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Legume Genetic Resources with Novel "Value Added" Industrial and Pharmaceutical Use*

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Consumer preferences and scientific developments are changing and this is leading to a significant adjustment for US agriculture. During the last century, most agronomic research and production were to increase yields of food and fiber (Abelson 1994). However, during the last decade more attention is being focused on the production of new and alternative crops and their by-products for industrial, and pharmaceutical use. The legume family (Fabaceae) is the third largest family of flowering plants, with approximately 650 genera and nearly 20,000 species (Doyle 1994). Its species range from large tropical canopy trees to small herbs found in temperate zones, humid tropics, arid zones, highlands, savannas, and lowlands (NPGS 1995).

The Fabaceae contains many taxa of industrial, or pharmaceutical importance. Legume seeds are the second most important plant source of human and animal food (Vietmeyer 1986). Other new products would include new food sources, but the majority would provide industrial products such as dyes from Indigo, fiber pulps, vegetable, and pharmaceutical products. Many legumes contain organic chemicals in sufficient quantity to be economically useful as feedstocks or raw materials for many scientific, technological, and commercial applications. Legumes can biologically fix nitrogen, adding annually up to 500 kg N/ha/year to the soil (NAS/NRC 1979). Not only do other legume species provide hope for combating food shortages in developing countries, but they also can provide many specialty products such as rotenoids (Balandrin et al. 1985) for use as pesticides in developed countries.

Genetic variation in legume species and their wild relatives is of prime importance to the successful breeding of improved crop cultivars with added value and durable resistance to pests. The collection and preservation of legume germplasm has been established to ensure that scientists have access to as many genes as possible. The USDA, ARS Plant Genetic Resources Conservation Unit (PGRCU) is dedicated to acquiring, conserving, characterizing, evaluating, documenting, and distributing the genetic resources of crops, including special-purpose legumes. More than 4,000 accessions of special-purpose legumes are stored as seed at –18°C at the USDA, ARS, PGRCU in Griffin, Georgia. The purpose of this article is to highlight some outstanding new uses where some underexploited legumes seem notably promising.

LEGUMES WITH USEFUL PHYTOCHEMICALS

The USDA, ARS, PGRCU is dedicated to conserving 17 leguminous species with potentially useful phytochemicals (Table 1). Examples of commercially useful phytochemicals are rotenone, tephrosin, and deguelin, which are used in limited quantities as pesticides (Beckstrom–Sternberg and Duke 1994; Gaskins et al. 1972; Minton and Adamson 1979; Tyler et al. 1976). The use of pesticidal plants is widespread in the developing countries (Balandrin et al. 1985). The legume tephrosia (*Tephrosia purpurea*) contains insecticidal properties and the antitumor compound, lupeol (Beckstrom-Sternberg and Duke 1994). Rotenoid compounds derived from fish poison bean (*Tephrosia vogelii*) (Lambert et al. 1993) are also used as insecticides and rotenone has been reported to have antitumor potential (Beckstrom–Sternberg and Duke 1994).

Some legumes are potential sources of glycosides, biologics, antibiotics, and alkaloids which are used in drug manufacturing by the pharmaceutical industry (Tyler et al. 1976). The glycosides include aloe-emodin, chrysophanol, emodin, and rhein. Another phytochemical with potential use as an antibiotic is prodelphinidin derived from snout bean (*Rhynchosia minima*) (Beckstrom–Sternberg and Duke 1994). The alkaloid genistein, derived from kudzu has been found to retard cancer growth (Brink 1995). Trigonelline, an anticancer agent is derived from jackbean (*Canavalia ensiformis*) (Beckstrom–Sternberg and Duke 1994). Canavanine, extracted from jackbean has been found to be cytotoxic to human pancreatic cancer cells (Swaffar et al. 1994; Swaffar et al. 1995). Jackbean is also cultivated throughout the tropics as a cover crop, forage and green manure (Oropeza et al. 1993).

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Both cowitch (*Mucuna pruriens*) and kudzu have been reported to contain multiple useful phytochemicals (Beckstrom–Sternberg and Duke 1994). Cell suspension cultures of cowitch accumulated the anti-Parkinson drug L-Dopa (Pras et al. 1993). The chemical, daidzin found in kudzu (*Pueraria montana* var. *lobata*) not only is cancer preventive, estrogenic, and spasmolytic but has also been effective in reducing alcohol consumption in hamsters (Braddock 1995). Kudzu starch extracted from the tuberous roots in Japan is sold as a health food worldwide (NAS/NRC 1979). Not only does winged bean (*Psophocarpus tetragonolobus*) provide useful phytochemicals such as polyunsaturated fatty acids used as an antipolyneuritic (Beckstrom–Sternberg and Duke 1994), but it also produces edible leaves, shoots, flowers, pods, and tubers as well as seeds whose composition duplicates that of soybeans. The most interesting feature of winged bean tubers is their protein content. Winged bean tubers average 20% protein as compared to 1% for cassava (*Manihot esculenta* Crantz, Euphorbiaceae) and 3–7% for potato (*Solanum tuberosum* L., Solanaceae) (NAS/NRC 1979). To date, winged bean has not yet met expectations due in part to its intolerance of cold temperatures during the fall and winter.

Lablab bean (*Lablab purpureus*) has a myriad of uses (NAS/NRC 1979). The young pods, dried seeds, leaves, and flowers can be eaten. Tyrosinase found in lablab bean has potential use for antihypertensive treatment (Beckstrom–Sternberg and Duke 1994). Lablab bean occurs in two botanical types. The garden type is twining, late maturing, and used mainly as a vegetable. The field type is erect, bushy, early maturing, and used as forage, cover crop, and an ornamental (NAS/NRC 1979).

Common indigo (*Indigofera tinctoria*) has been found to contain indirubin which is useful for the treatment of chronic myelocytic leukemia (Han 1994). Butterfly pea (*Clitoria ternatea*) contains antifungal proteins and has been shown to be homologous to plant defensins (Osborn et al. 1995). *Desmodium gangeticum* is used in Nigerian traditional medicine and has been evaluated for possible antileishmanial acitivity (Iwu et al. 1992). Tick clover (*Desmodium adscendens*), a medicinal herb used in Ghana has been evaluated for three active components including dehydrosoyasaponin I, soyasaponin I, and soyasaponin III for potential use as antiasthma (Mcmanus et al. 1993).

INDUSTRIAL LEGUMES

Indigo dye derived from indigo (*Indigofera arrecta*) (Purseglove 1981) is just one example of the usefulness and unfortunate obscurity of several potential industrial legume species (Table 2). The crop has been cultivated in India, but its importance has declined due to synthetic dye production. There were more than 600,000 ha cultivated in India in 1896, however by 1956 this had declined to 4000 ha. Indigo is still used for local dyeing in tropical Africa, but seldom enters into international trade (Purseglove 1981).

Guar (*Cyamopsis tetragonoloba*) is native to tropical Africa and Asia. The young pods are eaten as a vegetable and seeds are used as cattle feed in India and Pakistan, where it is also used as forage and green manure. Both guar and dhaincha (*Sesbania bispinosa*) contain galactomannan gum. This gum is water soluble, produces a smooth, light-colored, coherent, and elastic film useful for sizing textiles and paper, as well as for stabilizing the mud used in oil drilling (Vietmeyer 1986). Galactomannan gum is also used as a stabilizer and thickener in food products such as ice cream, bakery mixes, and salad dressings. Guar is grown for gum production in India and the southwestern United States. The plant is hardy and very drought resistant and grows well on alluvial and sandy loams (Purseglove 1981). Dhaincha can be grown in a rotation scheme for soil improvement, to provide fiber for paper pulp, for fodder, and has ornamental value (Vietmeyer 1986). Dhaincha appears to produce well on a large scale with little care or investment, and survives well on saline or wet soils (NAS/NRC 1979).

Leadtree (*Leucaena leucocephala*) is a multi-purpose legume tree providing fiber for paper products and is also beneficial as a cover crop, fodder, green manure, and ornamental (Mureithi et al. 1994; National Research Council 1984). In North America, the best-known nitrogen fixing trees are black locust (*Robinia pseudoacacia* L.) and honey locust (*Gleditsia triacanthos* L.). In the tropics, leadtree is so productive that on the most suitable areas it has reached heights of almost 6 m in its first year and 20 m thereafter in 6 years (Vietmeyer 1986). Leadtree produces vigorous sprouts after cutting and when young trees are grazed, the plants vigor reappears as lush shoots making useful livestock feed. High weight gains have been measured on cattle browsing a mixture of leadtree and grass in northern Australia (Vietmeyer 1986).

Table 1. Legume genetic resources with useful phytochemicals conserved at the PGRCU.

Name		Use		
Scientific	Common	Agricultural	Bioactive	Phytochemical (Pharmacological)
Canavalia ensiformis (L.) DC.	Jackbean	Forage, green manure, pulse	Pesticide, bactericide fungicide	Betonicine (Hemostat) Canavanine (Antiflu, anti-viral) Trigonelline (Anticancer: cervix, liver, hypocholesterolemic, hypoglycemic)
Clitoria ternatea (L.)	Butterfly pea	Cover crop, forage, ornamental	Antifungal	Antifungal proteins
Crotalaria juncea L.	Sunn hemp	Fiber, green manure		Senecionine (Antitumor hypotensive) Seneciphylline (Antitumor)
Crotalaria retusa L.			Pesticide	Monocrotaline (Antileukemic, antitumor, cardiodepressant, hypotensive Retusin (Antitumor)
Desmodium adscendens (Sw.) DC.	Tick clover			Dehydrosoyasaponin I, Soyasaponin I, Soyasaponin III (Antiasthma)
Desmodium gangeticum (L.) DC.				Antileishmanial
Indigofera tinctoria (L.	Common indigo	Pesticide Dye		Indigotin (Antiseptic, astringent) Indirubin (Antileukemic)
Lablab purpureus (L.) Sweet	Hyacinth bean	Browse, forage, ornamental, pulse		Tyrosinase (Antihypertensive)
Mucuna pruriens (L.) DC.	Cowitch	Pulse	Pesticide	Bufotenine (Cholinesterase inhibitor) Dopa (Anti-parkinsonian) Mucunain (Anthelminthic) Serotonin (Antiaggregant, antigastric, cholinesterase inhibitor, coagulant, myo-relaxant, myo-stimulant)
Psophocarpus tetragonolobus (L.) DC.	Wingbean	Vegetable		Erucic acid (Antitumor) PUFA (AntiMS, antiacne, antieczemic, antipolyneuritic)
Pueraria montana var. *lobata* (Willd.) Maesen & S. Almeida	Kudzu	Forage, human food		Daidzein (Anti-inflammatory, antimicrobial, coronary dilator, estrogenic, spasmolytic) Daidzin (Cancer preventive, estrogenic, spasmolytic) Genistein (Antileukemic, antimicrobial, cancer preventive, estrogenic)

				Puerarin (Antimyocarditis, hypoglycemic, hypotensive)
				Robinin (Cancer preventive)
				Tectoridin (Anti-inflammatory)
Rhynchosia minima (L.) DC.	Snout bean	Forage		Prodelphinidin (Antibiotic)
Senna alata (L.) Roxb.	Ringworm bush		Pesticide	Aloe-emodin (Antileukemic, antiseptic, antitubercular, antitumor)
				Chrysophanol (Antiseptic, hemostat)
				Emodin (Antiaggregant, anti-inflammatory, antimutagenic, antiseptic, antitumor (breast), antiulcer, spasmolytic)
				Rhein (Anticarcinomic, antiseptic, anti-tumor)
Senna occidentalis (L.) Link	Coffee senna	Coffee substitute	Pesticide	Aloe-emodin (Antileukemic, antiseptic, anti-tubercular, anti-tumor)
				Anthraquinone (Laxative)
				Chrysophanol (Antiseptic, hemo-stat)
				Emodin (Antiaggregant, anti-inflammatory, anti-mutagenic, anti-septic, antitumor (breast), antiulcer, spasmolytic)
				Physcion (Antiseptic)
				Rhein (Anticarcinomic, antiseptic, anti-tumor)
Tephrosia candida DC.	White tephrosia	Cover crop	Acaricide, antifeedant, pesticide, piscicide	Rotenone (Antitumor)
			Antifeedant, cytotoxic, pesticide, piscicide	Tephrosin
Tephrosia purpurea (L.) Pers.			Cytotoxic	Lupeol (Antirheumatic, antitumor)
			Acaricide antifeedant, pesticide, piscicide	Rotenone (Antitumor)
			Antifeedant, cytotoxic, pesticide, piscicide	Tephrosin
Tephrosia vogelii Hook. f.	Fish poison bean		Cytotoxic, insecticide, pesticide, piscicide	Deguelin
			Acaricide, antifeedant, pesticide, piscicide	Rotenone (Antitumor)
			Antifeedant, cytotoxic, pesticide, piscicide	Tephrosin

Table 2. Industrial legume genetic resources conserved at the PGRCU

Name		
Scientific	Common	Use
Cyamopsis tetragonoloba (L.) Taub.	Guar	Vegetable gum, forage, green manure, source of galactomannan gum
Indigofera arrecta Hochst. ex A. Rich	Indigo	Dye
Leucaena leucocephala (Lam.) de Wit	Leadtree	Fiber, forage, fuel, fodder, human food, green manure
Sesbania bispinosa (Jacq.) W. Wight	Dhaincha	Fiber, pulp, cover crop, fodder, green manure, ornamental, gum, source of galactomannan gum

CONCLUSIONS

Leguminous genetic resources have hardly been explored and sampled for their offerings. Intensive efforts should be expanded for maximizing the use of potentially useful leguminous species. Biotechnology can accentuate the use of these leguminous genetic resources by facilitating the isolation of unusually promising genetic characteristics. Advances in biotechnology have increased the value of legume genetic resources for industry and the pharmaceutical industry. The cost of manipulating new genetic material or identifying and isolating new phytochemicals is declining swiftly (Reid et al. 1995). Leguminous plant natural products have been and will continue to be important sources and models of forage, gums, insecticides, phytochemicals, and other industrial, medicinal, and agricultural raw materials. Since most of these legume species have not been examined for chemical or biologically active components, it is logical to expect that new sources of valuable substances remain to be discovered. The Plant Genetic Resources Conservation Unit is dedicated to quality conservation of legume genetic resources for distribution to scientists worldwide.

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