africa, in Brazil, Argentina and Paraguay, as well as in Mexico, the Dominican Republic, and other Caribbean countries. The crop is grown for export as unprocessed nuts, for processing into oil and meal, and for local use as a major food crop and a source of oil for cooking and home lighting. Despite such wide production and use, the application of modern technology has been quite deficient. In contrast to yields of 2300 to 3000 kg/ha. for groundnuts grown in developed countries, yields in Asian countries average about 1000 kg/ha., and African yields are in the range of 750 kg/ha. Latin American and Caribbean yields average about 750 kg/ha. There appear to be substantial opportunities to markedly increase yields of groundnuts in LDCs.

Groundnuts are grown in rotation with cereals (millet, sorghum and maize), and where rainfall permits, as an interplanted crop. The vine residues, after ripe pods are removed, are used as livestock feed. Groundnuts are a highly palatable and nutritious foodstuff, extensively used by rural people in LDCs, both as the whole nut, and for local extraction of oil, and the use of the meal for food. Whole groundnuts contain about 43% oil, 26% protein, 24% carbohydrates and 2.7% minerals. They are also rich in certain vitamins and minerals. When oil is extracted, the residual meal is much richer in the remaining nutrients.

The general value of groundnuts is recognized by most growers, but low yields constitute a major constraint in fully exploiting the crop. It should be feasible to greatly increase yields by the following measures; introduce improved high yielding varieties that are adapted to local soil and climatic conditions and are resistant to pests; adapt soil and water conservation practices to more fully utilize rainfall and use soil amendments to correct soil deficiencies and meet the crop's nutritional needs for phosphate, calcium, potassium, magnesium and sulfur, as well as any "trace" elements (boron, zinc, molybdenum, copper, manganese and iron). Cultural practices must be more effectively adjusted to local conditions, such as time of planting, weed control, and timely harvest (digging) and drying to insure high seed quality.

A major value of groundnuts in farming systems is their contribution to residual soil nitrogen. A vigorous crop of groundnuts should contribute 45 kg/ha. or more of residual nitrogen for the benefit of the following non-leguminous crops. The multiple uses of groundnuts to meet local family needs, as well as its ready sale for cash, give groundnuts a unique role in the entire list of foodgrain legumes.

Description: The groundnut is actually a type of pea, and not a nut. It is a warm-season, herbaceous plant that produces a central stem with numerous branches that range from erect to prostrate. There are two main types; the bunch type with pods closely clustered at the base of the plant, and the runner type that bears pods scattered along the prostrate, spreading stems. Flowers are borne in axils of the pinnate leaves, above or below soil surface. After pollination of the flowers, the ovary stalk elongates rapidly and pushes the embryonic pod into the soil. The pod develops only under the soil surface. Pods may have one to three seeds.

Climatic Adaptation: Groundnuts require warm temperatures and moderate rainfall for growth, and comparatively dry weather during seed ripening and harvest. Heavy rainfall causes deterioration. Groundnuts are grown in seasons when the rainy season will mature a crop, by choosing suitable varieties; early varieties mature in 90 to 100 days, and later varieties up to 140 days.

Soil Adaptation: Well drained sandy loams are best adapted to groundnut culture, both for starting the crop and for harvest. A friable soil is necessary for rapid maturation of the pods (borne below soil surface) and for digging the crop without loss of pods. Nutrient deficiencies must be corrected.

Culture: Groundnuts should be planted on a well prepared seedbed; and planted at the beginning of a rainy season, in moist soil to insure rapid germination and emergence of sprouts. In humid climates, planting of selected varieties should be timed so that ripening and harvest will occur during a dry season. Fertilizers and/or animal dung are best placed in shallow furrows below the intended plant row, covered lightly with soil, and the seed placed thereon at final depth of about 5 cm. Seeding rates of shelled seed are about 30 kg/ha., to provide one plant per 15 cm. of row, in rows 70 - 80 cm. apart. Early weed control is highly essential. When pods are mature, the entire plant is lifted out, and air cured for initial drying of pods; pods are then stripped off and rapidly cured on flat surfaces to protect against molding. Seed must not exceed 10% moisture for safe storage.

10. Soybeans - Glycine max

The soybean is an ancient crop in China and Japan, but did not receive much attention elsewhere in the world until recent times. The phenomenal development of soybeans as a major oil seed crop in the U.S. since about 1930, has attracted the interest of many other countries. World production now is largely centered in the U.S. and Canada, and in southern Brazil.

The adoption of soybeans as a major crop in the tropics and subtropics is dependent on overcoming several limitations: (1) the crop is strongly influenced by length of day, and is naturally suited to the sequence of day length found in the temperate zone, which paralells the situation in Manchuria where soybeans are native; (2) the soybean requires high soil fertility which is not easily provided by direct application of fertilizer. Soybeans yield well in maize growing regions where fertility is maintained at levels to support production of 8000 to 9000 kg. per hectare. Such fertility levels are rarely achieved with rainfed crops for the tropics and subtropics; (3) the whole, mature bean is not a readily digestible foodstuff under home cooking practices. Oriental countries convert soybeans to digestible forms by various types of fermentation and sprouting procedures that are not practiced in other regions. All of these factors may be corrected in time, by suitable research. The high cash value of whole soybeans, of the extracted oil, and of the oilmeal will stimulate further effort to introduce soybeans into tropical farming systems. The oilmeal produced by oil extraction at high temperatures is highly digestible, since such temperatures dissipate the inhibitors to digestion that otherwise constitute a problem.

The average composition of soybeans and the meal is:

	Protein	Oil	Carbohydrate	Minerals
Whole beans	39%	18%	25%	4.8%
Soybean meal (after oil extraction)	44%	3%	33%	6.0%

Soybean meal is a nutritious high protein foodstuff for human diets, and for feeding livestock. It is an excellent protein supplement to diets that are high in starchy foods (cereal grains, root crops, plantain, etc.) and low in protein. Soybean meal is rich in lysine and tryptophan, which are amino acids that are deficient in starchy foods. The meal may also be used to supplement scarce animal proteins (meat, milk, eggs, fish).

In addition to being a source of high protein food, and an attractive cash crop where yields of 2000 - 2500 kg/hectare are produced, the soybean is a strong contributor to residual soil nitrogen to benefit the following

non-leguminous crop. A reasonably productive crop of soybeans should contribute 45 to 5[illegible] kg/hectare of residual soil nitrogen. This is achieved when the soybean seed is inoculated with the soybean type of nodule-forming bacteria.

Description: The soybean is an annual warm-season legume, sensitive to length of day which controls the sequence of vegetative growth, flowering and seed production. Varietal selection for ecological regions is based partly on the adaptation to seasonal length of day. Soybeans are mostly bushy, leafy, with varieties ranging in height from 45 to 120 cm., and life-spans of 75 to 150 days. There is a strong central stem, with variable amounts of branching. The leaves are trifoliate, and small white or purple flowers are borne on short stalks along the stem. Pods are numerous, small, with one to four seeds, that are nearly round or elliptical. Most commercial varieties have yellow seeds, but green, brown and black seeded varieties exist. The plant is determinate in blooming habit, and all pods ripen about the same time. Leaves turn yellow and drop off as seed ripening begins. The soybean has a strong, branched tap root, which penetrates deeply and makes developed plants somewhat drought tolerant. The plant is self-pollinated, and varieties normally breed true with only limited rogueing to remove off-types.

Climatic Adaptation: Soybeans require warm weather, and moderate, well distributed rainfall. It will tolerate short droughts, and cooler weather at time of ripening. Excessive rain is harmful.

Soil Adaptation: Soybeans prefer well drained soils, that are deep friable and fertile. Soybeans respond to abundant supplies of phosphate, potassium, calcium, magnesium and sulfur, but makes less use of immediate fertilization than of residual fertility. Thus the crop yields well in farming systems with generally high fertility.

Culture: The crop should be planted on a well prepared seedbed when temperatures are above 15degrees C. and the soil is moist for prompt germination. All seed should be inoculated with soybean type of nodule-forming bacteria, since other types of bacteria are not effective. Fertilization should be planned to correct soil deficiencies, but it should be plowed under or otherwise incorporated in the seedbed. Seeding rates are 20 - 30 kg/ha. of seed, planted in rows 60 - 90 cm. apart, to produce one plant per 10 cm. of row. Seed should be planted shallowly, three to five cm. deep, to facilitate prompt emergence of sprouts. soybeans are not strongly competitive with weeds, and early weed control is essential. The crop is not harvested until seed is well dried, down to 10% moisture. Non-shattering varieties should be used to avoid seed loss. The ripe plants may be harvested by hand or by machine. After threshing, there should be a final drying in thin layers on a drying floor, to insure storage without molding.

Minor Food Grain Legumes for the Tropics and Sub-Tropics

Each of the following species is quite important as a food crop in certain regions of the tropics and sub-tropics, although their production is not as widespread as the major food grain legumes. Within each species there are many varieties, differing markedly in plant type, resistance to local pests, in adaptation to soil and climatic conditions and in yielding capacity. There appear to be substantial opportunities for markedly increasing yields of all of these crops.

	Common Name	Botanical Name
1.	Horsegram	1. Dolichos biflorus (D. uniflorus)
2.	Lablab (hyacinth bean, bonavista bean)	2. Dolichos lablab, Lablab niger
3.	Jack bean	3. Canavalia ensiformis
4.	Cluster bean (quar)	4. Cyamopsis tetragonolobus (C. psoralioides)
5.	Grass pea	5. Lathyrus sativus
6.	White sweet lupine	6. Lupinus albus
7.	Goa bean	7. Psophocarpus tetragonolobus
8.	Tepary bean	8. Phaseolus acutifolius
9.	Lima bean	9. Phaseolus lunatus
10.	Scarlet runner bean	10. Phaseolus multiflorus
11.	Adzuki bean	11. Vigna angularis
12.	Rice bean, moth bean	12. Vigna calcaratus, V. aconitifolius
13.	Catjang bean	13. Vigna unguiculata (V. cylindrica)
14.	Yardlong bean	14. Vigna unguiculata (V. sesquipedalis)
15.	Bambarra nut	15. Voandzeia subterranea

The choice of a crop species s[illegible] local soils and climate, plus the planting of the particular varieties that have proven to be high yielding in the region, and the effective use of cultural practices and necessary fertilizers, will normally increase yields very substantially.

The growing of one of these crops will normally increase the residual soil nitrogen by 40 or more lbs. per acre (44 kg/ha) for the benefit of the following crop.

For further information on legumes see Technical Series Bulletin No. 10, "The Contribution of Legumes to Continuously Productive Agricultural Syst[illegible] for the Tropics and Sub-Tropics".

Average Chemical Composition of Seed of Lesser Food Grain Legumes

Common Name	Botanical Name	Whole Seed Composition in Per Cent			
		Protein	Carbo-hydrates	Fat	Minerals
1. Horsegram	Dolichos biflorus	22.5	60.5	1.0	6.3
2. Lablab	Dolichos lablab	22.8	62.1	1.0	3.2
3. Jack bean	Canavalia ensiformis	24.5	59.0	2.6	3.2
4. Cluster bean (guer)	Cyamopsis tetragonolobus	(24.0)	(50.4)	(3.2)	(2.8) (Est)
5. Grass pea	Lathyrus sativus	27.4	59.8	1.1	3.3
6. White sweet lupine	Lupinus albus	40.2	26.4	4.1	3.6
7. Goa bean	Psophocarpus tetra-gonolobus	35.0	28.0	18.0	4.0
8. Tepary bean	Phaseolus acutifolius	19.3	67.8	1.2	3.1
9. Lima bean	Phaseolus lunatus	21.4	61.1	1.4	3.4
10. Scarlet runner bean	Phaseolus multiflorus	20.3	62.0	1.8	3.4
11. Adzuki bean	Vigna angularis	21.1	59.5	1.0	3.4
12. Rice bean	Vigna calcaratus	20.9	60.7	0.9	4.2
13. Catjang bean	Vigna unguiculata	23.1	61.4	1.4	3.3
14. Yardlong bean	Vigna unguiculata	22.9	48.9	2.5	3.4
15. Bambarra nut	Voandzeia subterranea	18.8	61.3	6.2	3.4

NOTE: The average protein content of cereal grains is less than half that of these food grain legumes. Cereal proteins also are seriously deficient in lysine and tryptophan, which are amino acids that are highly essential in human diets.

1. Horse gram - Dolichos biflorus, D. uniflorus

Description: There are various plant types in this species, varying from varieties that are erect, to those that are trailing; and from a short season to a long season life period. Flowers are violet to white pea-like, borne in clusters on a raceme, with lowest flowers opening first. Pods are narrow and hairy, and seeds are smaller than lablab. Relatively free of pests, but some varieties are susceptible to local insects unless controlled. When well grown, the crop makes important contributions to soil nitrogen (up to 40 kg/ha.) which greatly stimulates growth of following crops.

Climatic Adaptation: Similar to cowpea; erect, bushy types are adapted to the savanna regions, and the longer season trailing types to humid climates; but plant breeding may alter these relationships. Adapted to warm seasons; and yield best under moderate to abundant rainfall.

Soil Adaptation: Similar to cowpea; widely adapted to soils of widely different character, but intolerant of water-logging and flooding. Responds to phosphates on most soils. Inoculated with cowpea type of nodule-forming bacteria, which occur widely in soils of tropics and subtropics.

Culture: May replace cowpea where drought can be expected during the growing season. Planted in rows, on a well prepared seedbed, at the beginning of the rainy season. Early weed control is essential. Responds to animal manures placed in furrows below the seed, probably because of the available minerals present in such manures. Contributes to residual soil nitrogen to benefit the following crop.

2. Lablab (hyacinth bean, bonavista bean) - Dolichos lablab, Lablab niger

Description: This species has considerable diversity in plant types. It is related to the horse gram, with which it may be hybridized. It is a robust, twining type of plant, with a long growing season. Begins seed production from early blooms in three to four months, and may continue for extended periods. Grown widely throughout the tropics and subtropics as a green vegetable, for ripe seeds, and for livestock feed, and green manuring. About 2,200 seeds per kg.

Climatic Adaptation: Succeeds in regions of over 600 mm. rainfall yearly, but yields increase with higher rainfall. Requires warm weather for normal growth.

Soil Adaptation: Adapted to wide range of soil conditions, as to fertility and acidity; and is tolerant of flooding. Responds to phosphates where soils are deficient. Animal manures placed in furrows below plant rows usually enhances yields substantially.

Culture: This multipurpose crop has excellent value for human food as green beans and ripe seed. The variety selected should be one proven to be adapted to local climatic conditions. Seeding rate is about 22 kg/ha. in rows. When grown in rotation with maize or sorghum, has strong green manuring value. After seed harvest, the crop may be grazed in place, without reducing the contribution to soil nitrogen for the following crop. Seed yields from repeated pickings may amount to 800 kg/ha., under favorable cultural practices. Contributes to residual soil nitrogen to benefit the following crop.

3. Jack bean - Canavalia ensiformis

Description: Grown locally in the West Indies, tropical America, Africa and Asia. It is a fast growing, erect to twining, annual reaching heights of 60 - 120 cm. Leaves are trifoliate, dark green and shiny, 10 - 20 cm. long. Flowers are red to white, borne in racemes, producing linear pods with 10 to 30 seeds. Varieties used for food have seeds of various sizes and colors. Some forms of the species are toxic and are not suitable for food. Long cooking of edible types is practiced to preclude toxicity. The crop is resistant to most diseases and insect pests.

Climatic Adaptation: Successful in warm regions of moderate to variable rainfall. Intolerant of cool weather.

Soil Adaptation: Drought resistant, particularly on deep soils where deep rooting draws on stored soil moisture. Tolerant of wide range of soil types, and levels of soil fertility, including water-logging and salinity.

Culture: The crop contributes strongly to residual soil nitrogen supplies when inoculated with compatible strains of nodule-forming bacteria. Plant on well prepared seedbed at beginning of rainy season. Responds to phosphates on deficient soils; also to animal manures placed in furrow below plant row. The available minerals contained in manureare believed important. Yielding capacity probably equal to cowpeas on fertile soils; but succeeds where cowpeas are not adapted.

4. Cluster bean (guar) - Cyamopsis tetragonoloba (C. psoralioides)

Description: This is a warm season annual, erect, herbaceous plant, with varieties ranging from one to two meters tall, pubescent trifoliate leaves, and purplish flowers. Has long leathery pods. Used for green manuring and for forage, as well as a high protein food grain legume. Grown widely in drier regions of tropics and subtropics. Resistant to diseases; particularly cotton root rot that is often prevalent in cotton growing regions.

Seed size: 44,000 per kg.

Climatic Adaptation: Thrives in hot climates of uncertain rainfall. After seedling establishment, survives periods of moisture deficit, and resumes growth and development when rains recur. Suffers from pests in humid climates.

Soil Adaptation: Tolerant of wide range of soil conditions, including salinity. Drought resistant, but intolerant of waterlogging. Responds to phosphate fertilizers wherever soils are deficient.

Culture: Seeds require inoculation with compatible strains of root-nodule bacteria when grown on land not previously cropped to guar. Plant on well prepared seedbed, at beginning of rainy season. Substantial contribution to soil nitrogen for following crop, when healthy crop of guar is grown.

Seeding rate broadcast: 22 - 44 kg/ha.; seeded in rows at one-half that rate.

5. Grass pea - Lathyrus sativus (Chickling vetch)

Description: Annual, mostly under 30 inches in height (75 cm.), erect pubescent and herbaceous plants, three leaflets and one tendril per leaf, solitary flowers, pods 2½ - 3½ cm. in length, long and flat, with a few white seeds. About 11,000 seeds per kg.

Some strains are reputed to be free of toxic alkaloids and safe for fo_. Long cooking practiced to reduce toxicity, where this species is the principal reliance because of ability to produce a crop when other legumes fail (viz. India and Pakistan). Grown as a winter annual, or cool season crop.

Climatic Adaptation: Adapted to cooler periods in the tropics and subtropics, completing growth before onset of high temperatures. Prefers moderate rainfall, but tolerates considerable drought.

Soil Adaptation: Prefers fertile loam soils, but makes substantial growth on sandy soils and soils of low fertility. Tolerates wet soils, and some salinity or soil acidity. Responsive to phosphates on deficient soils.

Culture: Seed should be inoculated with a compatible strain of root-nodule bacteria, when crop is grown on land not recently planted to this species. Inoculated crops produce substantial soil nitrogen for use by the following crop. Plant at start of cooler season at rate of 22 kg/ha. when broadcast. Usually grown where lentils and chickpeas are undependable because of limited moisture, or unfavorable soils. Rarely grown as a main crop.

6. White sweet lupine - Lupinus albus

Description: Most species of lupines contain toxic alkaloids, but there are non-toxic (sweet) strains that are suitable for human food. The sweet white lupine strains are the most widely grown of the edible types of lupines, principally as a cool season crop in the subtropics and tropics. They have a useful place as a food crop at higher altitudes in the tropics, for those areas with moderate to good rainfall in the cooler season. This is an upright herbaceous annual, with rather coarse stems, with digitate (fingerlike) leaflets, and large showy flowers. Pods two to four inches long (5 - 10 cm.), hairy, with white seeds.

Seed size: 65,000 seeds per kg.

Climatic Adaptation: Prefers cooler weather, with well distributed rainfall. Tolerates light frosts. Rather intolerant of sustained higher temperatures.

Soil Adaptation: Prefers soils of at least moderate fertility, neutral to low soil acidity, that are well drained. May be grown on sandy soils when mineral deficiencies are corrected, particularly phosphates.

Culture: Grown for food at higher altitudes in the tropics, and regions of winter rainfall in the subtropics. Plant at beginning of the cooler moist season on well prepared seedbed, using seed inoculated with compatible strains of nodule-forming bacteria. Average seeding rate in rows 45 - 65 kg/ha. Planting depth 2 - 5 cm. Only the varieties known to be non-toxic should be grown. Of these, the specific strains tested and found to be high yielding in the locality should be used. Contributes residual soil nitrogen to benefit the following crop.

7. Goa bean, (winged bean) - Psophocarpus tetragonolobus

Description: An unusual species that is rich in oil as well as protein, in which all parts of the plant, including the fleshy roots, have a high protein content. This species is reported to have a higher nitrogen-fixing capacity than other legumes, as a result of abundant nodulation of the root system. It is a twining, glabrous perennial herb, usually grown as an annual. Numerous roots, some being long horizontal laterals becoming thick and tuberous. Annual stems, leaves trifoliate, broadly ovate; florets, showy flowers white to pale blue; pods 15 - 30 cm long with 4 longitudinal ridges, containing 8 -17 seeds of various colors, up to 1 cm long.

Climatic Adaptation: Thrives in hot, wet climates, but tolerates dry seasons up to 3 months by becoming dormant, and producting new stems with onset of rain.

Soil Adaptation: Adapted to many soils of humid tropics, provided they are well drained. Does not tolerate soil waterlogging.

Culture: Grown mostly for family subsistence, on stakes or trellises to provide leaf exposure on twining stems. Highest grain yields from plant spacing 60 x 60 cm. = 570 kg/ha, in experimental plantings. At present the crop is grown for its high protein roots, and green seeds, and high protein forage for livestock. The oil extracted from ripe seeds has desirable chemical properties. All parts of the plant are edible, nutritious and high in protein. Breeding for growth habits to facilitate harvest of seed, without sacrifice of grain yields and high protein content, is needed to make this a satisfactory industrial crop.

8. Tepary bean - Phaseolus acutifolius

Description: A short season annual, slender, slightly pubescent, bushy under adverse conditions but twining with favorable weather and soils, leaflets broad but pointed, small white or violet flowers, pods five to eight cm. long with sharp beaks, small seeds of various colors. Apparently native to U.S. Southwest and and adjoining Mexico where it has long been grown by Indians as a very drought resistant food crop. Outyields all other food grain legumes under droughty conditions. Somewhat harder to cook and less palatable than field beans and cowpeas but high in protein and nutritious. White seeds are somewhat smaller than navy beans, which they resemble.

Climatic Adaptation: Well adapted to hot subhumid-semiarid climates, with short season of rainfall. Tolerates considerable heat and drought and produces substantial grain yields.

Soil Adaptation: Comparatively deep rooted on permeable soils; tolerates some salinity, but intolerant of soil waterlogging. Responds to relatively high soil mineral content, particularly phosphates.

Culture: Plant at beginning of rainy season, using seed inoculated with compatible strain of nodule bacteria, unless land has recently grown this crop. Phosphates and other minerals needed to correct soil deficiencies, should be placed in furrow at least one inch below seed. Animal manures may be added with phosphates. Seeding rate; 11 kg/ha. Control of weeds is essential to conserve moisture for the bean crop. Under dryland conditions, outyields other food grain legumes. Contributes residual soil nitrogen to benefit the following crop.

9. Lima bean - Phaseolus lunatus

Description: There are several distinct types of lima beans; large seeded and small seeded, bush and pole types, as well as annual and short-lived perennials. Seed color may vary widely but whitish seeds are comercially preferred. Varieties may be pubescent or glabrous, and have smaller or larger trifoliate long leaves. Flowers are small and white. Pods are five to eight cm. long, flat and broad, seeds flat, variable as to plumpness. The varieties breed true, but natural hybridization often occurs, requiring continued selection to maintain varietal purity.

Climatic Adaptation: Prefers moderate rainfall, intolerant of droughts. Thrives in warm weather; but protracted hot, humid periods are conducive to disease attacks.

Soil Adaptation: Best suited to permeable, well drained soils of moderate fertility. Not as well rooted as field beans, and less drought tolerant. Responds to phosphate fertilizer.

Culture: Grown for harvest as green seeds, or as ripe seeds. Flavor and texture of seeds differ from beans and other food grain legumes, with significant market demand for limas. Nutritional values are equal to other food grain legumes. Planted at beginning of season of adequate rains, in hills or rows, at depth of about 5 cm., on well prepared seedbed, fertilized to correct soil deficiencies. Seeding rate 45 - 65 kg/ha. Seed should be inoculated with compatible strains of nodule-forming bacteria, to eliminate need for nitrogen fertilizer. Early weed control is essential to higher yields. Ripe seed harvest should be prompt to avoid seed shattering. Pod ripening is irregular, requiring several pickings to save all seeds. Contributes residual soil nitrogen to benefit the following crop.

10. Scarlet runner bean - Phaseolus multiflorus

Description: Potentially a perennial, but usually grown for food as an annual. Tall twining plants, requiring support for normal growth. Long leaflets (3); many flowered, scarlet and showy; pods 10 - 30 cm. long, plump, many seeded, mostly blackish with red markings. Varieties differ as to response to long days, short days, or insensitive to length of day, giving rise to specific regional adaptation of varieties. Planting of varieties must recognize seasonal rainfall to coincide with length of day preference.

Climatic Adaptation: Prefers continuously warm weather, with well distributed rainfall. Shorter season, rapidly developing varieties are required for regions with shorter rainy seasons. Only moderately tolerant of moisture deficiencies.

Soil Adaptation: Prefers permeable deep soils of moderate fertility, well drained. Independent of soil nitrogen supply when plants are well inoculated with nodule-forming bacteria. Responds to phosphates and sensitive to soil deficiencies in calcium, magnesium and sulfur.

Culture: Grown as a green vegetable (pods and seeds) and for ripe seed. Plant at beginning of normal rainy season, in hills or rows, with staking to support the vining plants. (A non-climbing, white seeded type is reported). Weed control during early growth is essential. Flowering and seed ripening are indeterminate, requiring repeated pickings to harvest the crop. Information is limited on grain yield, but it is believed to be equal or greater than vining types of field beans. Resistance to bean pests in humid climates is reported to be higher than for field and garden beans, but comparisons between improved varieties of both species are not documented. Contributes residual soil nitrogen to benefit the following crop.

11. Adzuki bean - Vigna angularis

Description: This is a bushy, erect annual of Chinese origin, grown extensively in the Far East and to a limited extent in Argentina, Paraguay and southernUnited States. Varieties range from 12 to 30 inches tall (30 - 75 cm.). Trifoliate leaves, leaflets ovate, flowers yellow,borne in clusters on short stems, cylindrical pods up to 12 cm. long, constricted between seeds, 6 to 10 seeds per pod, oblong, squared on the ends, in many colors. Regional adaptation in the Far East roughly parallels the soybean. The seed is rich in protein, but unlike the soybean, the oil content is low. Orientals use it as a protein supplement to rice and other starchy foods.

Climatic Adaptation: Requires warm temperatures for normal growth; production in summer season of subtropics. Moderate, well distributed rainfall, is favorable for growth. Not particularly drought tolerant.

Soil Adaptation: Thrives in permeable, well drained soils, with substantial water-holding capacity. Independent of soil nitrogen when seed is inoculated with compatible strains of nodule-forming bacteria. Responds to phosphates and other minerals that may be deficient in soil.

Culture: Grown primarily as a crop for home consumption, but marketed comercially in some regions. Planting should be made at beginning of warm season when rainfall permits prompt germination. Seeding rate 22 kg/ha. in rows. Depth no greater than needed for prompt germination. Fertilizer should be placed in bands below seed row, about two to five cm. of soil between seed and fertilizer. Comparative yields with other food grain legumes not available. Contributes residual soil nitrogen to benefit the following crop.

12. Rice bean, moth bean - Vigna calcaratus, V. aconitifolius

Description: Distinguished by leaflets being divided into three to five narrow lobes. Trailing hairy annual 30 - 60 cm. tall, small yellow flowers in clusters, pods 2 to 5 cm. long, nearly cylindrical, 5 - 7 very small seeds, oblong and somewhat rounded at the ends, various colors. It is a short-lived species, growing in warm regions of India, the Far East, South America, and southern United States. In various countries, grown after rice harvest as a seed crop. About 22,000 seeds per kg.

Climatic Adaptation: Requires warm weather, and moderate rainfall, or liberal soil moisture, as following irrigated rice. Intolerant of cold and drought.

Soil Adaptation: Well suited to alluvial soils, particularly after irrigated rice, utilizing residual soil moisture. Favored by moderate to good soil fertility, but independent of soil nitrogen when seed inoculated with compatible strains of nodule-forming bacteria.

Culture: Greatest use is as a following crop after irrigated rice is harvested, to utilize residual soil moisture, without further irrigatio Also suited to role of second crop in rainfed agriculture, where soil fertility and moisture permits a useful high protein food crop, to supplement diets that are rich in starchy components (rice, root crops, etc.) Grown primarily for subsistence, or local marketing, but suited for wider commercial sale where higher yields result in lower production costs per unit of beans. Seeding rate broadcast - 75 kg/ha. Contributes residual soil nitrogen to benefit the following crop.

13. Catjang bean - Vigna unguiculata (V. cylindrica)

Description: This is a distinct type of the cowpea species, being an erect, bushy plant, with uptilted pods, 6 - 8 cm. long. Leaves are hoe-shaped, flowers blue - purple to white, variable seed size (average 6,500/kg.) various colors, seed coat wrinkled or smooth. It is a relatively short-season crop, 55 - 90 days from planting to maturity, and it is insensitive to day length; i.e., life period is not influenced by length of day.

Climatic Adaptation: A warm weather crop, grown primarily under humid conditions. Shorter season varieties may be grown in regions with a shorter rainy season. Intolerant of cold but somewhat drought tolerant.

Soil Adaptation: Grows on a wide range of soils; from sandy soils to heavy clay soils. Tolerates infertile and acid soils better than most major food grain legumes, when plants are well nodulated to supply adequate nitrogen. Requires good soil drainage.

Culture: Grown both as a major crop, and as a second crop following harvest of a main crop. Plant soon after onset of rainy season on well prepared seedbed. Responds to phosphate fertilizer placed in bands below plant rows. Seeding rate 33 kg/ha. in rows. Useful as a high protein crop in regions where principal foodstuffs are starchy, low protein types (cereals, root crops, plantain). Contributes residual soil nitrogen to benefit the following crop.

14. Yard long bean - Vigna unguiculata (V. sequipedalis) (Asparagus bean)

Description: This is a distinct type of the cowpea species. It is a strong, long-running glabrous annual, leaflets 7 - 13 cm. long, violet to white flowers, very long, cylindrical pods up to three feet (1 meter), rather thick and fleshy, kidney shaped seeds about 1¼ cm. long. Mostly brown in color. The long pods and long seeds are distinctive. The crop is native to Central Africa, but is grown in warm climates on all continents.

Climatic Adaptation: Requires warm weather and moderate humidity, but tolerates combined high humidity and temperature better than most food grain legumes; similar to cowpeas in this respect. Intolerant of cold, but tolerates some drought.

Soil Adaptation: Similar to cowpeas - grows on a wide range of soils from sandy to heavy clays when well drained; tolerates relatively low fertility when plants are well-nodulated with nitrogen-fixing bacteria, and not sensitive to soil acidity. Responds to phosphate fertilizer placed in bands under the plant row.

Culture: Current use is primarily as a subsistence crop grown for its high protein content, and desirable palatability. The vining plants require staking, and the indeterminate flowering and fruiting requires periodic hand harvest that is feasible for subsistence type culture. However, yields are high under such close attention, and less land is required than for bushy type plants. As a legume, it does not need nitrogen fertilizer. Except for the requirement to provide support for trailing plants, culture is similar to that for cowpeas. Contributes residual soil nitrogen to benefit the following crop.

16. Bambarra nut - Voandzeia subterranea

Description: This is a groundnut, native to Africa, that somewhat resembles the groundnut (peanut) Arachis hypogaea, but does not contain significant amounts of oil. Bambarra nut is unique in having a very specific requirement for a strain of nodule-forming bacteria, unlike those of other legumes. It is a low-growing plant, with both bushy and trailing forms, that bear their fruits in pods below the surface of the ground. The leaves have three smooth leaflets. The number of seeds per pod varies according to the fertility of the soil, and the variety of the species. Seeds are hard, with wide variety of colors. Growth periods range from three to five months. The crop is remarkably free of insect pests and diseases both in the field and in storage.

Climatic Adaptation: Requires high temperatures and abundant sunshine for optimum growth. Prefers moderate to abundant rainfall, except at harvest time.

Soil Adaptation: One of the better legumes for low fertility soils, including sandy and sandy loam soils. Sandy soils also facilitate digging the pods. Bambarra nuts will respond to high fertility, particularly phosphates. Requires inoculation with compatible strain of nodule-bacteria to produce satisfactory yields. Good soil drainage is essential.

Culture: Grown as a food grain legume; rich in protein. Fills same role in cropping as groundnuts, but higher yields than groundnuts on low fertility soils. Cultural practices are similar to groundnuts. Varieties should be those that will mature by the end of the rainy season. Prompt harvest at maturity is recommended, and seed should be thoroughly dried before storage to avoid molding. Contributes residual soil nitrogen to benefit the following crop.

Green Manure Legumes

The following legume species has been reported as successful green manure species for the tropics and subtropics, when effectively innoculated with nodule-forming bacteria. The residual nitrogen derived from growing the green manure crop, may range from 40 to 100 lbs. per acre (44 - 110 kg/ha), depending on the vigor of the green manure crop, and the length of the growth period.

The following species are palatable and nontoxic to livestock, and may be grazed after full growth is made, without serious reduction in nitrogen contributions.

Common Name	Botanical Name
1. Alyce clover	1. Alysicarpus vaginalis
2. Beggarweed, tick clover	2. Desmodium tortuosum; D. gangeticum
3. Crotalaria species	3. C intermedia, C. lanceolata
4. Guar	4. Cyamopsis tetragonoloba (C. psoralioides)
5. Lablab	5. Dolichos lablab, D. uniflorus
6 Hairy Indigo	6. Indigofera hirsutus
7. Vetchling, grass pea	7. Lathyrus hirsutus, L. sativus
8. Lupines	8. Lupinus angustifolius (sweet type) Lupinus luteus (sweet type)
9. Serradella	9. Ornithopus sativus
10. Sesbania	10. Sesbania aculeata, S. exaltata
11. Velvet bean	11. Stizolobium deeringianum
12. Berseem	12. Trifolium alexandrinum
13. Fenugreek	13. Trigonella foenum-graecum
14. Cowpeas, forage type	14. Vigna unguiculata (V. sinensis)
15. Mungbean, forage type	15. Vigna radiatus (V. aureus, V. mungo)

Within each of these species there are many varieties that may differ widely in growth habits, and in adaptation to soil and climatic conditions. Growers are advised to select varieties that have been field tested under local conditions and found to be high yielding and resistant to insect pests and diseases.

For further information on legumes see Technical Series Bulletin No. 12, "The Contribution of Legumes to Continuously Productive Agricultural Systems for the Tropics and Sub-Tropics".

1. Alyce clover - Alysicarpus vaginalis

Description: Native of Asia. A perennial, often grown as a warm season annual for green manure and pasture. Spreading, erect type plant, reaching height of one meter. Leaves are unifoliate, oval on short leaf stalks. Seed shatters profusely, and crop may volunteer in subsequent years from initial planting. Seed size: 660,000 per kg.

Climatic Adaptation: Requires warm weather for rapid growth.

Soil Adaptation: Prefers fertile, well drained soils. Intolerant of soil waterlogging.

Culture: Seeded at about 11 kg/ha. When grown for green manure, may be grazed in place after reaching full growth without reducing contribution of nitrogen to the soil. When forage is cut and fed green to livestock, green manure value is reduced by about one-half. Forage is palatable and nutritious. Plants will make re-growth, if cut 10 cm. above ground level.

2. Beggarweed, tick clover - Desmodium tortuosum; D. gangeticum

Description: Beggarweed, tick trefoil - Desmodium tortuosum, ("Florida" beggarweed) is native to tropics and subtropics of the Americas, grown also in sections of Africa for forage and green manure. D. gangetica is grown widely in south Asia for green manuare and for forage. Both species are warm season annuals, that have upright growth one to two meters, herbaceous, pubescent plants, trifoliate large ovate leaflets, seeds borne in long slender segmented pods that soon break into single seed sections at maturity, pods covered with fine hooked hairs that stick firmly to clothing and to hair and fur of animals, fostering natural spread. Abundant seeders.

Climatic Adaptation: D. tortuosum fruits more readily with shorter days but makes vegetative growth in all warm seasons. Both species flourish at warm temperatures and well distributed rainfall.

Soil Adaptation: Both species are adapted to acid soils, but respond to higher levels of fertility. Phosphate fertilizers are useful. Resistant to tropical root nematodes.

Culture: Readily established by broadcast seeding. Full cover provided with 10 kg. of hulled seed per ha., or 30 kg. of unhulled seed per ha. Makes rapid growth, either when interplanted in standing crops when they reach full height, to continue growth after crop harvest; or when planted immediately after main crop is harvested. Natural inoculation with compatible root-nodule bacteria occurs on land where the crop has been grown; but inoculated seed should be sown on all lands where Desmodium has not previously been grown. Excellent contributions to residual soil nitrogen have been made by the time the beggarweed reaches one meter, or has begun to bloom. At that stage the crop may be grazed in place by livestock without reduction in green manure value. Removal of top growth for feeding livestock will reduce green manure value to the land by about one-half.

3. Crotalaria- Crotalaria species; C. intermedia, C. lanceolata

Description: These two species are non-toxic to livestock. They are erect annuals with coarse, profusely branched stems. Plants generally leafy, with showy yellow flowers, and set seed freely. Seed color varies from yellow to brown and black. C. intermedia has 220,000 seeds per kg. C lanceolata has 375,000 seeds per kg.

Climatic Adaptation: Tropical species, but also grown in warm season of subtropics. Prefers moderate to abundant rainfall.

Soil Adaptation: Both species grow well on poor, acid soils; and generally are not attacked by root nematodes.

Culture: Grown mainly for green manure and for soil cover. These species are palatable and non-toxic to livestock, which is useful where the crop is to be grazed. When fully grown crops are grazed in place, the green manure value is not reduced. When cut and fed green, at least half of the nitrogen supplying power of the green manure crop is removed. By interplanting between rows of a main crop that is approaching full development, the growing period for Crotalaria is considerably extended, and the contribution to soil nitrogen is enhanced. Seeding rates: C. intermedia - 11 kg/ha. C. lanceolata - 9 kg/ha.

4. Guar - Cyamopsis tetragonoloba (C. psoralioides)

Description: Annual erect herb, one to two meters tall, grown widely in India, Pakistan, Indonesia and elsewhere in the tropics and subtropics. Resistant to cotton root rot disease. There are numerous distinct varieties. About 45,000 seeds per kg.

Climatic Adaptation: Requires warm weather during the growing season. Tolerates drought; somewhat susceptible to pests in moist climates.

Soil Adaptation: Wide soil adaptation, similar to cowpea, but intolerant of soil waterlogging. Apparently deep-rooted, and drought tolerant.

Culture: Useful green manuring crop in dry climates, but may also be used for forage or for seed. If grazed in place, this should be done when plants begin to flower; so that there is little reduction in total contribution to soil nitrogen. If forage is removed, the nitrogen contribution may be only one-half to one-third that provided by plowing under top growth. Seeding rate: for broadcast seeding - 11 - 33 kg/ha. If planted in rows, reduce seeding rates by one-half to two thirds.

5. Lablab - Dolichos species; D. lablab, D. uniflorus

Description: Tropical (Africa, Asia) annual herbaceous plants, 30 - 45 cm. high. Twining, succulent, usually prostrate or partly erect, and normally having long runners. 3,000 seeds per kg.

Climatic Adaptation: Warm season crop; prefers moderate rainfall. Wide adaptation to climate.

Soil Adaptation: Drought resistant. Suited to sandy or shallow soils, but grows well on many soil types, if not strongly alkaline. Responds to phosphates.

Culture: Suitable for green manuring, and for forage. Lablab is sometimes allowed to mature and seed harvested, then grazed, and the land is then tilled for seedbed preparation of following crop. The green manure value is not diminished by this system. When harvested forage is removed, the green manuring value (contribution to soil nitrogen) is reduced. Interplanting between rows of a main crop after plants are full height, increases the length of growing season available to lablab. Seeding rate: 6 to 22 kg/ha.

6. Hairy indigo - Indigofera hirsuta

Description: This is a climbing annual, with heavy foliage on fine stems. A related species - I. pilosa is used by Ceylon farmers as green manure for paddy (rice). This species is non-toxic to livestock. Leaves silky or hairy with purple flowers. 440,000 seeds per kg.

Climatic Adaptation: Requires warm weather; moderate rainfall. Rapid grower under these conditions.

Soil Adaptation: Thrives on moderately poor sandy soils; with little lime. Tolerates some drought.

Culture: Well suited to green manuring, and for forage. Resistant to root knot and most pests. Good seed producer, and will volunteer when once introduced into a field. Delayed interplanting with a main crop, extends growing period of hairy indigo. Well grown crop may be grazed without significant reduction of green manuring value (soil nitrogen contribution). When forage is removed for feeding, the green manuring value may be reduced by one-half or more.

Seeding rate: about 9 kg/ha.

7. Lathyrus - Lathyrus species; L.hirsutus - vetchling, rough pea; L. sativus - chickling vetch, grass pea

Description: These are annuals, weak stems, trailing, reaching heights of 45 cm. Leaves with one pair slender leaflets, terminating in a coiled tendril. Good seed producers.

L. hirsutus has about 33,000 seeds per kg. L. sativus has larger seed.

Climatic Adaptation: Both species are grown in the cooler seasons of tropical and subtropical climates. Moderate rainfall preferred.

Soil Adaptation: Wide soil tolerances from acid to alkaline. Grows on sandy soils as well as less fertile soils. However, responds to phosphate fertilizers.

Culture: Primary value is for green manuring, or forage for livestock. (The food value of L. sativus seed is questionable because of toxicity). The usage is primarily limited to the cooler season of the subtropics. The green manuring values are good, and the nutritive value of the forage is often important. Grazing of the crop when the flowering stage is reached, does not reduce the soil nitrogen contributions. Removal of forage during the growth period will reduce the green manuring value by one-half to two-thirds.

Seeding rates: L. hirsutus - broadcast at 35 - 55 kg/ha.
L. sativus - has larger seed and requires heavier seeding rates.

8. Lupines - Lupinus species; L.angustifolius - sweet varieties of blue lupines; L. luteus - yellow lupine (low alkaloid type)

Description: The sweet varieties of blue lupines, and the low alkaloid types of yellow lupines, are cool season annuals that are palatable to livestock, as well as being important green manure crops when effectively inoculated with nodule-forming bacteria. The growth habit is bushy, about 60 cm. high. Seed size is about 5,500 per kg. for blue lupines, and 8,800 per kg. for yellow lupines.

Climatic Adaptation: Best suited to winter rainfall type of climate, with moderate rainfall. Tolerates cooler weather but grows most rapidly in warmer weather.

Soil Adaptation: Blue lupines prefer soils of moderate fertility, but yellow lupines are adapted to sandy, moderately acid soils of low fertility. Neither species is strongly drought tolerant.

Culture: Primary value is for green manuring, when it can be interplanted in the main crop, or planted between two summer crops as a catch crop to utilize available soil moisture. Lupines may be grazed down to the ground, prior to seedbed preparation for the following main crop, but should not be grazed during the growing period. Removal of the top growth at any time greatly reduces the green manuring value of the crop, but grazing at end of the growing season does not reduce value. Seeding rate is about 55 kg/ha.

9. Serradella - Ornithopus sativus

Description: This is a cool season annual, semi-vining growth habit, similar in appearance to the vetches. It is native to Spain and Morocco but not widely grown elsewhere.

There are about 350,000 seeds per kg.

Climatic Adaptation: Prefers cooler seasons (subtropics, or high altitudes of tropics), without prolonged dry season. Completes growth rapidly with onset of warm weather.

Soil Adaptation: Adapted to moist sandy soils, tolerant of some soil acidity and low fertility. Not drought tolerant.

Culture: Useful as a catch crop during the cooler season, following a summer grown main crop, to provide soil cover and serve as a green manure crop. It is palatable to livestock, and may be grazed in place at the end of the growing season, prior to seedbed preparation of the following main crop. When used in this fashion, the green manure value is not reduced since livestock manure is left on the land. Removal of the green crop during the growing season greatly reduces the green manure value.

Seeding rate is about 17 kg/ha.

10. Sesbania - Sesbania species; S. aculeata - native of India; S. exaltata (S.macrocarpa) southern U.S.

Description: These are annual species grown in warm seasons for green manuring. They are tall, branching herbaceous species, that seed profusely. Yellow flowers borne in racemes arising from leaf axils, later producing long slender pods. S. exaltata - 44,000 seeds per kg. S. aculeata has somewhat larger seeds. Sesbania plants form nodules even when grown in water.

Climatic Adaptation: Makes rapid growth in warm weather; not tolerant of cold. Prefers moderate to abundant rainfall (or irrigation) but dry atmosphere.

Soil Adaptation: Commonly found in rice fields, and is adapted to wet areas and heavy soils. Tolerant of alkalinity in irrigated soils. Continues rapid growth when irrigation ceases, to utilize available soil moisture.

Culture: Reported to be rather unpalatable to cattle, but not rated as toxic. Interplanting in main crop when full height reached, or as a catch crop for turning under as green manure crop in preparation of seedbed for seedbed for following crop.

Seeding rate 22 kg/ha. for S. exaltata; and 33 kg/ha. for S. aculeata. Excellent accumulation of fixed nitrogen as a green manure, when seed is inoculated with compatible strains of rhizobium bacteria.

11. Velvet bean - *Stizolobium deeringianum*

Description: A warm season annual with long vigorous trailing vines up to 25 feet (8 meters). Large trifoliate leaves, white to purple flowers in long pendant clusters. Pods are either covered with black or greyish white hairs. Pods 5 - 15 cm. long and contain 3 - 6 seeds. Seeds must be handpicked. Many varieties, some produce seed in three months; but crop can be grazed or plowed under any time after three months with strong contribution to soil fertility. 2,200 seeds per kg. This species is generally free of diseases and insect pests.

Climatic Adaptation: Requires warm weather and moderate rainfall for vigorous growth.

Soil Adaptation: Well adapted to less fertile soils, including sandier soil types. Makes poor growth on cold, wet soils.

Culture: Large seeds; but rapid spreading growth soon provides complete ground cover even when thinly planted. Highly palatable to livestock. May be grazed or plowed under after about three months growth, with excellent benefits as green manure crop.

Seeding rate: 22 kg/ha. Must be seeded at least 3 - 5 cm. deep to cover seed for prompt germination. Suitable for interplanting in maize or sorghum after crop reaches full height.

12. Berseem - Trifolium alexandrinum

Description: This is an annual grown widely in the subtropical regions of winter rainfall. Plant growth 30 - 60 cm. but may be cut repeatedly after full height is made. Branched stems, long leaflets, whitish flowers, in dense clusters. Important crop in Egypt and Middle East.

Seed size: 2 million seeds per kg.

Climatic Adaptation: Thrives in cooler weather of subtropics (and higher elevations in tropics), but is not tolerant of frost. Grows without irrigation in winter, but requires rainfall or irrigation when grown in warmer weather. Requires rainfall of at least 250 mm. during the growing season for satisfactory growth.

Soil Adaptation: Tolerant of relatively high salt concentration and may be grown on alkaline soils. Grows best on heavy loams, but also on light soils with adequate moisture. Responsive to phosphate fertilizer, and to lime where soils are deficient.

Culture: Since berseem produces regrowth rapidly when cut at full height, it may serve both as a green manure and a forage crop. Produces two to three cuts under natural rainfall, but may yield seven to eight cuts under irrigation. If irrigated 10 days before cutting, makes quick recovery after defoliation. Unique characteristic is the high nitrogen fixation (green manuring effect) even when top growth removed for forage.

Seeding rate: 6 kg/ha. Shallow planting is necessary

13. Fenugreek - Trigonella foenum graecum

Description: This is an annual herbaceous plant, grown for forage and as green manure in the Mediterranean countries, the Middle East, India and other parts of the tropics. It may be grown both as a winter crop, and as a summer crop, depending on the climate. The plant is single stemmed, pubescent, reaching height of 30 - 60 cm. with whitish flowers, and long slender pods. Completes life cycle in about three to four months.

Approximately 55,000 seeds per kg.

Climatic Adaptation: Grows well in cooler seasons, with or without irrigation. Not heat or drought tolerant.

Soil Adaptation: Wide soil adaptation, but not tolerant of waterlogged soils. Produces well on soils of rather low fertility.

Culture: As a green manure crop, it should be allowed to make growth up to the blooming stage for maximum nitrogen fixation. At this stage it may be grazed without loss of green manuring value; but if forage is removed, the nitrogen left in the soil is reduced by at least one-half. The forage has high protein and nutritive value. Fenugreek may be interplanted in a main crop without loss in yields, as a catch-crop to utilize short periods when soil moisture is available for quick growth.

Seeding rate: 20 - 30 kg/ha.

14. Cowpeas (forage type) - Vigna unguiculata (V. sinensis)

Description: The forage type of cowpea tends to be viny in growth habit, making strong vegetative growth, with somewhat longer growth period than seed types of varieties. The cowpea is a warm season annual, herbaceous, leafy, without hairs or pubescence. The flowers are white or purple, borne in pairs on short stalks; pods are smooth, 20 - 30 cm. long, cylindrical and somewhat curved, seeds generally are bean shaped but with ends somewhat flattened. Seed color varies with variety or strain. (6,600 to 8,800 seeds per kg.).

Climatic Adaptation: Prefers warm weather, moderate to abundant rainfall. Shorter season varieties maturing in three months or somewhat longer may be grown in regions of limited rainfall, during the short season when soil moisture is adequate. Grows well in warm humid climates. Sensitive to cool weather and frost.

Soil Adaptation: Very wide soil adaptation, grows satisfactorily on sandy soils as well as on clays. Tolerates acid and infertile soils. Requires good soil drainage. Seed should be inoculated with compatible strains of root-nodule bacteria.

Culture: May be grown as interplanted crop in maize, sorghum, etc., seeded when grain crop is full height; so that growth of cowpeas does not compete strongly for soil moisture. Seed requirement is 35 - 45 kg/ha. for a full stand; seed covered to insure prompt germination. Cowpeas may be grazed after blooming begins. Removal of forage greatly reduces contribution of the green manure crop to soil fertility. If not grazed, the top growth should be plowed under.

15. Mung beans (forage type) - Vigna radiata (V. aureus, Mung), (formerly, Phaseolus aureus, and P. mungo)

Description: The forage types are more vegetative in growth habit than grain types, and tend to have longer growing season before blooming begins. The growth habit is generally erect and bushy. Leaves, stems, and pods are hairy. The type termed V. aureus is taller than V. mungo, but there are wide differences between varieties in each group. The more vegetative types are those proposed for green manuring. Mung beans are native to India and Southeast Asia, but the crop is also grown sporadically through tropical Africa. There are about 25,000 seeds per kg.

Climatic Adaptation: Requires warm weather, and moderate to good rainfall. After establishment, the crop survives considerable drought. Short-season varieties are more tolerant of moisture deficits than longer season type.

Soil Adaptation: Wide adaptation to soils, both upland types, and alluvial irrigated soils.

Culture: The green manuring types may be planted immediately after harvest of rice, or interplanted between rows of maize and sorghum after the crop reaches full height. The crop is useful for forage, but for green manuring purposes, the mung bean should either be grazed in place, or plowed under. When forage is removed, the green manuring value is sharply reduced.

Seeding rate is 10 kg/ha.

Major Forage Legumes for Improved Grazing Lands and Forage Harvest in the Tropics and Sub-Tropics

Common Name	Botanical Name
1. Calopo	1. Calopogonium mucunoides
2. Centro	2. Centrosema pubescens
3. Dwarf koa	3. Desmanthus virgatus
4. Greenleaf desmodium	4. Desmodium intortum
5. Silverleaf desmodium	5. Desmodium uncinatum
6. Lablab	6. Dolichos lablab
7. Glycine	7. Glycine wightii (G. javanica)
8. Leucaena	8. Leucaena leucocephala
9. Lotononis	9. Lotononis bainesii
10. Lucerne (alfalfa)	10. Medicago sativa
11. Siratro	11. Phaseolus atropurpureus
12. Phaseybean	12. Phaseolus lathyroides
13. Puero (kudzu)	13. Pueraria phaseoloides
14. Stylo (Brazilian lucerne)	14. Stylosanthes guyanensis
15. Townsville lucerne	15. Stylosanthes humilis

These legume species are perennials (except no. 15 is a reseeding annual) that are productive when effectively innoculated with nodule-forming bacteria. They are rich in protein and highly nutritious to livestock. They are usually grown in mixture with compatible forage grasses.

These legumes are strong nitrogen fixers; records of 200 to 500 lbs. per acre (220-550 kg/ha) of residual soil nitrogen per year have been reported. Such contributions to soil nitrogen are highly important when a seeding of forage legumes is made as part of a crop rotation to maintain soil productivity.

There are distinct varieties of each of these species. Growers are advised to plant those varieties that have been field tested and found to be well adapted to local soil and climatic conditions.

For further information on the use of perennial forage legumes see Technical Series Bulletin No. 13, "Seeded Forages for Grazing and for Harvested Feeds in the Tropics and Sub-Tropics".

The Role of Seeded Forages in Productive Agricultural Systems for the Tropics and Sub-Tropics

The effective use of seeded perennial forage legumes and grasses offers great promise in improving the productivity of tropical agriculture. The opportunities include both the arable lands now used for crop production, and the non-arable lands that include the extensive native grasslands, and the land areas not suited for cropping that are intermingled with those cropped. The latter are generally used for communal grazing of village flocks. This bulletin undertakes to collect useful information on each forage legume and grass species that have been reported as being productive in the tropics and sub-tropics. The information is fragmentary, but this report may stimulate publication of data not yet in printed form.

In the developed countries of the world - Western Europe, North America, Australia, Japan, etc., the production of forages from seeded plantings, on natural grasslands, and on improved permanent grazing lands, is recognized as a significant component of more productive agriculture. There is reason to believe that these benefits in developed countries may also be widely applicable to the less developed countries of the tropics and sub-tropics. Enough has been done in various tropical and sub-tropical regions to illustrate some of the basic principles and practices, to support an optimistic approach.

Seed Characteristics and Adaptive Features of Forage Legumes

Species	Approximate Seed Quality		Seed Size		Seeding Rates		Minimum Yearly Rainfall		Tolerance	
	Min. Germination	Min. Purity	Number Seeds lb. In thousands	Kg.	Acre	Ha.	in.	mm.	to Drought	to So Water Loggi
					lbs.	Kg.				
1. Calopo	85%	50%	33	73	1 to 3	1 to 3	50	1250	fair	fair
2. Centro	90	50	18	40	1 to 6	1 to 6	40	1000	fair	good
3. Dwarf Koa	(80)	(70)	(20)	(40)	(2)	(2)	20	500	good	poor
4. Greenleaf Desmodium	90	50	375	755	1 to 2	1 to 2	35	875	fair	good
5. Glycine	90	50	70	154	2 to 5	2 to 5	30	750	good	poor
6. Lablab	90	50	2½	5	5 to 20	5 to 20	40	1000	good	fair
7. Leucaena	90	50	12	26	4 to 6	4 to 6	25	625	good	poor
8. Lotononis	90	50	1600	3500	¼ to 1	¼ to 1	35	875	fair	good
9. Lucerne	90	80	200	440	½ to 5	½ to 5	25	625	good	poor
10. Phasey bean	90	70	56	125	1 to 3	1 to 3	30	750	good	good
11. Puero	90	50	37	81	1 to 3	1 to 3	50	1250	poor	good
12. Silverleaf Desmodium	90	50	95	210	1 to 3	1 to 3	40	1000	fair	fair
13. Siratro	90	50	36	79	1 to 3	1 to 3	40	1000	good	fair
14. Stylo	90	40	160	350	2 to 5	2 to 5	35	875	good	fair
15. Townsville lucerne	90	40	200	440	2 to 3	2 to 3	25	625	good	poor

*Figures in parentheses are estimates

Forage Legume Species for the Tropics and Subtropics

1. Calopo: Calopogonium mucunoides

Description: A short lived perennial from tropical South America. It has trailing or climbing stems covered with long hairs, rusty brown on young shoots; oval leaflets; blue flowers in 2 to 4 flowered bunches in axils of leaves or in racemes on long hairy stalks; brown seed pods with 2 to 4 seeds. Seeds freely and regenerates naturally from seed.

Climatic adaptation: Adapted principally to warmer regions with rainfall above 50 inches (1275 mm). Moderately shade tolerant.

Soil adaptation: Grows well on newly cleared lands.

Uses: Rapidly established, grows well in mixtures with tall, tropical grasses, including elephant grass, and tolerates moderately heavy grazing. Produces dense mat of foliage if ungrazed.

2. **Centro: *Centrosema pubescens***

Description: Perennial; produces long trailing stems, rooting moderately at the nodes, capable of extending 10 feet or more in a single growing season. Produces a dense mat of foliage, or climbs strongly on coarse grasses. Trifoliate leaves, pea type flowers, dark brown pods, 5 inches in length, containing up to 20 brownish black seeds. Specific in its requirement for adapted strains of nodule-forming bacteria.

Climatic adaptation: Prefers humid conditions - over 50 inches rainfall, but not less than 40 inches (about 1000 mm.) yearly. Prefers warm temperatures, but survives frost (at higher altitudes and latitudes). Tolerates limited shade as seedlings, but competes strongly with tall forage grasses.

Soil adaptation: Will grow on acid soils, but prefers medium fertility soils. Responds well to superphosphate, and to minor nutrient elements where these are deficient. Tolerates seasonal flooding, on alluvial soils.

Uses: Grown in mixtures with grasses (guinea grass, elephant grass, and other tall grasses), for grazing, or for harvest, as green feed. Has high mineral and protein content, as feed for livestock. Seeding rate - 1 to 4 lbs. per acre (1 to 5 kg per hectare).

3. Dwarf Koa: Desmanthus virgatus

Description: An upright, dwarf, bushy perennial native to tropical and subtropical America, where rainfall is limited. Characterized by good potential for reseeding in natural stands. (Although many species of native legumes are found in semi-arid and dry savanna grasslands, little attention has been given to commercial seed production of any of these, and there is scant information on suitable management practices.)

Climatic adaptation: Adapted to tropics and to low altitude sub-tropics having rainfall of 20 inches (500 mm) and above. It is more drought tolerant than huaxin (Leucaena leucocaphala), a taller species of similar plant type.

Soil adaptation: Apparently adapted to wide range of soils occurring in semi-arid and dry savanna ecological zones.

Uses: Useful for both grazing and harvested forage in regions of limited rainfall. It is somewhat woody but quite palatable. The woody stems have the advantage of permitting survival during periods of occasional overgrazing, and making quick recovery when rains occur. Used for fodder, grazing, soil cover, and green manuring in Hawaii, Mauritius, West Indies, and Indonesia.

4. Glycine: Glycine wightii (formerly, Glycine javanica)

Description: Trailing perennial, widespread in tropical Africa and Asia. Long stems root at the nodes. Broad leaflets, finely hairy underneath. Small white flowers, and short pods (1-2 inches), dark brown-black, with small seeds. Deep rooted, and more drought tolerant than centro or desmodiums.

Climatic adaptation: Prefers warm climate, but useful in subtropics where good growth continues in cool season. Only moderate in shade tolerance. Continues growth into dry season because of deep rooting habit.

Soil adaptation: More demanding of fertile, well drained soils than other tropical legumes (not as exacting as lucerne). It has a high demand for phosphate, potash, and lime, but will grow on a wide rang of soils where fertility is improved. Not suited to strongly acid soils, nor where waterlogging occurs.

Uses: Resistant to many pests, but must be protected from heavy grazing. Grows well in mixtures with grasses (especially green panic) Seed at 2-4 lbs per acre (2.2 to 4.5 kg/ha), and inoculate with specific strain of rhizobium bacteria. Tinaroo, Clarence, and Cooper varieties used in Australia. Rich in protein and mineral content, and excellent forage for cattle.

5. Greenleaf desmodium: Desmodium intortum

Description: A trailing perennial, originated in Central America. Coarse thick stems that root freely at nodes. Leaves finely hairy, with characteristic reddish-brown to purple flecking on upper surface. Flower racemes lilac to pink. Curved pods. Small seed. Competes strongly with tall grasses.

Climatic adaptation: Adapted to humid regions; long growth period where moisture and temperatures are favorable. Survives some frost (at higher altitudes and elevations). Rainfall - 40 inches (about 1000 mm) per year and higher.

Soil adaptation: Very versatile as to soil requirements. Tolerates waterlogging, but makes excellent growth on grey sands to yellow clay soils and red loams. Tolerant of acid soils and does not require liming. Most responsive to phosphate, and molybdenum where soils are deficient; and fixes large quantities of nitrogen when roots are well inoculated with specific rhizobium bacteria.

Uses: Combines well with vigorous pasture grasses; setaria sphacelata guinea grass, green panic, molasses grass, and others. Seeding rates ½ to 2 lbs. per acre. Seed inoculation with specific rhizobium bacteria is necessary. Forage is rich in protein and minerals, making excellent feed. Cattle feed readily on leaves and shoots, and gain weight well.

6. Lablab: Dolichos lablab

Description: Short lived perennial (up to 4 years), or annual, with many cultural forms. Native of the Old World tropics. The white seeded types are used as human food. Forage types have long trailing stems, with very large leaves, white flowers, and large heavy pods.

Climatic adaptation: Grown in areas with 25 or more inches of rainfall (about 635 mm), and is relatively drought resistant. Prefers tropical temperatures.

Soil adaptation: Grows on a wide range of soils (similar to cowpeas), including acid soils. Responds well to superphosphate. Not tolerant of water-logged soils.

Uses: Suitable for grazing, or harvest and green feed. Protect from overgrazing; remove stock when leaves consumed. May displace cowpeas as forage because of drought resistance, longer growing season, perennial habit, and resistance to pests. Large seeds require 10-15 lbs. per acre (10-15 kg/ha) planted alone, and 1/3 as much in mixture with forage grasses.

7. Leucaena: Leucaena leucocephala (L. glauca)

Description: Native to Central America, perennial, shrubby plant, deep rooted. Some varieties grew quite tall. Leaves are bipinnate, narrow leaflets, the yellow and white flowers borne in ball-like clusters, long brown pods. Extensive distribution of buds on stems, and so become shrubs under continued grazing (browse). Heavy seed production. Contains the alkaloid mimosine which causes shedding of wool in sheep, and hair in horses, but not toxic to cattle. Open canopy permits light penetration to lower growing grasses. Also known as "hawain".

Climatic adaptation: Grown successfully with 25-60 inches (600-1500 mm) rainfall. Tolerates drought when plants well established, and retains green leaves in dry seasons. Semi-dormant at lower temperatures, thrives at higher temperatures.

Soil adaptation: Prefers well drained soils, grows on wide range of soils with little response to fertilizers, after establishment. Thus, adapted to low soil fertility level.

Uses: Grows well in mixtures with guinea grass and similar tall grasses. Should be grazed or pruned to stimulate branching and to keep tops at about 3-4 feet. Cattle make excellent gains and milk flow on this high protein nutritious forage. Establish stands by planting seed inoculated with specific strain of rhizobium in rows 2.5 - 4.0 meters apart, about 5 kg. seed per ha. (4-5 lbs/acre), using 375 kg. molybdenized superphosphate/ha (300 lbs/a) as a starter fertilizer. Plant grass between rows.

8. **Lotononis: Lotononis bainesii**

Description: Creeping perennial, native to southern Africa. Only recently recognized as valuable forage legume, after especially adapted strain of root nodule bacteria was discovered. Slender, smooth, soft plants with low stems that root at the joints. Highly palatable to grazing stock; and must be protected from excessive grazing, to permit rooting of stems. Resistant to most diseases and insect pests. Small trifoliate leaves, yellow flowers in open racemes, and very small seed.

Climatic adaptation: Prefers moist environments, but grown in regions of 35 inches (890 mm) rainfall or more, where evaporation rates are modest (windward coastal regions). The most frost tolerant of all tropical forage legumes.

Soil adaptation: It is tolerant of waterlogging, poor drainage, and flooding. It grows on very acid soils, but responds to fertilization. It thrives on a wide range of soil textures, but may not root at joints of the creeping stems on very tight soils.

Uses: One of the very few legumes that grows well in a mixture with pangola grass, but it succeeds also in mixtures with other tall and short forage grasses. Useful as pasture and for harvested green feed. Moderate grazing permits continued rooting of creeping stems. Very high quality feed, in protein and minerals, superior digestibility. New seedings at ¼ to 1 lb per acre, (¼ to 1 kg/ha) on firm seedbed.

9. **Lucerne: Medicago sativa**

Description: Native of Middle East, long cultivated [illegible] through temperate, subtropical and tropical zones of world. Deep long-lived perennial producing many stems from basal crown, with new crop of shoots starting when top growth removed at blooming. Very deep rooted on well drained permeable soils. Trifoliate leaves, herbaceous stems, violet colored flowers, spineless curled pods, 2-6 seeds each. Plant produces a low-set crown after first cutting.

Climatic adaptation: Prefers low humidity, but grows best with rainfall of 30 to 60 inches yearly (750-1500 mm). Susceptible to leaf diseases in periods of high humidity. The "non-hardy" Peruvian and Arabian types well suited to irrigation agriculture in tropical and subtropical regions.

Soil adaptation: Prefers deep, well drained soils, non-acid, with abundant of phosphate, potash potash, calcium, and magnesium. Also, grown successfully on less fertile soils when limed to pH above 6.0, and adequately fertilized with phosphate and potash.

Uses: Major use as hay, or green feed, alone or in mixture with grass. Lucerne capable of producing 6 to 10 cuttings per year under irrigation, or 4 to 6 cuttings under abundant rainfall. Periodic short-term grazing feasible, but will not survive continued grazing. Seed on firm but mellow seed bed, using inoculated seed @12-15 lbs/acre (13-16 kg/ha), planted shallow. First harvest at full bloom, and successive harvests at early bloom stage.

10. Phasey bean: Phaseolus lathyroides

Description: A self-generating annual or biennial; native to India. An erect plant which develops long twining stems, reaching heights of 3 to 4 ft (90-110 cm). Leaflets-3, smooth, oval. Red to purple flowers, giving rise to cylindrical pods that shatter violently when ripe. Little basal branching of stems.

Climatic adaptation: Requires over 30" rainfall (750 mm). Annual in subtropical regions; biennial in tropics.

Soil adaptation: Prefers soils of good mineral content, heavy textured. Susceptible to nematodes on light textured soils. Fairly tolerant of occasional waterlogging.

Uses: Compatible with para grass, and scrobic grass. Produces nutritious pasturage. Grazing practices must permit seed production of phasey bean, to ensure natural regeneration yearly. Siratro and desmodium may be included in mixtures where phasey bean does not regenerate regularly.

11. Puero: Pueraria phaseoloides

Description: Pioneering perennial legume, native to East Indies. Climbing plant, spreading by vigorous runners up to 25 feet (8-9 meters) in length. Forms dense, smothering mat except where grazed or cut frequently. Leaflets large, round and hairy. Large pale bluish purple flowers, cylindrical seed pods about 5 inches (13 cm) in length. Seed pods mature irregularly. Rapid seedling growth. Also known as kudzu.

Climatic adaptation: Prefers abundant rainfall, and warm conditions, but survives fairly long dry seasons by virtue of deep rooting. Less cold tolerant than Glycine wightii.

Soil adaptation: Grows well on newly cleared forest lands. Tolerant of acid soils, but responds to phosphate fertilizers. Endures occasional waterlogging.

Uses: Palatable, rich in protein, useful in mixtures on new land. Rapid seedling growth permits early grazing. Intermittent grazing, or harvest for green feed, essential to maintenance of stands. Seeded in mixtures at 1 to 3 lbs per acre (1-3 kg/ha).

12. Silverleaf desmodium: Desmodium uncinatum

Description: Perennial trailing legume, native to area from West Indies to Brazil. Rather coarse hairy plants, distinguished by broad, irregular silver band along the midrib. Flowers pale lilac-pink and produce pods with dense, hooked hairs which stick to man and beast. This facilitates spread of the species.

Climatic adaptation: Similar to greenleaf desmodium. Adapted throughout the tropics and warmer subtropics, wherever rainfall is above 40 inches (about 1000 mm) yearly. Tolerates light shading and thus competes well with taller grasses.

Soil adaptation: Similar to greenleaf desmodium. Tolerant of some waterlogging, and of acid soils. Responsive to phosphates. Has capacity to extract copper from soils low in this element.

Uses: Perennial pastures in mixtures with taller grasses, and for harvested green feed. Seeding rates of 1 to 2 lbs. per acre (1-2 kg/ha). Seed inoculation with specific rhizobium bacteria is necessary. Forage is rich in protein and minerals. Cattle graze it readily, and weight gains are good.

13. Siratro: Phaseolus atropurpureus

Description: A native to Central and South America, the cultivated type was bred in Australia from Mexican stocks. A perennial that spreads by creeping stems. Leaves broad and lobed, green on upper surface and silvery grey fine hairs on lower surface. Flowers are dark red, and produce pods about 3 inches (7.5 cm) long with large seeds (twice the size of Glycine). May be propagated by planting rooted joints of creeping stems. The most hardy of tropical forage legumes. Deep, well developed root system.

Climatic adaptation: Prefers a moist warm climate, tolerates high temperatures. Persistent growth in dry seasons. Best development with 35-70 inches (900-1800 mm) yearly rainfall.

Soil adaptation: Adapted to wide range of soil conditions, including shallow and hillside soils. Responds to phosphates, and to correction of other deficiencies (incl. molybdenum) in mineral nutrients, but less exacting than glycine or lucerne.

Uses: Excels as permanent pasture legume in mixtures with Rhodes grass and other shorter tropical grasses (setaria, guinea grass, green panic, etc.). Prefers moderate intensity of grazing, both intermittent and continuous. Seed at 2 lbs (900 gms) per acre, at ¼ to 1 inch depth (1¼ to 2 mm). Plants nodulate well, but seed inoculation recommended. Produces nutritious forage high in protein and mineral content.

14. **Stylo: Stylosanthes guyanensis**

Description: Perennial legume, native in Brazil. Erect shrubby growth, reaching height of 5 feet (150 cm), when ungrazed. Stems coarse and hairy, trifoliate leaves long and pointed, small yellow flowers, small seed pods with 1 seed, about ½ larger than lucerne seed. Well developed root system. Not sensitive to 2,4-D herbicide, permitting easier control of broad-leafed weeds in pastures. Suited for periodic mowing for hay, and moderate grazing.

Climatic adaptation: Grows well in true tropics. Fairly drought resistant, but also grows successfully in high rainfall areas. Requires protection from grazing in seedling stage, to develop root system tolerant of drought.

Soil adaptation: Succeeds on wide range of soils, but responsive to superphosphate. Sensitive to copper deficiency in soil, and probably to other minor mineral nutrients. Grows on acid soils and somewhat tolerant of poorly drained conditions. Useful on soils of low fertility.

Uses: Not tolerant of shade, and grows best in mixtures with short grasses, such as green panic, guinea grass, pangola, brachiaria, etc. Makes good hay. Grazed successfully after haying. Prefer stocking rates heavy enough to prevent accumulation of dense thicket of fibrous stems. New plantings require inoculated seed to insure good root nodulation. Seed at 2 lbs per acre (2 kg/ha) in mixture with grasses, planted shallow. Nutritious feed.

16. Townsville lucerne: *Stylosanthes humilis*

Description: Reseeding annual or biennial, native to tropical America, but an accidental importation to Australia about 1900, where it has become an important pasture and forage plant. Low growing plant with narrow fibrous stems; trifoliate leaves, narrow, elongated and pointed; small flowers; seed grouped together in small balls; each seed grooved, with stiff, hooked bristle on one end, that facilitates spread. Plants variable in vigor, density of tillering, and other characters.

Climatic adaptation: Survives and reproduces in rainy periods of climates that have no more than 25 inches rainfall per year (600 mm), by virtue of yearly reseeding, but also successful up to 50-60 inches rainfall (1200-1500 mm). Thrives at high temperatures. Intolerant of shade.

Soil adaptation: Prefers good drainage, but thrives on wide range of soils. Tolerant of acid, infertile soils but responsive to phosphates. Sensitive to soil copper deficiency. Intolerant of soil waterlogging. Notable as a poor soil legume.

Uses: Excellent pasture and hay, in mixtures with short growing grasses, such as buffel and birdwood. Management systems of mixed swards must suppress grass to permit annual reseeding and growth of this legume. Highly nutritious and palatable to livestock. Surface seeding at 2-3 lbs per acre (2-3 kg/ha) is successful in established sod, with soil scarification and grazing intensity to hold grass in check for seedling development.

Section V - A

Perennial Forage Grasses for the Tropics and Subtropics

Species propagated by seed.

1. Alabang grass - Dicanthium caricosum
2. Angleton grass - Dicanthium aristatum
3. Bahia grass - Paspalum notatum
4. Bermuda grass - Cynodon dactylon
5. Birdwood grass - Cenchrus setigerus
6. Blue panic grass - Panicum antidotale
7. Buffel grass - Cenchrus ciliaris
8. Carib grass - Eriochloa polystachya
9. Dallis grass - Paspalum dilatatum
10. Green panic grass - Panicum maximum trichoglume
11. Guinea grass - Panicum maximum
12. Harding grass - Phalaris tuberosa, var. stenoptera
13. Love grass (weeping) - Eragrostis curvula
    (a. Boehr lovegrass - Eragrostis chloromelas)
    (b. Lehmann lovegrass - Eragrostis lehmanniana)
14. Makarikari grass - Panicum coloratum makarikariense
15. Molasses grass - Melinis minutiflora
16. Pigeon grass - Setaria sphacelata
17. Plicatulum grass- Paspalum plicatulum
18. Rhodes grass - Chloris gayana
19. Scrobic grass - Paspalum commersonii
20. Yellow bluestem - Bothriochloa ischaemum

For further information on legumes see Technical Series Bulletin No. 10, "The Contribution of Legumes to Continuously Productive Agricultural Systems for the Tropics and Sub-Tropics".

Seed Characteristics and Adaptive Features of Forage Grasses

Grass Species	Seed Quality		Seed Size		Seeding Rate		Minimum Yearly Rainfall		Tolerance	
	Min. Germination %	Min. Purity %	Number per lb. In thousands	Kg.	per Acre lbs.	per Ha. Kg.	in.	mm.	to Drought	to Soil Water Logging
Alabang grass	34	23	*	*	18	20	40	1600	fair	fair
Angleton grass	34	23	*	*	18	20	40	1600	good	good
Bahia grass	50	70	150	336	4 to 6	4 to 7	50	1250	poor	good
Bermuda grass	20	80	1900	4000	6 to 8	7 to 9	30	750	good	poor
Birdwood grass	30	80	80	175	½ to 2	½ to 2	10	250	very good	poor
Blue panic grass	50	80	650	1430	1 to 3	½ to 3	20	500	very good	fair
Buffel grass	30	80	200	440	½ to 4	½ to 4	10	250	very good	poor
Carib grass	30	20	*	*	18	20	40	1000	poor	good
Dallis grass	50	70	220	485	6 to 10	7 to 11	35	875	fair	good
Green panic grass	35	60	880	1900	½ to 6	½ to 7	25	625	good	fair
Guinea grass	35	40	1100	2400	2 to 6	2 to 6	35	875	fair	fair
Harding grass	60	90	300	660	2 to 4	2 to 4	30	750	good	good
Love grass, weeping	80	90	1500	3300	½ to 1	½ to 1	10	250	very good	poor
Love grass, Lehmann	80	90	6800	14950	¼ to ½	½ to 1	10	250	very good	poor
Makarikari grass	30	90	725	1600	1½ to 3	1½ to 3	20	500	very good	good
Molasses grass	30	(60)	6000	13200	2 to 4	2 to 4	40	1000	fair	fair
Pigeon grass	30	90	600	660	2 to 5	2 to 5	35	875	fair	good
Plicatulum grass	30	55	385	850	2 to 4	2 to 4	30	750	good	good
Rhodes grass	30	90	1750	3850	½ to 6	½ to 6	35	875	good	fair
Scrobic grass	30	95	170	375	2 to 5	2 to 5	35	875	fair	good
Yellow bluestem	20	25	1400	3000	1 to 2	1 to 2	20	500	good	poor

NOTE: figures in parentheses are estimates.

* Usually propagated vegetatively from nurseries planted to seed

Forage Grasses Propagated by Seed

1. Alabang grass: Dicanthium caricosum

Description: Also known as Nadi bluegrass, and Antigua haygrass. Tufted grass, spreads by creeping stems rooting at nodes. Flowering stems 30 to 60 cm tall (12-24 inches). Propagated by seed; good seed producer. Reported in Far East, India, West Indies, and South Pacific Islands.

Climatic adaptation: Adapted to tropical and subtropical regions with summer rainfall. Withstands considerable periods of drought, but makes little growth in dry weather. Well suited to regions with 400-800 mm rainfall (15-30 inches) yearly.

Soil Adaptation: Grows well on clay soils with good internal drainage, on undulating topography. Succeeds on wide range of soil alkalinity and acidity, and various levels of fertility (phosphates), and salt content.

Utilization: Useful for both pasture and hay. Withstands close grazing, and makes good quality hay. Compatible with legume stylo (Stylosanthes gracilis), centro, greenleaf desmodium, glycine.

2. Angleton grass: Dicanthium aristatum

Description: Decumbent, branching perennial, spreading by long runners. Propagation by seed, or by vegetative planting of pieces of runners.

Climatic adaptation: Grows well in both tropics and subtropics with moderate, well distributed rainfall. Tolerates considerable drought, but makes little growth in dry weather; adapted to 600 mm rainfall and above

Soil adaptation: Tolerant of relatively infertile soils.

Utilization: Valuable for both pasture and hay, makes open turf when heavily grazed. Combines well with stylo (Stylosanthes guyonensis), centro, greenleaf desmodium, glycine.

3. Bahia grass: Paspalum notatum

Description: Low growing, deep rooted perennial, spreading by short stout rhizomes. Forms dense turf. Culms 15 to 60 cm in height (6 to 25 in) with racemose panicle inflorescence. Pensacola variety is good seed producer. Other improved varieties are Argentine, Paraguay, Paraguay 22, Tifhi 1, Tifhi 2, and Wilmington.

Climatic Adaptation: Adapted to both tropics and subtropics by one or more varieties. Prefers moderate to abundant rainfall, but continues growth in dry season by virtue of deep root system.

Soil Adaptation: Wide soil adaptation, including sandy soils. Survives on soils of low fertility, but productivity dependent on improved fertility, and supplies of nitrogen from associated legumes, or fertilizer.

Utilization: Well adapted to grazing; makes dense sod and withstands tramping. Tends to become sod-bound and to crowd out legumes, when continuously heavily grazed. Seeding rate in mixtures, 4 to 6 lbs per acre (4 to 7 kg/ha). Periodic tillage used to partially suppress grass and open sod for planting legumes. Compatible legumes are calopo, puero, siratro, silverleaf desmodium.

4. **Bermuda grass: Cynodon dactylon**

Description: A highly variable, fine-leafed perennial spreading by stolons and rhizomes, and forming a dense turf. Flowering stems 10 to 30 cm (4 to 12 inches tall). Aggressive in tilled crops, where it is considered a serious pest. Occurs throughout tropics and subtropics. Produces seed freely, but spreads both by seed and vegetatively. Probably native to Africa.

Climatic adaptation: Makes optimum growth at temperatures above 24°C (75°F). Relatively drought resistant, but makes better growth with abundant rainfall. Not shade tolerant.

Soil adaptation: Grows on any well drained soil, and responds strongly to higher levels of fertility and adequate soil moisture.

Uses: Primarily used for grazing, but makes good quality hay when cut at beginning of flower stem elongation. However, hay yields of common bermuda are relatively low. Compatible legumes are stylo, calopo, puero, siratro, silverleaf desmodium.

Birdwood grass: Cenchrus setigerus

Description: A tufted perennial, growing to height of 2 feet (60 cm). Spreads by short rhizomes. Resembles short buffel grass. Seed has short stiff teeth, which facilitates seeding and establishment. Seeds abundantly. Rapid development from seed when moisture permits.

Climatic adaptation: Adapted to regions of low rainfall, 10 inches and above. (250 mm) occurring in summer. Makes growth mostly in season of rainfall, but survives prolonged rainless periods.

Soil adaptation: Prefers sandy or other free draining soils. Reputation for growth on infertile soils.

Utilization: A palatable forage species, particularly for sheep. Suited only for grazing. Established from seed with little tillage, because of short stiff teeth. Combines well with Townsville lucerne (Stylosanthes humilis)* Replaced by selected strains of buffel grass where yearly rainfall is 15 to 35 inches (350-750 mm).

*and dwarf koa and leuceana.

6. Blue Panic Grass: Panicum antidotale

Description: Erect, perennial bunch grass. Tall coarse plant, growing to 8 feet (240 cm) under favorable conditions. Leaves bluish in color and rather tough. Very deeply rooted, with crown developed by swollen leaf bases. Spreads by short, thick rhizomes Seed borne in open panicle. Abundant seed.

Climatic adaptation; Thrives under 20 to 30 inches rainfall (500-750 mm) in warm season. Continues growth in dry season by virtue of deep rooting, when subsoil moisture available. Ceases growth at temperatures approaching 40°F (4.5°C). but thrives at higher temperature.

Soil adaptation: Versatile in soil requirements, both sandy and clay soils, at various levels of fertility.

Utilization: Useful both for grazing, and for hay if cut before blooming. Becomes woody after blooming. Rapid regrowth after cutting. Forage palatable even though coarse. Retains vigor under heavy stocking. Compatible legumes are centro, greenleaf desmodium, glycine and stylo.

Buffel Grass: Cenchrus ciliaris

Description: Perennial quite variable in growth forms. Strong, deep root system. Short Type: W.A. is tussock type plant, fine and dense, very early flowering. Medium Height Varieties: Gayndah grows to 3½ feet (105 cm), with short underground rhizomes, leafy plants. American has fine stems and dense foliage, seed heads purplish. Cloncurry is shorter, laxer, and earlier flowering than American, with straw-colored seedheads. Tall Varities grow to 5 feet (150 cm) and spread by rhizomes. If undergrazed, produces numerous secondary shoots on main stems.

Varieties: Biloela, Nunbank, Boorara, Tarewinnabar, Molopo, Lawes. These differ in leafiness and time of flowering. All varieties tend to breed true from seed, being apomictic.

Climatic adaptation: Highly drought resistant; and resumes growth rapidly when rains occur. Successful under 12-35 inches (300-900 mm) yearly rainfall. Prefers warm climates.

Soil adaptation: Versatile in soil requirements, prefers lighter textured (sandy) soils. Does not tolerate waterlogging. Responds to higher levels of fertility.

Utilization: Suited to grazing, and taller varieties for hay. Readily established from seed. Germination improves with age. The secondary branching of seed stalks when not harvested, increases palatability by growth of these more palatable shoots. Compatible legumes are dwarf type, leucaena and Townsville lucerne.

8. Carib Grass: Trichloris pluriflora

Description: Grown in west India. Tufted perennial, 20 to 40 inches (50-100 cm) tall, spreads by runners, inflorescence is appressed racems, with pubescent spikelets in pairs.

Climatic adaptation: Requires warm climate, and moderate to abundant rainfall. Not drought resistant.

Soil adaptation: Prefers moderately fertile, moist soils, but will grow on wide range of soil fertility levels, where moisture supply is adequate.

Utilization: Palatable to both grazing and hay. Palatable, high nutritive value. Compatible with glycine as companion legumes. Grazing should not be excessive, and periods of recovery are needed after each grazing. Since seed is not abundant, often planted vegetatively.

as well as centro, greenleaf desmodium, and stylo

9. **Dallis Grass: Paspalum dilatatum**

Description: Strongly tufted, rather coarse, leafy, deeply rooted perennial. Spreads to a limited extent by short rhizomes. Wide palatable leaves. Erect stems 2-4 feet (60-120 cm) tall. Propagated from seed, produced on tall seedstalks with few leaves. Heads often attacked by ergot disease, making them unacceptable for feed.

Climatic adaptation: Natural distribution is in sub-humid subtropics; tolerates light frost. Makes growth primarily in warmer seasons.

Soil adaptation: Prefers heavier textured, well drained, relatively fertile soils, and suffers invasion by other plants when fertility declines. Responds to presence of legumes, or to nitrogen fertilizer.

Utilization: Excellent pasture when managed to prevent seed head production. Palatable, and nutritious. Good quality hay if kept vegetative without seed heads. Combines well with legumes, glycine, siratro, and greenleaf and silverleaf desmondiums. Without legumes, dallis grass tends to become sod-bound. May be rejuvenated by light tillage with application of phosphate fertilizers and overseeding with legumes.

10. Green Panic Grass: Panicum maximum trichoglume

Description: A distinctive type of Panicum maximum. A bunch grass with ascendent habit; the crown expanding by short horizontal stems, leaves fine and soft on slender stems. May reach heights of 5 or 6 feet (1½ to 2 meters). Seeds borne in open panicles. Root system deep and richly branched. Rapid growth response to light rains. Natural seedling regeneration is good. Propagated by seed.

Climatic adaptation: Good drought resistance; survives with rainfall as low as 25 inches (650 mm), but grows well with rainfall up to 70 inches (about 1800 mm), strongly shade-tolerant under trees and shrubs. Survives light frost, but adapted to tropics and subtropics.

Soil adaptation: Versatile soil adaptation, but not productive on deep sands and tight clays. Very responsive to improved fertility.

Utilization: Highly palatable and nutritious, when grazed or made into hay. Tolerates periodic heavy grazing, and regenerates quickly when rested. Combines well with phasey bean, lucerne, and glycine, as well as centro and siratro. Shallow planting necessary because of small sized seed.

11. Guinea Grass: Panicum maximum

Description: Erect perennial bunch grass native to Africa but widely distributed in all tropical and subtropical regions of South America, West Indies and south east Asia. The grass has a stool-forming habit, the plant crown enlarging by short rootstocks. Leaves are long and broad, with variable hairiness. Long seed stalks, up to 150 cm., carrying seed in open drooping panicles. Seeds are small, enclosed in hulls or glumes, which are smooth and hairless. Flowering and seed setting over a long period, with a succession of ripening panicles. Seeds shatter freely making harvest difficult. Varieties breed true, since seed formation is apomictic. Root system deep, dense and fibrous.

Climatic adaptation: Best adapted to warm regions with over 35 inches yearly rainfall (above 900 mm), but survives long droughts on deep soils because of deep rooting. Makes best growth in humid climates, but growth slows in cool weather. Shade tolerant, and competes well with tall legumes and other growth.

Soil adaptation: Adapted to wide range of soils, and most responsive to higher fertility conditions. Does not tolerate poorly drained soils.

Uses: Excellent for grazing if not grazed shorter than 6 to 9 inches (15-23 cm.) Suited for both continuous and rotational grazing. Grows well in combination with centro legume*, and maintains productivity when grown in legume mixture. Produces nutritious feed, supporting 1 cow or steer per acre (2.2 per ha.) under prudent management in humid regions. Seed may be variable in quality,

as well as calopo, silverleaf desmodium, and siratro;

11. Guinea Grass, con't.

but establishment by seeding is entirely feasible. Named varieties include: Hamil grass, Colonico guinea grass, Gatton panic. Each of these breed true, and have somewhat different plant characters and forage values.

12. **Harding Grass: *Phalaris tuberosa stenoptera*.**

Description: A perennial, with loose branching rhizomatous base, with stout leafy stems that may reach heights of 1.5 meters (55 inches). It is generally palatable at all growth stages. Seeds somewhat larger than blue panic grass (600,000 per kg.). Deep rooted on permeable soils.

Climatic adaptation: Makes excellent winter growth in subtropics and at higher altitudes of the tropics. Most productive under annual rainfall of 40 inches (1000 mm.) or more. Continues growth for several months in dry seasons following periods of rain. Tolerates some frost, but also moderately heat tolerant. Survives extended droughts.

Soil adaptation: Responsive to higher levels of fertility, but adapted to fairly wide range of soil conditions. Tolerates some waterlogging.

Uses: Useful for both grazing and hay, in mixtures with compatible legumes -- stylo, centro, siratro, etc. Makes rapid growth from seed, an advantage for seeded pastures in rotations. When grown on cobalt deficient soils, the forage may cause nutritional disorders in sheep. The addition of small amounts of cobalt to the soil, or as supplement to animal diets corrects the disorder. Generally, a nutritious forage.

13. Love Grass, weeping: Eragrostis curvula

Description: A variable, strongly tufted, deep-rooted bunch grass, forming large clumps with abundant, drooping basal leaves. Flowering stems 1 to 1.5 meters (40 to 60 inches) tall. Seeds abundantly; very small seeds. Native of East Africa. Related grasses are Boer love grass (E. chloromelas) adapted to semi-desert conditions, and Lehmann love grass (E. Lehmanniana) adapted to hot semi-desert regions. These grasses are deep rooted.

Climatic adaptation: Adapted to semi-arid and subhumid regions with summer rainfall in the tropics and subtropics, survives prolonger dry seasons.

Soil adaptation: Wide range of soil adaptation, including low-fertility and sandy soils.

Uses: For perennial grazing lands in semi-desert and subhumid regions; and also as a forage planting in tilled crop rotations of subhumid regions. Compatible with forage legumes with similar climatic adaptation, such as koa (Desmanthus virgatus),* and stylo. Useful for erosion control on low-fertility soils because of extensive fibrous root system. Palatability good during early seasonal growth; declines thereafter.

as well as leucaena, Townsville lucerne).

14. Makarikari grass: Panicum coloratum makarikariense

Description: A drought tolerant perennial, first cultivated in Bechuanaland, Africa. This species is variable as to appearance and growth habits; three of the important types are Burnet, Bambatsi and Pollock. The prevailing plant type is that of a tussocky perennial of erect to prostrate habit, with a variable amount of stolon development. Each type tends to breed true, since seed formation is largely apomictic. Makarikari panic is prostrate and strongly stolonifierous, permitting rapid spread under favorable conditions. The Burnet and Pollock varieties are commercially available. Bambatsi grass spreads very slowly and is essentially a bunch grass. It has better seed habits than the unselected Makarikari type, and seed is therefore more plentiful. All types of this species are deep rooted.

Climatic adaptation: Adapted to regions of limited rainfall; 25 inches (1000 mm.) yearly and above. Tolerates lower temperatures and thus suited to subtropical regions with winter rainfall. Also grows well in tropics having summer rainfall.

Soil adaptation: Wide adaptation to soil conditions; but most successful on deeper soils. Thrives on heavy clay soils. Tolerates seasonal flooding.

Uses: Primarily useful for grazing; on seeded pastures and on rangelands where seeding is feasible. Compatible with drought tolerant legumes, viz. stylo, greenleaf desmodium, and glycine, etc.

15. Molasses Grass: Melinis minutiflora

Description: A spreading perennial forming loose tussocks up to 1 meter (33 inches) in height. Leaves are densely covered with viscous hairs and have a pronounced molasses-like odor. The viscous characteristic is believed to prevent spread of ticks, which cannot climb grass stems to make attachment to animal hosts. The volatile oil responsible for the odor, does not taint meat or milk. Native to humid tropical Africa, but naturalized throughout world tropics. Long season of vegetative growth, culminating in flowering and seed production on small closed panicles. Seed production good.

Climatic adaptation: Adapted to warm climates with rainfall above 40 inches (1000 mm) yearly. Grows best under abundant rainfall. Intolerant of frost.

Soils adaptation: Grows well on relatively infertile soils. Does not tolerate flooding, or seasonal high water tables. Responds to phosphates, and nitrogen fertilizer or legumes.

Uses: Best suited to intermittent grazing; continued close grazing does not permit maintenance of stands. Compatible with stylo, calopo, puero, siratro and phasey bean forage legumes. Excellent yields of nutritious forage.

16. Pigeon Grass: Setaria sphacelata

Description: Sometimes called "golden timothy". A stout tufted perennial native to tropical Africa, occurring in Kenya at altitudes above 1300 meters (about 4000 ft). Variable plant types, even within named varieties, ranging from short fine-leafed bunch types to erect tall broadleafed coarse types. Named varieties are Nandi from Kenya, Kazungula from Natal Province in South Africa. The plants are deep rooted, have thick stems and abundance of leaf; and will grow up to height of 5 ft (150 cm) when left ungrazed. The inflorescence is a long spike-like panicle, which seeds profusely, spreads rapidly from self-sown seed, and by rhizomes.

Climatic adaptation: Grown successfully at higher elevations in the tropics, where rainfall exceeds 35 inches (1400 mm). Drought resistant on deeper soils. Somewhat cold tolerant (higher altitudes).

Soil adaptation: Tolerates acid soils, and some seasonal waterlogging. Responsive to higher levels of fertility, particularly nitrogen, whether from fertilizer or associated legumes.

Uses: High yielding, nutritious forage, for grazing or harvested feed. Compatible with glycine, siratro, greenleaf and silverleaf desmodiums, and lotononis. Seeding rate 2 to 5 lbs per acre (2-5 kg/ha). Prefers shallow planting at beginning of rainy season. Established grass remains green and nutritious long in dry seasons.

17. Plicatulum Grass: Paspalum plicatulum

Description: A tufted perennial, occurring naturally in tropical and subtropical America. Erect growth habit, long broad leaves, with branched panicle carried well above leaves and containing dark brown shiny seeds. Small seed -- about 400,000 per lb. (1 million per Kg). Unlike some other paspalums, it is resistant to ergot disease of the seeds. Has long vegetative growth period, culminating in seed production late in growing season. Apparently, deep rooted. Seed of two named varieties -- Rodd's Bay and Hartley is produced in Australia.

Climatic adaptation: Makes best growth in regions with more than 30 inches rainfall (750 mm.) yearly. Tolerant of drought, and of light frost, but makes most growth in warm seasons.

Soil adaptation; Persistent and productive on soils of moderate fertility. Tolerates some seasonal flooding. Responds to nitrogen, either from fertilizer, or associated legumes.

Uses: Excellent for grazing. Compatible with silverleaf and greenleaf desmodiums, and probably other legumes*, since erect leaves of plicatulum enables sunlight to penetrate readily into lower levels of the sward. Good forage production in both drier and more humid climates.

*such as stylo, centro, and glycine,

18. Rhodes Grass: Chloris gayana

Description: This is a tufted, runnering perennial native to southern and eastern Africa; now widely grown in many tropical and subtropical regions. Named varieties include Callide, Samford, and Katambora, with somewhat different palatability and adaptation. Rhodes grass is relatively fine-stemmed, leafy; and ungrazed plants may grow to heights of 4 to 5 feet (120-150 cm.). Spreads to some extent by creeping stems, but sward is sufficiently open to permit mixtures of other grasses and of legumes. Seed production is good; seed size very small. Strongly developed root system.

Climatic adaptation: Best suited to regions of 30 to 60 inches (750-1500 mm) yearly rainfall, that occurs mostly in summer. Tolerates cool temperatures of subtropical zones, when well established.

Soil Adaptation: Wide soil adaptation, but responds strongly to higher fertility levels, particularly nitrogen from either fertilizers or associated forage legumes. Somewhat tolerant of salinity.

Uses: Excellent for grazing, particularly in mixtures. Well suited for use in seeded pastures or hayland grown in rotation with tilled crops. Compatible with phasey bean, siratro and centro legumes, and also with lucerne on fertile soils. High degree of stock acceptance. Useful for erosion control. Readily established from seed, but easily controlled by tillage when grown in rotation with annual crops.

19. Scrobic Grass: Paspalum commersonii

Description: A short-lived perennial, widely distributed in the tropics. Upright succulent stems produced from broad crown. Leaves soft and palatable, and seed head largely retained within leaves. Height may reach 60 - 90 cm. (2 to 3 feet). Indeterminate habit of seed ripening makes harvest difficult but plant seeds abundantly. Often maintains stands by natural reseeding, which compensates for short life period. Somewhat resistant to ergot disease of seed, but best control is by grazing or clipping to suppress seed head production. Rather shallow rooted.

Climatic adaptation: Scrobic is essentially a summer grower, adapted to regions of summer rainfall, having more than 35 inches (900 mm. approx.) rainfall yearly. Not frost tolerant.

Soil adaptation: Prefers fertile soils; fairly tolerant of waterlogging. Best performance on alluvial bottom lands.

Uses: Suited for seeded pastures, grown in rotations with tilled crops. Compatible with siratro* and phasey bean legumes. Not as tolerant of heavy stocking as Rhodes grass or pangola, but heavy grazing is useful prior to seedbed preparation for subsequent tilled crops.

*as well as calopo, puero, silverleaf desmodium,

20. Yellow Bluestem: Bothriochloa ischaemum

Description: A perennial, semi-prostrate bunch grass, native to India. Introduced into subtropical, subhumid regions. Plants leafy. Good seed production, but harvest and cleaning complicated by light chaffy character of seed. Natural reseeding is common.

Climatic adaptation: Adapted to subhumid climates with summer-type rainfall.

Soil adaptation: Wide soil adaptation.

Uses: For grazing in subhumid regions. Scant information on compatability with forage legumes. Probable that stylo* and Townsville lucerne would be compatible. Yellow bluestem reported to be palatable and nutritious in subhumid regions.

* and greenleaf desmodium, silverlead desmodium.

B. Species propagated vegetatively.

21. African stargrass - Cynodon plectostachys
22. Cynodon Hybrids - Cynodon hybrids
23. Elephant grass (Napier grass) - Pennisetum purpureum
24. Imperial grass - Axonopus scoparius
25. Kikuyu grass - Pennisetum clandestinum
26. Palisade grass - Brachiaria brizantha
27. Pangola grass - Digitaria decumbens
28. Para grass - Brachiaria mutica
29. Signal grass - Brachiaria decumbens

For further information on the use of perennial forage legumes see Technical Series Bulletin No. 13, "Seeded Forages for Grazing and for Harvested Feeds in the Tropics and Sub-Tropics".

Vegetatively Propagated Forage Grasses

21. African Star Grass: Cynodon plectostachys

Description: Perennial with creeping stems that root well. Forms low growing dense turf with adequate rainfall. Inflorescence of 3 to 20 spikes arranged on common axis, but not digitate as in bermuda grass. Very sparse seed production; propagated mostly by planting pieces of creeping stems. More productive than bermuda grass from seed. Varieties - Naivasha and local types.

Climatic adaptation: Prefers tropical climates. Grows well at 25 inches (635 mm) annual rainfall, and above.

Soil Adaptation: Wide range of adaptation, from sands to black earths.

Utilization: Primary use is for pastures in combination with other low growing species of grasses and legumes. Tolerates close grazing by all classes livestock. Also useful for stabilizing gullies and grassing waterways to carry rainfall runoff. Compatible legumes include perennial soybean (Glycine wightii) and stylo.

22. Cynodon Hybrids

Description: Coastal and Midland are specific strains that are classed as bermuda grass types, which were bred by G. W. Burton of U. S. Department of Agriculture in Georgia, U.S.A. Coastal is a hybrid between a selected Georgia strain of bermuda grass and an introduction from South Africa. Midland is a hybrid between Coastal and a cold-hardy strain from Indiana, U.S.A. Coastal and Midland are the outstanding strains resulting from these hybridization programs. Both strains are virtually sterile, but are readily propagated vegetatively. They are high yielding, resistant to disease and nematodes, and have been widely planted through the southern tier of states in the U. S. Deep rooting habits.

Climatic Adaptation: Coastal is well adapted to humid tropics and to sub-tropical regions of low altitude, having rainfall above 40 inches (1000 mm) rainfall yearly. Midland tolerates lower temperatures and has been used effectively in an ecological zone on the northern border of the subtropics, where rainfall exceeds 1000 mm. Both strains are markedly more drought resistant than bermuda grass.

Soil Adapatation: Widely adapted to most well-drained soils; highly responsive to higher fertility, particularly nitrogen supply. Intolerant of prolonged flooding, or poor drainage.

Uses: Superior pastures under intensive management, and also productive for harvested forage. Palatable and nutritious; greatly exceeding common bermuda grass. Propagated solely by vegetative means; by labor saving practices that reduce costs of establishment to equal those of seeded bermuda. Useful in crop rotations. Compatibility with legumes not well documented; probably the following should be evaluated - calopo, silverleaf desmodium and siratro.

23. Elephant Grass (Napier Grass): Pennisetum purpureum

Description: Tall, bunch type perennial, native to tropical Africa, deeply rooted. Thick, cane-like stems. Spreads by short stout rhizomes, to form large clumps or stools, up to 40 inches (1 meter) across. Wide leaves, 1- to 1½-inches wide (2 - 3 cm), comparatively succulent. Stalks may reach 15 feet (4½ meters) if uncut. Propagated principally by stem cuttings with 2-3 nodes. Capricorn is an improved variety.

Climatic adaptation: Grows best under warm conditions, wherever yearly rainfall exceeds 40 inches (1000 mm.), strongly drought tolerant because of deep root habit, on alluvial soils. Highly responsive to irrigation.

Soil adaptation: Tolerant of wide range of soils, but does not stand flooding or waterlogging. Makes best growth on deep loamy soils, of moderate to strong fertility.

Utilization: Excellent feed if properly managed to permit a maximum height of about 4 feet (120 cm). Used for green feed, pasture, and silage. Thick stems make it unsuited for hay. Combines well with such legumes as calopo, centro, puero and glycine, when grass and legumes planted in alternate rows. For grazing, consumption by livestock is improved by periodically slashing to 6-12-inch height, to stimulate new vegetative growth.

24. Imperial Grass: Axonopus scoparius

Description: This is a densely tufted perennial grass forming large tussocks, that grow 1 to 1½ meters tall. Believed native to Central and South America. Deep rooting habit. Propagated vegetatively.

Climatic adaptation: Grows well in moist tropics and subtropics, over 40 inches (1000 mn) rainfall yearly. Tolerant of both high and low temperatures. Drought resistant on deep soils.

Soil adaptation: Best suited to deep sandy or alluvial soils. Responds to higher levels of fertility, particularly nitrogen supplies.

Use: Grown for cutting and feeding green to livestock. Does not persist well under heavy grazing. When grown with compatible legumes, yields of 100 metric tons per hectare in 4 cuts yearly have been reported. Compatible legumes include calopo, silverleaf desmodium, and siratro.

25. Kikuyu Grass: Pennisetum clandestinum

Description: A low-growing, deep rooted perennial, forming dense turf and spreading by numerous creeping rhizomes and stolons, which root at nodes, throwing up single, or more often, clustered short stout branches. Flowering stems short, scarcely raised above the ground, with the inforescence almost completely enclosed by leaves. Seeding is stimulated by close grazing or cutting off the main growing points of shoots, since these inhibit flowering. Also propagated vegetatively. Native of Kenya.

Climatic adaptation: Well adapted to elevations of 2,000 to 5,000 meters in the tropics, and to all elevations in the subtropics, where rainfall averages above 40 inches (1000 mm) yearly. Sensitive to frost, thrives at warm temperatures.

Soil adaptation: Prefers lighter textured soils of good depth and drainage. Responds well to fertile soils and use of fertilizers. Deep rooted on well-drained soils.

Uses: Primarily useful for grazing. An excellent cover to control erosion. Grows best in mixture with compatible forage legumes, such as desmodiums and glycine. Continued close grazing is less productive than intermittent grazing that permits strong regrowth of the associated legume. Provides nutritious pasturage.

26. Palisade Grass: Brachiaria brizantha

Description: Perennial, variable in plant type, rhizomatous, more or less erect, reaching heights of 1 to 2 meters. Seed production poor, propagated mostly by vegetative means (division of rootstocks). Deep rooted. Native of humid tropical Africa, but widely used in other tropical regions.

Climatic adaptation: Prefers warm humid climates, but continues growth for extended periods after rains cease. Good performance in Ceylon, humid Africa, West Indies and Central America.

Soil Adaptation: Wide adaptation, makes effective utilization of deep soils. Thrives in moist low-lying soils.

Uses: Valuable pasture grass, forming a coarse open turf when grazed. Compatible with taller forage legumes such as lotononis, phasey bean and siratro. Produces palatable, nutritious feed. Continuous growth for extended periods in dry seasons.

27. Pangola Grass: Digitaria decumbens

Description: A low-growing, creeping perennial, native to South Africa; now widely planted in Caribbean countries and in Australia. Spreads by long, trailing rooted runners, and by spreading leafy flowering stems often rooting at nodes. Plant height up to 100 cm (3 1/3 feet). Forms open turf, permitting mixtures with legumes. Identified by prominent ligule on each leaf. Very poor seed production; propagated vegetativel.

Climatic Adaptation: Flourishes with abundant rainfall; requiring more than 40 inches (1000 mm.) yearly rainfall. Growth ceases below 11°C (52°F), and during dry seasons.

Soil Adaptation: Grows well on wide range of soils; tolerates some water-logging. Responsive to nitrogen, either as fertilizer or from associated legumes.

Uses: Grows well in association with centro and lotononis legumes. Highly palatable forage for both dairy and meat animal production. Planted by spreading cuttings of stems from mowed swards, broadcast and lightly disced into seed bed, at time when rainfall abundant. Periodic (rotational) grazing needed to maintain productivity.

28. Para Grass: Brachiaria mutica

Description: A creeping perennial, apparently native to tropical Africa and Brazil. Grown extensively in swampy areas of Australia. Has trailing stems and above ground runners that root freely at nodes, from which erect shoots are produced. Hairy leaves up to 12 inch (30 cm) lengths. Root system is relatively shallow. Plant height may reach 2.5 meters (95 inches). Very poor seed production; propagated vegetatively.

Climatic adaptation: Requires abundant rainfall, over 40 inches (1000 mm). Ceases growth in dry seasons. Prefers warm weather; intolerant of cold.

Soil adaptation: Thrives on wet or waterlogged soils. Improves soil permeability on heavy soils. Responsive to fertility; particularly nitrogen from either fertilizer or associated legumes.

Uses: Widely used for cutting and feeding green, or as pasture. Compatible with centro, phasey bean, and greenleaf desmodium legumes. When well established, produces high yields of forage, and supports heavy stocking. Used on wet soils to produce abundant feed in dry seasons. Propagated by spreading cuttings on prepared seed beds and discing lightly. Spreads of 1 to 2 meters (3 to 6 ft.) in 1 year are reported. Cattle tend to treat para as a browse plant; mowing or heavy periodic grazing is needed to produce palatable forage.

29. Signal Grass: Brachiaria decumbens

Description: Trailing perennial grass with long stolons, rooting at the nodes. Spreads rapidly under favorable conditions to produce dense turf. Native of tropical Africa. Produces seed in first year of growth, but generally propagated vegetatively from cuttings or stolons.

Climatic adaptation: Prefers humid climate with no more than 4 months dry season. Not suited to subtropics.

Soil adaptation: Grows best on moist soils, and withstands some seasonal flooding. Very little growth in dry seasons.

Uses: This grass useful in rotation with tilled crops to improve soil porosity of heavy soils and increase crop rooting depth. Also, excellent perennial pasture, particularly when grown in mixture with forage legumes, such as stylo*. Periodic close grazing or mowing may be needed to maintain herbage in palatable condition.

* as well as calopo, silverleaf desmodium, and siratro.