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UNDERSTANDING LEGUME CROPS

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Betsey Eisendrath as editor, Suzanne Brooks handling typesetting and layout, and Margaret Crouch as project manager.

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VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers.

UNDERSTANDING LEGUMES

by VITA Volunteer Carl S. Hoveland

I. INTRODUCTION

The two groups of plants of greatest importance to world agriculture are grasses (such as maize, wheat, rice, sorghum, pearl millet, sugar cane, and forage grasses) and legumes (such as peas, beans, soybeans, alfalfa, clovers, cowpeas). Legumes are extremely important because of the high nutritive quality of the seeds for human and animal food and of the entire plant for ruminant animal feed, and because of their ability to fix atmospheric nitrogen in a form usable by plants, thus reducing the need for nitrogen fertilizer.

Legumes were grown by ancient civilizations in China, Europe, the Middle East, and Central and South America. However, it was not until the late 1800s in Germany that it was understood how bacteria growing in association with legumes could accomplish the remarkable task of collecting atmospheric nitrogen and making it available for other growing plants.

Legumes are used mainly as

o grains for human and animal food;

o forage for cattle, sheep, camels, goats and rabbits;

o oilseeds (especially soybeans and peanuts); and

o green manure to improve the yield of other crops in rotation systems.

Although legumes are widely grown throughout the world, there is a great opportunity for expanded usage, especially in the tropics and subtropics where nitrogen fertilizer is lacking and protein deficiency is a serious problem in human and animal populations.

The legume family name, Leguminosae, is derived from the term legume, which is the name of the fruit (often called a pod) characteristic of this group of plants. A legume is a fruit that contains a single row of seeds and breaks open along the ribs of

the pod. Legumes may be annuals (completing their life cycle in one year) or perennials. Legume species vary greatly in other respects. Leaves may be compound or simple. Stems vary in length, size, branching, and woodiness. Most legumes have tap-roots. Most, but not all, have nitrogen-fixing bacteria associated with their roots. Flowers, often brightly colored, also vary, but the most common type has five petals on each flower.

The flowers are often clustered in dense heads as on white or red clover. Figure 1 shows the leaves, flower structure, and fruit

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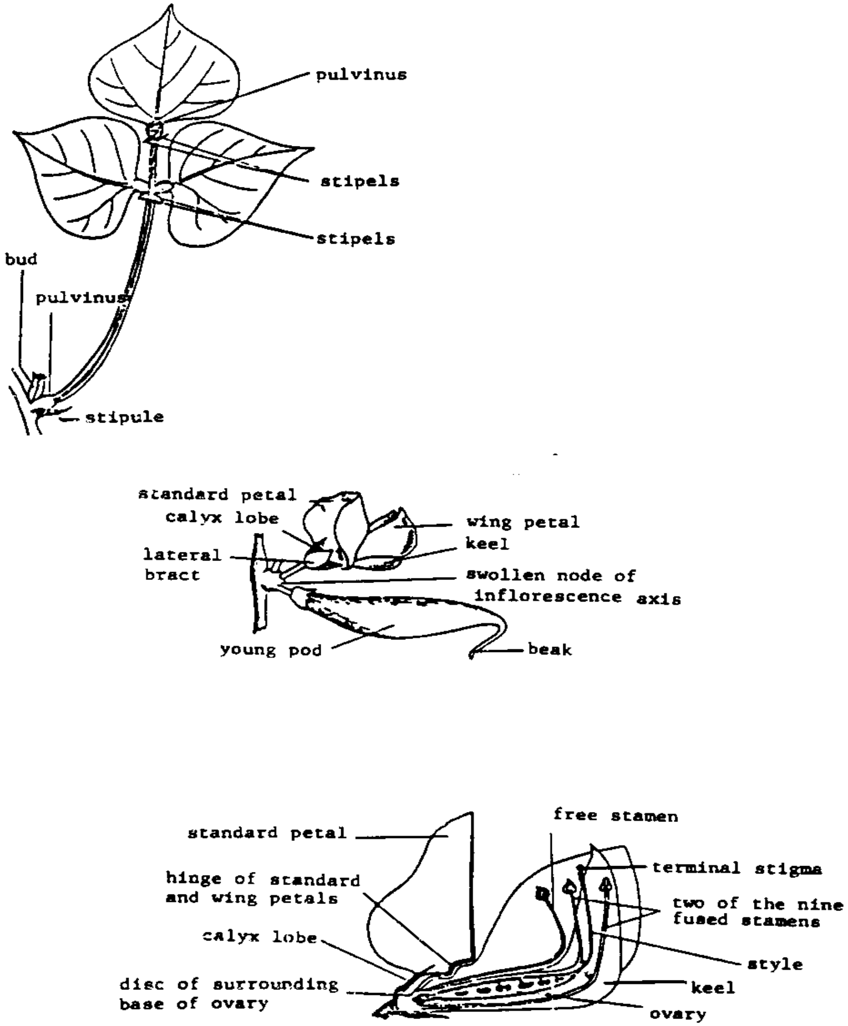

Figure 1. Hyacinth Bean (Dolichos lablab)

Source: Cobley, Leslie S., An Introduction to the Botany of Tropical Crops. New York: Longman, Green and Company, 1956, p. 147.

pod of the hyacinth bean (Dolichos lablab), a common legume.

There are over 11,000 species of legumes in the world. They include tropical shrubs (indigo), trees (locust and mesquite), vines (kudzu), and herbs (clover and vetch). Most of the economically important cool season legumes, such as clovers, peas, lupines, vetch, and alfalfa, originated in the Mediterranean and Middle Eastern area. Soybeans, lespedeza, velvet bean, and adzuki bean are native to China. A number of pulses such as pigeon pea, guar, winged bean, and mung bean are native to Southeast Asia. Cowpeas and hyacinth bean are native to Africa. Peanut or groundnut, lima and common bean, centro, tick clover, stylo, and many other tropical legumes are native to Central and South America.

NITROGEN FIXATION

Most legumes have the unique capacity to fix atmospheric nitrogen and make it available for plant growth. Bacteria of the genus Rhizobium infect the root hairs of legume seedlings, causing the formation of a swelling on the root. This swelling is called a nodule. The process is shown in Figure 2. The nodule bacteria

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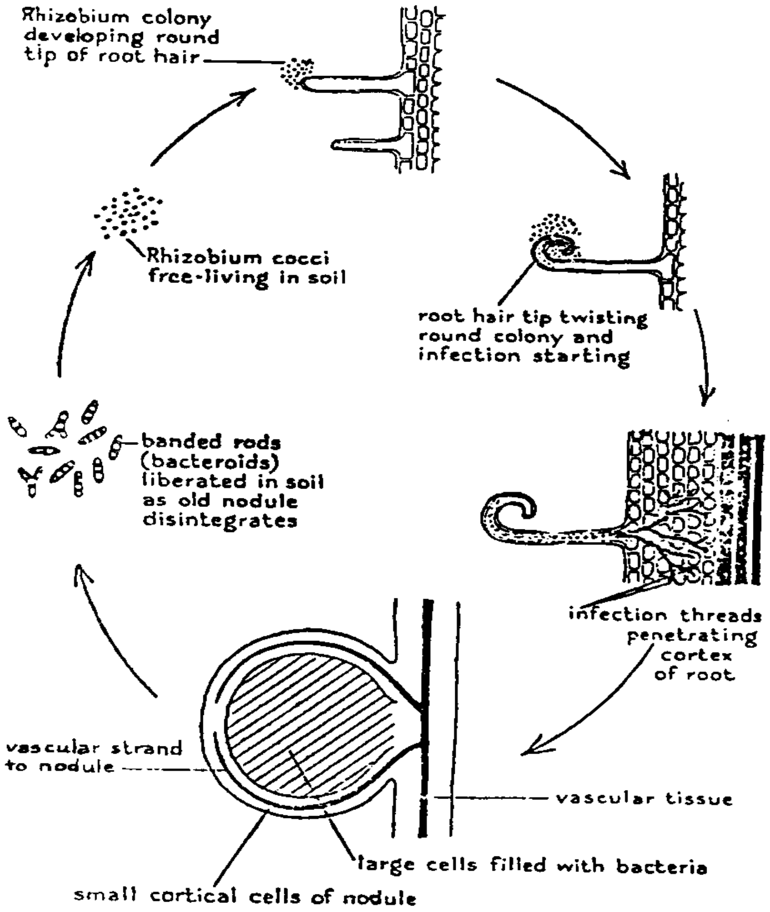

Figure 2. Diagrammatic Representation of Nodule Formation in a Legume, and the Life Cycle of the Root nodule Bacteria (Rhizobium sp.)

Source: Cobley, Leslie S., An Introduction to the Botany of Tropical Crops. New York: Longman, Green and Company, 1956, p. 140.

take their energy from the legume plant, which in turn receives nitrogen that has been fixed (made available by the bacteria). This ability to fix nitrogen allows the plant to meet its nitrogen needs even when soil nitrogen is limited. This mutually beneficial association is called nitrogen fixation. It happens when the bacteria cause the nitrogen to combine chemically with hydrogen to form ammonia, and ultimately amino acids and plant protein. Legumes are vitally important in agriculture because of their high protein content and their independence of soil nitrogen resources.

Effective nitrogen-fixing nodules can easily be identified by their bright red color when sliced open with a knife. Legumes may also be infected with non-nitrogen-fixing nodules, which lack the red color. In this case, nitrogen fixation will not take place unless the plant is infected with the proper strain of bacteria.

The association between legume species and rhizobial strain is often highly specific. One bacterial strain is able to infect the root system and produce effective nodules on one group of legumes but not on legumes of another species. For instance, rhizobia that are effective on soybean are not effective on alfalfa. Even within the clover species, certain rhizobial strains are specific to one clover species. Many tropical legumes also have specific bacterial strains. Figure 3 shows the root

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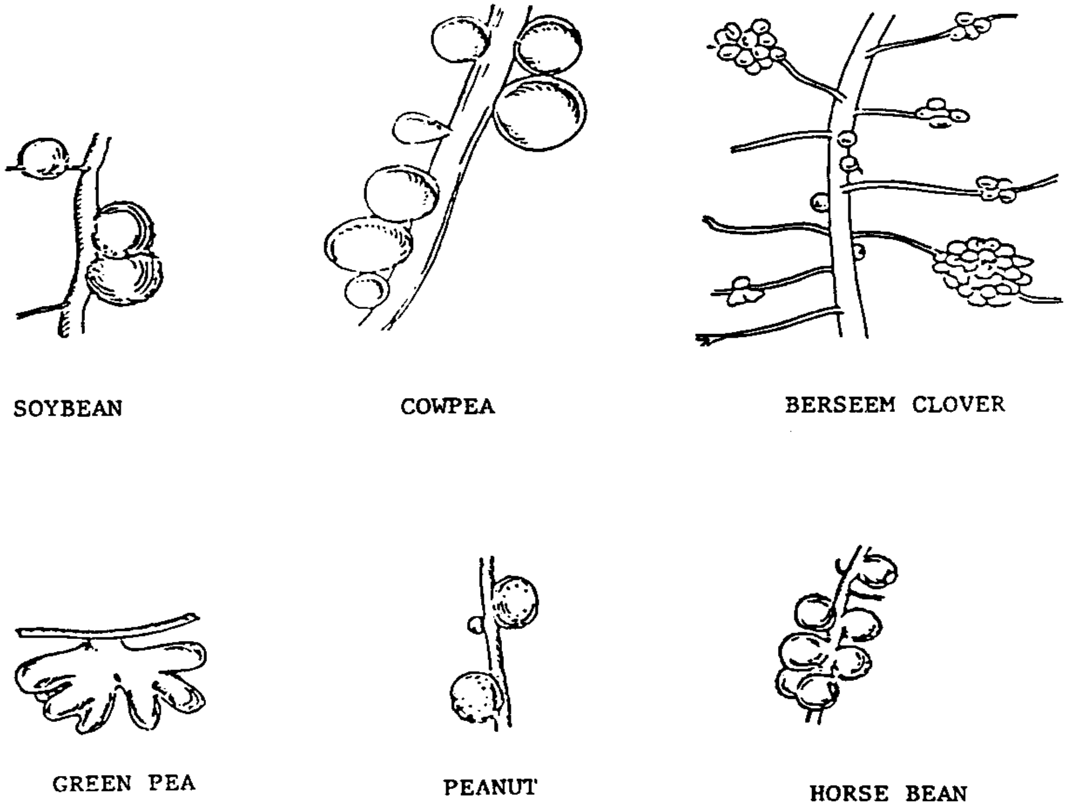

Figure 3. Representative Legume Root Nodules

Source: Cobley, Leslie S., An Introduction to the Botany of Tropical Crops. New York: Longman, Green and Company, 1956.

nodules associated with certain representative legumes.

When the proper strain for a particular legume species is not present in the soil, it is essential to inoculate the plant with this strain by adding the specific rhizobial strain to the legume seed at planting.

Successful inoculation of legume seeds depends on several factors:

1. The proper rhizobial strain is applied to the legume seed at planting. Commercial inoculants may be available in peat-based mixtures.

2. The bacteria are sensitive to heat, so inoculum should be stored in a cool place until used.

3. A syrup or molasses-water mix should be used to moisten the seed before applying the inoculum. This holds the inoculum on the seed.

4. Hot, dry conditions after planting will kill many of the bacteria. Planting in moist soil or just before rain will greatly improve survival of the bacteria. Pelleting the seed with gum arabic and inoculum will also improve survival in hot, dry soils.

5. Most of the non-tropical legume species require adequate lime or calcium in the soil for the rhizobia to survive and infect the legume plant. Tropical species are generally more tolerant of soil acidity.

III. SUCCESSFUL LEGUME CULTIVATION

CLIMATIC REQUIREMENTS

Legume species must be adapted to local weather conditions, though irrigation can compensate for insufficient rainfall. Legumes such as white or red clover are best adapted to regions where the temperature will remain moderate during the period of active growth. Other legumes, such as alfalfa, can withstand high atmospheric temperature provided soils are not waterlogged. Tropical species such as indigo, centro, and stylo are tolerant of high temperature and high humidity. In regions where the climate is mild and wet in winter, and hot and dry in summer, annual cool-season legumes such as arrowleaf, crimson, subterranean clovers, or peas are better suited. In tropical climates with wet summers and dry winters, summer annuals such as soybean, cowpeas, peanuts, or pigeon peas may be desirable.

SOIL REQUIREMENTS

In developed countries, soils are generally modified by liming and fertilization to grow a particular legume successfully. Alfalfa, which is intolerant of soil acidity, often requires heavy applications of lime. Other legumes such as cowpeas, red clover, soybeans, and subterranean clover are more tolerant of soil acidity. Tropical legumes are generally quite tolerant of soil acidity. Peanuts, tolerant of soil acidity, do require adequate calcium in the soil zone where flowers form pegs. Sericea lespedeza is very tolerant of acidity and of the toxic aluminum often found in tropical soils.

Tropical soils, in addition to being acid, are often very low in phosphorus; where fertilizers are not readily available or are too expensive, it may be necessary to choose a legume that is tolerant of low levels of phosphorus. Because low potassium levels also often limit the growth of legumes, fertilization may be needed. Trace elements such as boron, manganese, zinc, or molybdenum may also be needed in small quantitites.

Poor soil drainage may restrict the oxygen available to plant roots. This problem increases at higher temperatures. Selection of legume species tolerant of poor drainage can overcome this problem to some extent. Strawberry and ladino clovers are tolerant of poor drainage while alfalfa, red clover, and crimson clovers require well-drained soil.

ESTABLISHMENT AND MANAGEMENT OF LEGUMES

It is essential to select a legume species adapted to the particular climate and soil. Even when this is done, failures may occur during the critical establishment period. The following checklist may be useful in ascertaining the cause of failure.

1. Failure of seed to germinate in the soil.

o Dead seed. Germination declines in old seed. Poorly stored seed increases the problem.

o Dry seedbed. Seeds have a high water requirement for germination. A well-prepared seedbed provides better soil-seed contact and can assist in surrounding the seed with sufficient moisture for seed germination.

o Hard or dormant seed. Many legume species have hard seedcoats. These will not germinate unless the seedcoats are scratched or scarified to allow water to penetrate. This problem is particularly serious in many small-seeded legumes such as arrowleaf clover or vetch, and in many trees. (Seeds may be scarified by tumbling them in a container with course sand.)

o Unfavorable temperature. Warm season legume species such as soybeans, cowpeas, peanuts, and alyce clover have a higher temperature requirement than cool season species such as ladino, crimson, and arrowleaf clovers, or alfalfa.

o Soil-borne pathogens. Fungi and bacteria may rot seeds.

2. Early emergence failures. (The seed germinates but fails to emerge from the soil.)

o Overly deep planting. Small-seeded legumes such as ladino or white clover should not be planted more than 1 to 2 centimeters deep. In contrast, large-seeded legumes such as soybeans, peanuts, peas, or beans can

be planted deeper.

o Soil crusting. This is often a problem in high temperature areas of the tropics and subtropics where soil organic matter is very low. The crust physically prevents emergence of the seedling. Adding organic matter to the soil or providing a mulch can reduce the crusting problem.

o Insects. Insects may destroy seedlings, especially those of small-seeded legumes planted in grass sods. It may be necessary to apply insecticides for control of crickets and other insects in grass sods.

o Extremes of temperatures. Extremely high temperatures or freezes may kill small legume seedlings.

o Soil-borne pathogens. Fungi, bacteria, or nematodes may kill germinated seeds before emergence.

3. Early seedling stage failures.

o Soil acidity, low fertility, or poor physical conditions.

o Insects or diseases.

o Drought.

o Poor nodulation of roots with nitrogen-fixing bacteria.

o Weed competition.

o Damage from cold in winter.

Subsequent management of legumes depends on the legume species and the use made of them. Adequate supplies of soil phosphorus and potassium are essential for many of the most productive legumes. Various root and leaf diseases, nematodes, and insects may sharply reduce production unless they are controlled. Before applying a pesticide, it is important to determine if it can be safely used on a particular food or forage crop, and how soon after application the crop may be harvested or grazed.

IV. LEGUME SPECIES BY MAJOR USE

The three primary uses for legumes are as food grains and seeds for people and lifestock; as forage for livestock; and as a green manure to improve the yield of other crops in rotation. This section lists some of the major legumes in each of these categories and briefly describes their cultural characteristics.

LEGUMES FOR FOOD

There are a large number of warm- and cool-season annual legumes that are important for grain or vegetable production. Others are of minor importance, while yet others could be food crops but are not cultivated.

The legumes most widely used for food are:

Soybean Peanut Cowpea
Green bean Lima bean Broad bean
Adzuki bean Mung bean Winged bean
Carob Chickpea Lentil
Lupine Green pea Pigeon pea
Hyacinth bean Moth bean Tepary bean
Tamarind

LEGUMES FOR FORAGE

A large number of legume species are used for grazing and hay. These are divided into season cool annuals and perennials and warm season annuals and perennials.

Cool season annuals:

Arrowleaf clover - no bloat problems in livestock, long productive season.

Ball clover - tolerant of wet soils.

Berseem clover - tolerant of high temperature during seed germination, no bloat.

Crimson clover - vigorous early growth, early maturity.

Persian clover - tolerant of wet soils.

Rose clover - drought-tolerant.

Strawberry clover - tolerant of wet soils and salt.

Subterranean clover - tolerant of hard grazing by sheep.

Hairy vetch - very cold-tolerant.

Common vetch - high winter productivity in mild climates.

Rough pea - tolerant of wet soils.

Cool season perennials:

Alfalfa or lucerne - highest yielding forage legume, long productive season.

Red clover - short-lived productive legume tolerant of soil acidity.

Ladino clover - very tolerant of close grazing, long prductive season.

Bird's-foot trefoil - non-bloating legume tolerant of acid soils.

Cicer milk vetch - tolerant to drought and alkaline soils.

Sainfoin - tolerant of drought, low phosphorus, and alkaline soils.

White clover - tolerant of close grazing.

Warm season annuals:

Alyce clover - high quality but susceptible to nematodes.

Annual lespedeza - tolerant of low soil fertility, low forage yield.

Hairy indigo - tolerant of low soil fertility, resistant to nematodes, mildly toxic.

Joint vetch - tolerant of soil acidity, productive.

Phasemy bean - leafy shrub that reseeds well in tropical areas.

Townsville lucerne - reseeding leafy shrub, tolerant of low fertility, well adapted to Australian tropics.

Warm season perennials:

Sericea lespedeza - highly productive, very tolerant of soil acidity and low fertility.

Perennial peanut - productive, tolerates grazing well, tolerant

of acidity.

Centro - high quality viny shrub that grows well with grasses in tropics.

Stylo - tolerant of low fertility, not tolerant of drought or frost.

Lotononis - creeping-type plant that tolerates grazing well.

Leucaena - shrub that can be grazed while it continues to supply nitrogen to associated grasses in tropics.

LEGUMES FOR GREEN MANURE IN ROTATION

Many soils, particularly in the tropics and subtropics, are low in nitrogen. Legume crops, grown in rotation with other crops can be used to add nitrogen to the soil. The amount of nitrogen fixed annually by rhizobia varies with legume species:

Legume kg N/hectare

Alfalfa 200-400
Ladino clover 100-200
Lupines 100-150
Red clover 100-150
Crimson clover 100
Cowpeas 100
Vetch 90

Annual lespedeza 80
Soybeans 50-100
Peas 60
Peanuts 40
Beans 40

The nitrogen in the nodules, top growth, and roots of the legume becomes available for use by other plants growing with the legume or growing in the same soil later. Approximately 80 percent of the nitrogen is in the uncut top growth, and 20 percent is in the roots. Nitrogen usually averages 3.5 percent of the plant material on a dry matter base.

Maximum availability of nitrogen from legumes usually occurs within two months after the legume blooms. Thus, the full-bloom stage is a good time to plow under a legume crop to obtain a substantial quantity of nitrogen to enrich the soil for the next crop. Where a winter annual legume such as crimson clover is grown, as in the southeastern United States, the amount of nitrogen fixed in the soil is adequate to produce an excellent grain sorghum crop following the clover, with no additional nitrogen fertilizer.

Legumes normally used in rotation with other crops are:

Cool Season Annuals: Cool Season Perennials:

Crimson clover Alfalfa
Berseem clover Red clover

Vetch
Annual sweet clover
Lupines

Warm Season Annuals:

Sesbania
Pigeon peas
Velvet beans
Cowpeas
Sword bean (Canavalia gladiata)

LEGUMES

Adzuki bean Vigna angularis

Alfalfa Midicago sativa

Alyce clover Alysicarpus vaginalis

Arrowleaf clover Trifloium vesiculosum

Ball clover Trifolium nigrescens

Beans Phaseolus vulgaris

Berseem clover Trifolium alexandrinum

Bird's-foot trefoil Lotus corniculatus

Broad bean Vicia faba

Carob Ceratonia siliqua

Centro Centrosema pubescens

Chickpea Cicer arietinum

Clover Trifolium spp.

Common vetch Vicia sativa

Cowpea Vigna sinensis

Crimson clover Trifolium incarnatum

Egyptian clover. See Berseem clover

Fenugreek Trigonella foenum-graecum

French bean. See Bean

Garbanzo. See Chickpea

Green pea. See Pea

Groundnut. See Peanut

Guar Cyamopis tetragonolabus

Hairy indigo Indigofera hirsuta

Hairy vetch Vicia villosa

Haricot bean. See Bean

Hyacinth bean Dolichos lablab

Indigo Indigofera spp.

Jack bean Canovalia ensiformis

Joint vetch Aeschynomene americana

Kidney bean. See Bean

Kudzu Pueraria lobata

Ladino clover. See White clover

Lentil Lens culinaris

Lespedeza Lespedeza spp.

Leucaena Leucaena leucocephala

Licorice Glycyrrhiza

Lima bean Phaseolus lunatus

Lucerne. See Alfalfa

Lupine Lupinus spp.

Mesquite Prosopsis juliflora,

P. glandulosa,
P. chilensis, others

Mimosa Mimosa spp.

Moth bean Vigna aconitfolia

Mung bean Vigna radiata

Peanut Arachis hypogaea

Pea Pisum sativum

Persian clover Trifolium resupinatum

Phasemy bean Phaseolus semirectus,
Phaseolus lathyroides

Pigeon pea Cajanus cajan

Red clover Trifolium pratense

Rose clover Trifolium hirtum

Rough pea Lathyrus hirsutus

Sainfoin Onobrychis viciifolia

Scarlet runner Phaseolus coccineus

Sericea lespedeza Lespedeza cuneata

Sesbania Sesbania exaltata

Snap bean. See Bean

Soybean Glycine max

Strawberry clover Trifolium fragiferum

String bean. See Bean

Stylo Stylosanthes spp.

Subterranean clover Trifolium subterraneum

Tamarind Tamarindus indica

Tepary bean Phaseolus acutifolia

Velvet bean Mucuna deeringiana

Vetch Vicia spp.

White clover Trifolium repens

Winged bean Phosphocarpus tetragonolobus
Winter vetch. See Hairy vetch

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