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Cajanus cajan (L.) Millsp. as a potential agroforestry component in the Eastern Province of Zambia

A. BOEHRINGER[1] and R. CALDWELL[2]

[1] *Msekera Regional Research Station, P.O. Box 510089, Chipata, Zambia Present address: University of Hawaii, Department of Agronomy and Soil Science, 1910 East West Road, Honolulu, HI 96822, USA* [2] *University of Hawaii, Department of Agronomy and Soil Science, 1910 East West Road, Honolulu, HI 96822, USA*

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Abstract. Farmers in the Eastern Province of Zambia are faced with problems common to other parts of the tropics: increased pressure to expand food production leading to accelerated forest clearing, decrease in traditional fallow periods, increased soil erosion, and reductions in soil fertility. Of special concern are shortages of labor during their growing season, a shortage of staple foods during January through March, pest (termite) problems, and seasonal fires. Alleycropping appears able to solve some of the farmers' problems. Both on-farm and experiment station trials were initiated to screen potential agroforestry species. Perennial pigeonpea, *Cajanus cajan* (L.) Millsp., a species indigenous to the Province, showed particular promise. Cultivars grew over 3 m tall and produced up to 4.8 tons/ha dry matter (in 7 months after pruning) for green manure. Farmers reacted favorably to their experience with the on-farm trials. Ease of establishment and production of food (green pod and grain) make perennial pigeonpea a special agroforestry option in the Province, deserving additional research.

1. Introduction

In the Eastern Province of Zambia today, permanent cultivation systems have replaced the traditional shifting cultivation due to land pressure. Fallow periods of 20 years or longer, sustaining modest yields with low financial inputs, have been abandoned. Presently crops are often planted every year. Shortened fallow periods have caused declines in soil fertility and crop yields, increased clearing of steep hillsides unsuitable for crop production, and additional labor requirements to obtain fuelwood.

The development of sustainable and productive agricultural systems, based largely on locally available resources, is of critical importance. The integration of trees or shrubs into the current farming system is one way to sustain permanent crop production while providing food, fodder, fuelwood, and green manure.

Given a lack of information on performance of agroforestry species in the region, research was initiated to screen tree and shrub species. Both on-farm and experiment station trials were conducted with a special focus on the particular farming systems constraints of the region. One species, pigeonpea (*Cajanus cajan* (L.) Millsp.), was of special interest. Pigeonpea is commonly grown as an annual in India, and so is not often considered as a possible 'tree' species. But long-lived pigeonpea is a common sight in the Eastern Province of Zambia. Some specimens found were estimated to be older than 10 years, with stem diameters of approximately 15 cm. Pigeonpea also is indigenous to East Africa [8, 10, 11], suggesting possible advantages over exotic tree species.

Pigeonpea gave promising results in dry matter (DM) production, nitrogen contribution through green manure, grain yields, forage production, and erosion control. Its performance suggests that pigeonpea could be successfully and easily integrated into the current farming systems of the region. This paper reports the results of that research. General background is also provided for pigeonpea and the constraints on existing farming systems in the Province.

2. General description of the area

2.1 Climate

The year is divided into a wet season from Nov. to April, a dry-cold season from May to Aug. and a dry-hot season from Sept. to Oct. The growing season starts in Nov. and lasts between 135 and 155 days. Total rainfall varies between 870 and 1,100 mm per annum. The mean temperature in the cold season is 17 °C and 24 °C in the hot season [1].

2.2 Soils

The soils, although highly variable, may be roughly classified into two major types. To the north and around Chipata, loamy sands are interspersed with red and red-brown clays (Ferric Luvisols). In hilly areas these often are replaced by Lithosols. Towards the south of the province, along the border with Mozambique, the soils are predominantly yellowish-red to light yellowish-brown loamy sands or sands (Acrisols). All soils are moderately leached and their pH ranges between 4.5 and 5.5 in average [1].

2.3 Farming systems

Cropping systems throughout the province are centered around maize production, the staple food of the people. Farmers dedicate most attention and inputs to this crop. Local maize occupied an average 1.2 ha per farm [Harvey RH, unpublished]. Additional cash crops, in order of importance, are peanuts (0.3 ha), and hybrid maize and/or sunflower (0.2 ha). The majority of the farmers are hoe-cultivators. In the southern districts of the province a remarkable shift towards cultivation with oxen is taking place. The relative importance of crops for ox-cultivaros is similar to hoe-cultivators, though their cropping area is bigger (2.5 ha). The current average yields of maize are estimated to be 0.8–1.2 t/ha [Eastern Province Agric. Dev. Project, unpublished].

Both cultivation systems share the same constraints: a shortage of labor during planting and weeding (November through January), a staple food shortage at the end of January through April, declining soil fertilities, non-available inorganic fertilizers, and increasing soil erosion. The increased use of land for food production and shortening of fallow periods has in some cases made fuel wood more difficult to obtain. During the cropping period, the herding of animals puts additional strains on the labor supply of the farming family. Free-range grazing only occurs after the crop harvest (June/July) and may be short due to devastating bush fires occurring then. Goats and fire cause great damage to trees during that time of the year.

3. The role of agroforestry

The specific and ultimate criteria for an agroforestry species selection for the Eastern Province may be formulated as:

1. Tolerance to prolonged drought, termites, and bushfires, suggesting the need for fast, vigorous, deep rooted species with good regrowth capability.
2. Minimum labor demand: preferably direct seeded with no seed scarification, a minimum of weeding required, and good establishment during one rainy season.
3. Supplies moderate amounts of food, recognized as such by the people, especially during the 'hungry period' from January to March.
4. Supplies nitrogen-rich mulch material for use as fertilizer.
5. Stabilizes ridges and hillsides, especially during the first heavy downpours of rain after the dry season (when there is no groundcover!).
6. Can be managed for secondary products such as fuelwood and animal feed.

4. Pigeonpea as an agroforestry component

4.1 Origin, distribution and production

While there is some disagreement, pigeonpea may have its center of origin in East Africa [6, 8, 9, 10, 11]. Today pigeonpea is pantropical, reflecting its wide adaptation. The most important centers of cultivation are on the Indian-subcontinent, East Africa and the Caribbean [15]

The time of introduction into the south-central parts of Africa and to the Eastern Province of Zambia, either from within the continent or from outside, is unclear. Most likely it had been introduced at large by Arab traders around 900 to 1400 A.D. [7]. This would explain their more common distribution in the lower Luangwa river valley, where at the confluence of the Zambezi, a very important Arab trade post was established and maintained for a long time [7]. With the arrival of ethnic Indians during the British colonial erea, the crop gained importance through the establishment of a limited market.

Actual production figures for pigeonpea are scarce since the bulk of the crop is grown on homeconsumption-scale. The biggest producers in East Africa are Kenya (world's 2nd largest), Uganda, Malawi and Tanzania [15].

It is unclear how much of the crop is produced today in the Eastern Province. The neighboring country of Malawi is the third biggest producer on the continent [15]. In the Eastern Province pigeonpea is common around homesteads and along field-edges. Often only a few individual plants are managed as part of the farming system. It is impossible therefore to accurately estimate production. A constant supply (primarily for the ethnic Indian population) can be found on the markets in the province throughout the year.

4.2 Characteristics of pigeonpea

Pigeonpea is a member of the tribe Phaseolae Benth. subfamily Papilionideae of Leguminosae [9]. All cultivars have trifoliate leaves, bear papilionaceous flowers of 2.5 cm length and multi-colored pods with constrictions between seeds. The pods are non-shattering and the 100 g weight of the seed ranges between 4 and 25 g [6, 9, 11, 15]. The agronomic distinction into three maturity classes, early (120 to 150 days), medium (150 to 180 days) and late (180 days and more) is still widely in use [6]. Most of the indigenous Zambian genotypes belong to the latter class. The plant reaches a height up to 4 m and its growth is either erect-compact or spreading [8, 10, 11]. Individuals have been found to survive for decades [8, 10, 11]. Determinate and indeterminate fruiting types exist [6, 8, 10]. The plant has a deep tap-root with short lateral roots. Spreading types often have longer laterals and denser spreading roots [8].

4.3 Uses

In India, pigeonpea has always been a very important source of protein for the people, largely consumed as dhal [6, 10, 11]. The use by Africans seems to be more restricted and variable. They are commonly eaten as whole, fresh pods, much like in the Caribbean [8, 10] and cooked as 'ndiwo' (a kind of relish). To a somewhat lesser extent the dry beans are also cooked [17]. Today they are widely referred to as a 'famine food'. All parts of the plant are known to be used for various medicinal purposes [10, 17]. In Malawi the bark, roots or leaves are used in a liquid for treatment of ear ailments [17]. A number of medicinal uses (i.e. sedative, analgesic) are reported from India, Java, Argentina, the Caribbean, and China [10].

In the Eastern Province, pigeonpea is an important source for animal feed. Pigeonpea has a high crude protein content: 29.8% for leaves and twigs [16]. As a livestock-feed it is highly esteemed in the semi-arid and wet tropics. All non-woody parts are edible, palatable, and non-toxic to ruminants and fowl [8, 10, 16, 18]. The plant has the capability of persisting under heavy browsing for many years [8]. Other reported uses of regional importance are bee-forage [8], silk-worm feed, host for lac-insects, thatching and fencing material, and fuel wood [8, 10, 11].

5. Experimental results

5.1 Genotype evaluations

In November 1985 an unreplicated trial with 33 pigeonpea lines as entries was planted at the Msekera Research Station near Chipata. A blanket basal dress of 40–20–20 kg/ha was broadcast and incorporated prior to planting. The seeds were hand-drilled at a row spacing of 1.5 m and at a within-row spacing of 12.5 cm. Each plot had three rows of 5 m each. The lines originated in India, Kenya, Tanzania and Zambia. During the first season, mainly phenological growth observations were taken. Throughout the trial the alleys between the pigeonpea rows were kept moderately free of weeds by hand. All plants were cut back at 1 m height in May 1986 and DM-yields were taken. After the first pruning in May 1986 the plants were left untouched until the following cropping season. Again growth performance was observed and the plants were cut back a second time at 1 m height in early January 1987. Table 1 gives the results for selected lines for both seasons. Three were selected for further on-farm evaluation. This selection was largely based on DM-yield, grain yield, mortality rate and growth habit. Erect-compact indeterminate types were selected to minimize above- and below-ground competition [6, 12, 14].

There were dramatic differences among entries in terms of survival and persistence. The short to medium maturity types with determinate growth seemed to suffer from pruning and drought. Some of these lines did not recover during the following wet season and were sensitive to termite attackes. Lower grain yields of entries ICP 11298, 11295 and 8869 were associated with heavy damage by *Mylabris* spp. during flowering. Pod bearing continued among indeterminate types after the May 86 harvest. The nitrogen yields were calculated as 2.15% of dry matter [2, 13]. During the growing season, competition from weeds appeared lower than in other crops, despite the wide row-spacing. This was attributed to the good amount of leaf litter covering the soil. Pigeonpea is reported to shed leaves throughout the year [3, 4, 5, 10]. Leaf litter quantities have been observed between 2000 [3] and 3330 $kg\,ha^{-1}\,yr^{-1}$ [8]. The former amount was calculated to add 36 kg/ha N to the system [3]. Results at ICRISAT indicate lower values of 10 to 11 kg/ha for short and medium maturing genotypes [6].

Along with the nitrogen contribution to the alleycrop, additional food from pods and grains is provided for a long period of time during the year. Grain yields in Table 1 are from unpruned trees in the first season; some drop in yield is anticipated under a pruning regime. Plants whose flowers were heavily attacked by *Mylabris* spp. (Dec.–Feb.) showed a sharp decline in reproductive yields, as in line 11295. This was associated with a stimulation of additional vegetative growth.

5.2 On-farm experience

In 1986 on-farm evaluations were established in parallel to the on-station research. Pigeonpea and other species were planted on three different sites in the districts of Chipata-North and South in November 1986.

At Chipata-South, a group of farmers asked for help with soil improvement, wind breaks, food, animal feed, and firewood. In 1985, ICP 11289, K423/11, and ICP 7035 were planted along the edges of the farmers' fields. On return visits, the plants were found never pruned back by the farmers and had grown up to heights of 3 m. During the second season adjacent maize rows clearly suffered from competition. When asked about this, the farmers commented about the labor demand for pruning and incorporating

Table 1. Performance of selected pigeonpea lines at Msekera RRS, Chipata, Zambia, from 1985 to 1987

Line	Plant height	Stem diam.	Grain yield	Dry matter	N	Survival	Plant height	Stem diam.	Dry matter	N	Mean N (2 cuttings)	Survival
	May 1986						January 1987					
	[CM]	[CM]	[KG/HA] (RANK)	[KG/HA]	[KG/HA] (RANK)	%	[CM]	[CM]	[KG/HA]	[KG/HA] (RANK)	[KG/HA]	%
ICP 11289	331	2.86	836(14)	1832	39(5)	91	226	4.26	2742	59(6)	49	79
ICP 11298	336	3.44	387(21)	1993	42(2)	93	219	4.82	3587	77(3)	59.5	71
ICP 11295	300	2.99	26(32)	2398	52(1)	81	208	4.02	4756	102(1)	77	57
ICP 8896	267	2.87	288(25)	1728	37(7)	76	218	3.97	3139	67(5)	52	52
K 423/11	214	2.34	1634(3)	1530	33(9)	84	171	3.08	2511	54(7)	43.5	63
ICP 6643	267	1.12	346(22)	1883	40(4)	71	211	3.11	2131	46(8)	43	51
ICP 12829	257	3.57	44(31)	1156	25(19)	64	162	4.37	525	11(30)	18	42
HY 3 C	151	1.08	1943(1)	843	18(24)	52	113	2.91	762	16(25)	17	52
ICP 7035	198	1.27	1443(6)	1193	26(18)	96	117	2.79	611	13(27)	19.5	56
BAHAR	142	1.21	0	1392	30(13)	76	139	3.02	1199	26(23)	28	46
Mean (33)	199	1.83	788	1230	26	72	184	3.08	1372	29	27.5	41

the cuttings at their busy time of the year. At a later time (after Feb.) they feared the hedges would not tolerate the pruning to survive through the dry season. They appreciated however their value as a food and windbreak and, most importantly, as a source of feed. (An additional observation of farmer practice in that area involved use of pigeonpea as a 'nurse crop'. Farmers had started planting *Khaya nyasica* seedlings along field edges for timber production. Seedlings received occasional hand watering in the first season. They found pigeonpea planted in a diameter of about 40 cm around their seedlings reduced damage from fires and goats [Rauch J, personal communication]. This could be attributed to suppression of weeds (that can promote fire) and pigeonpea's maintenance of green foliage throughout the year. Pigeonpea may thus act as a fire barrier while distracting goats from the seedlings inside).

At two other sites, in Chipata-North, farmers asked mainly for advice on how the flooding of their homesteads could be prevented. The locations were on slopes measuring 10% and 30%. The farmers' fields were on the upper parts of their land, channeling runoff water into low lying homesteads. An alleycrop was selected with three rows of combined maize (cv. MMV 600) plus climbing beans (cv. VRA 81027) at a row spacing of 0.75 m. The rows were bounded by hedges 2.25 cm apart. At both locations the land was first surveyed and contour-ridges were formed (with major ridges spaced at every 1 m drop of slop). Pigeonpea lines ICP 11298 and 7035, *Sesbania grandiflora,* and *Sesbania sesban* were used as the hedge species in four plots at the first location. Lines ICP 11289 and K423/11, *S. grandiflora,* and *S. sesban* were used in four plots at the second location. All crops and trees were directly seeded at the beginning of December. No fertilizers were applied to either pigeonpea or *Sesbania.* Field management was performed by the farmers.

Pigeonpea emerged uniformly within 10 days and established well to 0.4 m height within 30 to 40 days. Weed control was inadequate and weeds became well established along with the pigeonpea. At 50 to 60 days after sowing, the growth of the pigeonpea accelerated. It gained increasing dominance within the cropping system, and plants reached an average height of 1.7 m at the time of maize flowering. From then on, weeds in the whole plot were effectively suppressed. Weeds within maize rows never established well due to the good canopy cover provided by the climbing beans. At both sites, rats and termites were a problem for maize (exacerbated by an unusually dry December and January). Survival rates of the pigeonpea after the season were around 82%. At both locations, farmers believed the hedges were effective in reducing erosion. Field observations revealed that uniform, close spacings within the row (approximately 12.5 cm) were necessary for effective erosion control.

Table 2. Agroforestry species evaluated at Chipata/Zambia

Acacia albiba	*Flemingia congesta*
Acacia magium	*Gmelina arborea*
Acacia tortilis	*Khaya nyasica*
Azadirachta indica	*Leucaena leucocephala*
Balanites aegyptica	*Maesopsis eminii*
Cassia spectabilis	*Parkinsonia aculeata*
Casuarina equisetifolia	*Sesbania grandiflora*
Cordia abyssinica	*Sesbania sesban*
Eucalyptus grandis	*Vitex keniensis*
Eucalyptus lesnifera	

The farmers decided the use of the hedges. In all cases some pods and grain were collected for food and the trees were left for free-range browsing of cattle and goats over the dry season. At one site the farmer reported that overbrowsing by goats had killed many of the plants. He thought it not much of a problem since seeds were in ample supply for replanting next season.

None of the participating farmers regretted the trees on their land and all found them in one way or another useful. At the same time they expressed concerns about their labor shortage during the growing season and felt they would be unable to spend time managing their trees during that time.

5.3 Other agroforestry species

Other agroforestry species were planted in an observation nursery for comparison with pigeonpea at Msekera in 1986 (Table 2).

The following species were killed by termites during the first two months of study and were eliminated from further evaluation: *Acacia mangium, Casuarina equisetifolia, Ecualyptis spp.* All other species established reasonably well, but only *Cassia spectabilis, Flemingia congesta, Parkinsonia aculeata, S. grandiflora* and *S. sesban* showed fast and vigorous initial growth and compared favorably with pigeonpea. They were found suitable for direct seeding on-farm. *Maesopsis eminii* had a very fast initial growth and dense canopy establishment, but did not germinate when directly seeded. *Gmelina arborea* behaved similar to *Maesopsis*, though initial growth was somewhat slower. Promising, especially in terms of drought resistance and termite resistance, were all other *Acacia spp., Balanites aegyptica, K. nyasica* and *Vitex keniensis*, although their growth rates were extremely slow and they required intensive weeding in the nursery. These species are timber species and therefore fill a niche distinct from pigeonpea. *Leucaena leucocephala* most likely suffered under acidic soil conditions (pH 5.0) [Holden S, personal communication].

Unlike pigeonpea, *Sesbania, Flemingia*, and *P. aculeata* emerged over a 2 to 3 month period (seeds were not pretreated). This led to a large variation in plant growth stages. Very small seedlings were found below the heavy weed canopy. At maturity of the weeds, the seedlings seemed to have no problem 'pushing' through and overgrowing the weeds. Survival of the latest emerged seedlings (Feb.; 5 to 10 cm height) through the following dry season was low. In all cases *S. grandiflora* was found to emerge faster, more uniformly, and with higher initial growth rates than *S. sesban*. However, the former one reportedly does not tolerate coppicing and would thus not be very valuable in an alleycroping system [Evans D, personal communication]). The latest emerging species were *F. congesta* and *P. aculeata* – some of them as late as March. *P. aculeata*, despite its short period of establishment, was able to persist throughout the following dry season and had good survival rates (Schermer M, personal communication). The survival rate was also good, though somewhat lower, for *F. congesta* (Phirri S, personal communication).

Damage from free-ranging goats was observed in the species trial. No differences among the species were observed: all would be defoliated if left unprotected in the presence of high goat populations. Considerable mortality is anticipated for all species under these conditions.

6. Future research needs for pigeonpea in agroforestry

Additional data on the amount of pigeonpea leaf litter and fuel wood production need to be collected. At the same time, different management practices in alleycropping systems with maize should be tested. Although the cutting height used in this study (1 m) seems a reasonable practice, other heights would produce different results (influencing DM production and stand longevity) without adding significantly to the labor requirement. The optimum time of pruning – to minimize light competition and supply N for maize production – is unknown.

Considerable controversy exists about the importance of belowground interactions. It is unclear if and how much pigeonpea competes for nutrients and water and if there are any genotypic differences.

All future research should strictly address farming system constraints that have been identified locally. Labor demand should, in this sense, be given priority. We do not know the change in labor demand in alleycroping systems versus existing systems. There are indications that the labor demand might be increased. If so, how much do the pigeonpea hedges reduce weed pressure in the field? How much labor is then made available for pruning

Fig. 1. A mixed hedgerow of pigeonpea (right) and *S. grandiflora* in an alleycropping system with maize. Pigeonpea (directly seeded) and *Sesbania* (transplanted) are both approximately three months old in the field. Note heavy weed-pressure; weeds on ridge were removed for picture.

and incorporation of green manure? This should be a focus in attempts to optimize the management of alleycropping systems. Also a fair economic comparison between costs for these organic manures and inorganic fertilizers has to be established to estimate the returns to land and to labor for each system.

The potential benefits of species mixtures in the hedge rows needs to be addressed. Pigeonpea may complement other species such as *S. sesban, F. congesta,* and *P. aculeata* (see Fig. 1). This would help to diversify the system and may stabilize production and survival rates of the hedge.

7. Conclusion

In the Eastern Province of Zambia, any kind of agroforestry concept will only be adopted by farmers if immediate and noticeable returns are provided by the trees, such as food and feed, with little additional strain on the labor supply of the farming families.

In on-farm and experiment station observations, pigeonpea showed high potential to alleviate some of these constraints. Pigeonpea was easy to plant, exhibited vigorous growth, and required little attention in the field. Its labor requirements were thus low compared to other possible agroforestry species. A number of those species were found to be unsuited to the Province, having high mortality rates. Pigeonpea – an indigenous species – may prove to have a number of adaptive advantages.

Anticipating two cuttings per growing season at a height of 1 m, it was demonstrated that the N-contribution within an alleycropping system, such as with maize, can be between 40 to 50 kg N/(ha yr) from DM and 10 kg/(ha yr) from leaf litter using a very conservative calculation. At current recommended fertilizer levels for maize in the province, farmers could save their whole top-dressing by using pigeonpea as a source of organic nitrogen. However, the optimum management of such a system is still subject to further investigations.

Substantial amounts of food, recognized as such by the local people, from pods and grain, can be supplied by the plant from Jan./Feb. throughout the dry season. Simultaneously, animals were able to browse the pigeonpea. Pigeonpea's production of human food and its ease of establishment, coupled with its characteristics as a nitrogen fixing tree, make perennial pigeonpea a special choice for farmers in the Eastern Province of Zambia. The species deserves additional research to expands its use in agroforestry systems over a wider range of environments.

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