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New Forage, Grain, and Energy Crops for Humid Lower South, US

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The Humid Lower South (HLS) of the United States (Fig. 1) has a predominantly subtropical climate with high rainfall, a long warm growing season and mild winters. Temperate perennial crops tend to have difficulties surviving the summer and many tropical perennial crops tend to have difficulties surviving the winters.

RHIZOMA PERENNIAL PEANUT, NEW FORAGE

Until the introduction of rhizoma perennial peanut (RPP) (*Arachis glabrata* Benth., Fabaceae) to Florida from Brazil in 1936, there was no persistent forage legume available. Two cultivars of RPP have been released as forage: ‘Florigraze’ (Prine et al. 1981) and ‘Arbrook’ (Prine et al. 1986). The RPP must be propagated by rhizomes as they make few seed and these seed do not usually breed true. Bermudagrass sprig harvesters and planters have been adapted to dig and plant RPP. The two forage cultivars of RPP, are now planted on about 8,000 ha in HLS. Most of the hectarage (7,500) is in ‘Florigraze’ which can grow under colder conditions and wetter soils. Of the two cultivars, ‘Arbrook’ is the most drought resistence and best adapted to deep droughty sands. RPP is adapted to the climate of the HLS which extends to the northern limit indicated by the dashed line shown on map in Fig. 1. Two other perennial peanuts, *A. pintoi* and *A. kretschmerii*, which can be propagated by seeds, are restricted to warmer portions of peninsular Florida due to their intolerance to winter freezes.

For a more complete review of RRP refer to the proceedings of an international workshop entitled “Biology and Agronomy of Forage *Arachis* held at International Center for Tropical Agriculture at Cali, Colombia in 1993 (Kerridge and Hardy 1996). French et al. (1996) covered RPP as a forage crop in United States at the workshop in much greater detail than will be possible in this report.

RRP has been fed to dairy and beef cattle, horses, dairy and meat goats, sheep, swine, rabbits, and ostrich as hay, silage and pasture. The hay is usually more palatable than alfalfa and good quality hay compares favorably with alfalfa. Rhizoma peanut leaf meal also compared favorably with yellow maize and alfalfa meal as xanthophyll pigment source for egg yolk coloring in laying hens (Janky et al. 1986). Wild hogs, deer, turkey, rabbits and other wildlife readily graze RPP and are attracted to RPP plantings.

The dry matter hay yields of RRP have ranged from 7.0 to 15.7 Mg ha^{-1} yr^{-1} with 9 to 11.2 Mg ha^{-1} yr^{-1} yields most common. The protein content of the forage has reached 22% with a range of 15 to 17% being most common. Three cuttings of hay are possible in good seasons when cut at 7 or 8 weeks intervals. Drought often reduce the number of hay cuttings to two a year.

The rhizoma peanuts have a mass of rhizomes just below the soil surface like bermudagrass and an occasional tap root which can go to great depths in many soils. Fine roots are attached to the rhizomes and tap roots. The RPP have exceptional drought tolerance. They make little growth during severe drought conditions, but often remain green beyond the point that grasses have browned off and resume growth quickly after rainfall begins. RPP is useful for creep-grazing beef calves whose mothers are grazing low quality bahiagrass pastures (Saldivar et al. 1981).

The use of ‘Florigraze’ and ‘Arbrook’ as forage crops is well established now. Soon to be released RPP plant introductions, PI 262839, ‘Arblick’ and PI 262840, ‘Ecoturf’ are shorter in height and have better flower production than currently used forage types. The flushes of yellow flowers from the RPPs planted as turf or ground cover on lawns, highway medians, and shoulders, parks, playgrounds, off

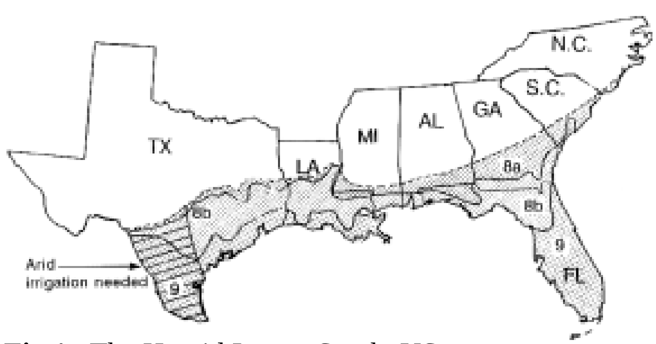

Fig 1. The Humid Lower South, US.

play areas of golf courses, and any low traffic area brighten up the landscape. Better drought tolerance and freedom from need of nitrogen fertilization and are bonuses for using RPP instead of grasses. The dense rhizoma mat of RPP sod helps control soil loss from water and wind erosion.

Persistence is the attribute which sets RPP apart from other forage legumes in HLS. The first planting of RPP made by first author in 1961 still survives today. Many commercial RPP plantings are now over 18 years old and still performing well. This persistence is due to plants tolerance to disease and insects and high resistance/immunity to root knot nematodes. The RPP appears to be conservative in partitioning nutrients to top growth and maintains food reserves in the rhizome system. The root system is a good procurer of nutrients and water from the soil.

Low temperature which freeze the rhizomes in the upper soil zone and flooding for long periods limit the location where RPP can be planted in HLS. RPP is not adapted to poorly drained soils or soils which flood. Soil pH for RPP should be in range of 4.8 to 7. At pH near 7 and higher, RPP may demonstrate iron deficiency chlorosis. Optimal forage production for Florida released cultivars is at pH 6.0.

PIGEONPEA NEW GRAIN LEGUME

Pigeonpea [*Cajanus cajan* (L.) Millsp., Fabaceae] is an ancient crop in the world but a recent introduction to the Lower South US. Pigeonpea in an important grain legume crop in many parts of the world including India, Asia, Africa, Latin America, and the Caribbean. In these areas, the grain is used as a food component at the mature green and dried stages. Migrants from these regions who reside in the United States still favor this legume in their diet. Except for Hawaii and Puerto Rico, the pigeonpea is not commercially grown in the US. Although a tropical crop, growth of adapted pigeonpea is possible in the Lower South. The pigeonpea is a weak perennial but performs as an annual where it is killed by freezing temperatures. Grain production has to occur between early spring to early fall and requires a long growing season. A pigeonpea cultivar named 'Norman' was released by the North Carolina Experiment Station as a green manure crop, but has disappeared from seed trade. This paper has purpose of introducing a couple of pigeonpea populations adapted for grain production in Florida and Lower South, US which are being increased for release as cultivars by Florida Agricultural Experiment Stations.

The experimental pigeonpeas, 76 WW and 99 WW, are the result of a pigeonpea developmental program started in 1976 to develop an adapted pigeonpea cultivar for grain production. Some 96 lines were obtained from two pigeonpea crosses received from ICRISAT. In 1977, 3 additional pigeonpea populations were obtained from the University of West Indies, Trinidad. Other pigeonpea accessions were obtained from USDA Plant Introductions. Individual plants and lines were selected for earliness, large seed size, and high seed yields, and in later years for light-colored seed coat. Besides selective breeding, various management and seed production trials with various selected pigeonpea lines and populations have been conducted over the years at Gainesville. In recent years, three selected populations, FL 76WW, FL 99WW, and FL DO, were evaluated at Florida A&M University at Tallahassee.

Grain yields of pigeonpea lines at Gainesville have varied from 340 to 3360 kg/ha with most grain yields falling between 1200 and 2000 kg/ha. Pigeonpea yields are not consistent from year to year or location to location. Fall freezes have killed pigeonpea or reduced seed yield and are the reason for our slow development of the crop. In 1996, grain yields at Tallahassee when harvested at the mature green and dried stages were 3220 and 1180 kg/ha for FL 76WW, 2640 and 1470 kg/ha for FL 99WW and 2270 and 1080 kg/ha for FL DO, respectively. Pigeonpeas are a promising home garden and U-pick vegetable harvested at the mature green pod stage. They are shelled by hand or with a commercial pea sheller.

Pigeonpeas are day length sensitive requiring day lengths under 12.5 h for best flowering and seed production. Date of planting has great effect on plant size, earlier planted plants being largest. Planting date may affect grain yields but varies from season to season. June is the best time to plant for combine harvesting for grain but earlier plantings in late April or May are best for home garden and U-pick operations as a vegetable.

Pigeonpeas are attacked by nematodes, insects, and diseases. Rotations and insecticides for controlling insects like corn earworm and stink bug on flowers and seed pods are usually all that is needed for successful production. Pigeonpeas are very drought resistant and produce seed where other grain legumes will fail. Pigeonpeas are resistant to most root-knot nematodes, but are susceptible to the peanut root-knot nematode

Meloidogyne arenaria race 1. It is recommended that pigeonpeas not be planted in rotations with other grain legume crops. Pigeonpea will grow on well-drained soils with a wide range of textures and pH's.

Table 1. Average annual biomass yield of elephantgrass (eg), energycane (ec), sugarcane (sc), at five locations in southeastern United States over three growing seasons (Prine et al. 1991, 1997).

	Oven dry biomass (Mg ha^{-1} yr^{-1})				
	Florida				Alabama
Crops	Ona	Gainesville	Quincy	Jay	Auburn
N-51 eg	46.7	39.7	33.8	32.1	24.0
PI 300086 eg	41.6	28.6	24.1	24.0	18.6
L79-1002 ec	23.3	32.2	30.1	33.9	24.2
CP72-1210 sc	19.4	10.4	19.2	8.2	6.0

BIOENERGY CROPS

The Humid Lower South has the most suitable climate (warm temperature, high rainfall and longest warm growing season) for biomass crops in the continental US. High biomass yields are attained from full-season growth of adapted cultivars of tallgrasses; elephantgrass (*Pennisetum purpureum* K.Schumach., Gramineae), erianthus (*Erianthus arundenaceum,* Michx. Gramineae), energy and sugar cane (*Saccharum* spp., Gramineae); the tree legume, leucaena (*Leucaena* spp., Mimosacea); and short rotation woody crops, cottonwood (*Populus deltoides* Bartr. ex Marsh., Salicaceae), slash pine (*Pinus elliottii* Engelm., Abietaceae) and *Eucalyptus* sp., Myrtaceae (Prine and Rockwood 1998).

Energy crops must be efficient converters of solar energy to biomass for long periods of time each growing season. Perennial energy crops must also be very persistent and long lived and give dependable production for five or more seasons from the same planting. The tall grasses such as sugarcane, energycane, elephantgrass, erianthus and intermediate grasses such as switchgrass (*Panicum virgatum*) have the C4 metabolic system and stature (strong enough to hold up an entire seasons growth without lodging) to make high biomass yields over a long growing season. The tall grasses have high biomass yields because of linear crop growth rates of 18 to 27 g m^{-2} d^{-1} for long periods, 140 to 196 days and sometimes longer (Woodard and Prine 1993). Oven dry biomass yields of tall grasses have varied from about 20 to 45 mg ha^{-1} yr^{-1} in colder subtropical and warmer temperate locations to over 60 Mg/ha in the lower portion of the Florida peninsular. The results of a 3 year study for several tall grasses in HLS is shown in Table 1. Many tallgrass genotypes are long-lived and resistant to winter kill, the killer of tropical grasses in the colder subtropics.

Most of the perennial tall grasses are propagated vegetatively, which limits their use as energy crops, but once established adapted crops may persist many years. Switchgrass will fit into many bioenergy situations because it can be seeded, has good resistance to winter kill and is persistent and sustainable, and has yielded up to 22 Mg ha^{-1} yr^{-1} (Bransby and Sladden 1995). Overlooked among bioenergy crops is castor (*Ricinus communis* L. Euphorbiaceae). A tall ecotype produced stems seven meters tall that had dry weight of 40 Mg/ha at Gainesville, FL in 1997.

Sewage Effluent Experiments

Lower South cities have sewage sludge and effluent disposal problems plus high energy requirements. Applying this waste on energy crop plantations and using the crop can satisfy some of the cities energy needs. The energy content of 1 Mg of oven dry tall grass and leucaena is equivalent to that of 423 and 466 L (112 and 123 gallons) of number 2 diesel fuel, respectively. Table 2 shows the annual dry matter yields of selected tallgrasses on Tallahassee and Leesburg sewage spray fields. More complete information on these sewage effluent experiments is given by Prine et al. (1997) and Prine and

Table 2. Dry matter yields of selected tall grasses grown on the sewage effluent spray field of cities of Tallahassee and Leesburg, FL.

	Average annual dry matter biomass yield (Mg/ha)	
Tallgrass energy crop	Tallahassee, FL (3 seasons)	Leesburg, FL (2 seasons)
'Merkeron' elephant grass	22.3	32.8
N-51 elephant grass	21.0	37.0
PI 300086 elephant grass	21.9	52.0
US 72-1153 energycane	19.3	--
L79-1002 energycane	18.7	21.7
Alamo switchgrass	9.1	--

Table 3. Performance of three cottonwood clones in Florida. Source: Rockwood et al. 1996.

		Clone		
Location	Measurement	Ken 8	S7C1	S13C20
Tallahassee (irrigated with sewage effluent)	7 mo. ht. (m)	1.9	1.7	1.4
	43 mo. ht. (m)	8.3	9.1	8.9
	43 mo. survival (%)	48.0	43.0	34.7
	43 mo. volume (m^3/ha)	72.3	71.1	69.4
Quincy	4 mo. ht. (m)	1.4	1.0	1.1
	8 mo. ht. (m)	2.6	2.3	2.2
	3 mo. coppice ht. (m)	1.2	1.0	1.0
Winter Garden	3 mo. ht. (m) with effluent	1.0	0.7	0.5
	3 mo. ht. (m) with effluent, compost and mulch	1.4	1.1	1.2

McConnell (1996). The productivity of cottonwood receiving sewage effluent of Tallahassee was promising (Table 3).

Phosphate Mining Land

The use of phosphatic mining land in central Florida is also favorable for biomass energy crops. The approximately 100,000 ha phosphate mining land base includes about 30,000 ha of phosphatic clays. The phosphate lands have considerable potential to grow sugarcane, energycane, elephantgrass, leucaena, *Eucalyptus*, and slash pine (Table 4). Crop yields for the tropical grasses, generally more than 40 Mg/ha dry matter dry weight (Stricker et al. 1993 and 1996), varied slightly with land type. Dry matter yields for the woody crops exceeded 20 Mg ha^{-1} yr^{-1}. Leucaena (Cunilio and Prine 1995; Prine et al. 1997) is projected to be the most productive and after an 18 month establishment period, would be harvested annually for at least 10 years. Leucaena can be harvested at longer cycles where top growth is not killed by freezes. Of the several *Eucalyptus* species that may be grown in central Florida (Rockwood 1997), *Eucalyptus grandis* Hill ex Maiden is now showing the greatest potential for the mined lands, with particular clones being most productive. It would be harvested initially after three years and would continue to be harvested in five more three-year cycles. Stricker et al. (1995) discussed the economic development through integration of various biomass systems in phosphatic mining area of Central Florida.

Short Rotation Woody Crops

SRWC hectarege in Southeastern United States, some 12,000 in 1995 was projected to increase to 27,000 in the year 2000 (Land et al. 1996). A considerable portion of the SRWC area in Humid Lower South will be planted to cottonwood. With the assistance of many public and private cooperators in 1997 and 1998, seed were collected from some 200 cottonwood trees distributed across the Southeastern Atlantic, Eastern Gulf, and Central Gulf portions of cottonwood's range (Land et al. 1996). Approximately 1,300 clones are now being produced from these seedlots for field testing and eventual release of improved planting stock for the region. As has been shown for currently available clones (Table 3), cottonwood productivity in the Humid Lower South can be enhanced by sewage effluent, various clones, and is greater in coppice rotations.

Other species suitable for SRWC (Prine and Rockwood 1998) in the Hu-

Table 4. Annual yields (dry Mg/ha)/length of cropping cycle (years)/number of cycles for promising biomass crops by phosphate land type. Source: Segrest et al. (1998).

	Phosphate land type		
Biomass Crop	Clay	Overburden	Cropland
Sugarcane	49.3/1/6	40.3/1/4	40.3/1/4
Energycane	44.8/1/6	35.8/1/5	33.6/1/5
Elephantgrass	40.3/1/6	40.3/1/6	40.3/1/6
Leucaena	35.8/1/10	33.6/1/10	26.9/1/10
Eucalyptus grandis	29.1/3/6	26.9/3/6	24.6/3/6
Slash Pine	--	20.1/8/1	20.1/8/1

mid Lower South include slash pine (*Pinus elliottii*) and, for Florida's more subtropical regions, several *Eucalyptus* species. Slash pine intensively cultured and closely spaced can produce up to 23 dry Mg ha^{-1} yr^{-1}. Under similar culture, *E. amplifolia* can yield as much as 25 dry Mg ha^{-1} yr^{-1} on good sites in northeastern Florida, and *E. grandis* can yield up to 35 dry Mg ha^{-1} yr^{-1} in central and southern Florida. Yields can be enhanced by the addition of wastewater and waste products.

CONCLUSIONS

Perennial peanut is a good persistent forage legume for most soils in Humid Lower South. Pigeonpea is a new warm season grain legume for the area on well-drained soils. The availability of land with an excellent climate and several adapted rapid growing bioenergy crops makes the Humid Lower South a likely area for development of bioenergy industries.

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