Agroforest Syst (2011) 82:275–284
DOI 10.1007/s10457-011-9396-1

The framework tree species approach to conserve medicinal trees in Uganda

Torunn Stangeland · John Tabuti · Kåre A. Lye

Received: 15 March 2010 / Accepted: 30 March 2011 / Published online: 8 April 2011

Abstract Framework species are indigenous tree species planted in a mixed stand to accelerate natural regeneration of forest and encourage biodiversity regeneration. In this study we used the framework species method to make multipurpose tree gardens to provide traditional healers with woody species used for medicine and other needs like food and firewood. We specifically determined the phenology, germination behaviour, survival and growth after planting 19 indigenous and 8 introduced woody species. The species were planted in a mixed stand together at a density of 3125 ha^{-1}. Field performance was assessed by monitoring survival, height and crown width once every month for 13 months after planting. Eleven species (*Artocarpus heterophyllus*, *Calliandra calothyrsus*, *Callistemon citrinus*, *Carica papaya*, *Carissa spinarum*, *Leucaena leucocephala*, *Markhamia lutea*, *Sarcocephalus latifolius*, *Senna siamea*, *S. spectabilis* and *Terminalia schimperiana*) proved to be excellent framework species. Eight species qualified as 'acceptable' FWS (*Albizia coriaria*, *Ceiba pentranta*, *Entada abyssinica*, *Erythrina abyssinica*, *Eugenia jambos*, *Ficus sycomorus*, *Maesopsis eminii* and *Milicia excelsa*), while seven species were ranked as 'marginally acceptable' (*Acacia macrothyrsa*, *Calpurnia aurea*, *Canarium schweinfurthii*, *Capparis tomentosa*, *Ficus natalensis*, *Senna* sp. and *Warburgia salutaris*). *Annona squamosa* was the only species rejected since both germination and survival was low. Trees with good reforestation traits could be recommended for planting while the species that were marginally acceptable or rejected require extra research since some of them are important medicinal woody species of conservation concern.

Keywords Framework species · Medicinal woody species · Seedling performance · Reaforestation

T. Stangeland (✉) · K. A. Lye
Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway
e-mail: torunn.stangeland@umb.no

J. Tabuti
Institute of Environment and Natural Resources, Makerere University, P.O. Box 7062, Kampala, Uganda

Introduction

The dry forest in Africa is one of the most degraded forests in the world, and often densely populated. Most of the rural population is poor and depend on forest resources for their livelihood. Non-timber forest products (NTFP) have been harvested by people for subsistence use and trade for thousands of years. Population increase and growing commercial trade in NTFPs, especially medicinal plants, have caused increasing concerns on the sustainability of their harvesting (Hamilton 2004; Ticktin 2004). It is estimated that up to 15,000 medicinal and aromatic plant species are threatened with extinction worldwide.

Woody species are especially threatened because they are slow growing (Hawkins 2008; Schippmann et al. 2002) and often roots and bark are used.

Medicinal plants are very important because they contribute to primary health care by providing an easily accessible and affordable source of medication. It is estimated that in Uganda, 70–80% of the population use medicinal plants for their primary health care. Medicinal plants contribute over 57% to the forest revenue in Madagascar (Walter 2001) and income in foreign earnings for Namibia from the sales of Devil's Claw (*Harpagophytum procumbens*) in 2002 was estimated at US$ 2.7 million (Cole 2003). Besides their medicinal values woody species also have other values such as provision of firewood. In Uganda, 90% of the population depends on firewood for cooking, and about 1 million earn their income from forest products (NEMA 2002).

Considering the important values that these species have, it is important that they are conserved to minimise the suffering of the marginalised who cannot afford expensive allopathic medicines, and to reduce poverty levels of practitioners and other people who depend on medicinal plants for income generation.

One conservation strategy is cultivation of these species. Cultivation has several advantages, for instance, adulteration of species is easily avoided, postharvest handling can be controlled and a steady source of uniform quality raw material can be secured (Schippmann et al. 2002). On the other hand it is possible that the content of secondary metabolites will be different for cultivated species.

In this paper we describe how we applied a modified version of the framework species (FWS) method (Blakesley et al. 2002; Elliott et al. 2003, 2008) to make multipurpose tree gardens in Kaliro District, Uganda. Seedlings of mainly local tree species were raised in a nursery and planted in one single event. Species that satisfy the FWS should have (i) a rapid and even germination, (ii) high field performance (high survival and rapid growth), (iii) dense and spreading crown that outcompete weeds and (iv) provide resources that attract seed-dispersing wildlife (fruits, nectar, nesting sites etc.). The FWS method was developed to restore forest and has proved very successful in Queensland, Australia (Tucker and Murphy 1997) where framework species plots were reported to be colonised by 15–49 naturally establishing trees within 5–7 years of planting, and in Thailand (Blakesley et al. 2002; Elliott et al. 2003). We planted seedlings of 27 woody species out of which 10 species (*Acacia macrothyrsa*, *Albizia coriaria*, *Calpurnia aurea*, *Capparis tomentosa*, *Carissa spinarum*, *Entada abyssinica*, *Erythrina abyssinica*, *Markhamia lutea*, *Sarcocephalus latifolius* and *Warburgia salutaris*) are highly preferred medicinal plants in Uganda and elsewhere (Kokwaro 1976; Heine and Heine 1988; Chhabra et al. 1987; Adjanohoun et al. 1993; Neuwinger 1996; Geissler et al. 2002; Tabuti et al. 2003; Krog et al. 2006; Kisangau et al. 2007; Ssegawa and Kasenene 2007; Tabuti 2007; Lye et al. 2008; van Wyk 2008; Tabuti et al. 2009).

The specific objectives of this study were (i) to gain knowledge about flowering and fruiting phenology and seed germination of selected medicinal trees, (ii) to assess each species as potential framework species and (iii) to find out if the framework species can be successfully used for forest restoration or establishment of community forests in Uganda.

Materials and methods

Study site

Field gardens were established in the sub-counties of Gadumire and Nawaikoke in Kaliro District. Kaliro District is situated 200 km northeast of Kampala, 33° 30′–33° 35′ E and 1° 04′–1° 15′ N at an elevation of 1030–1080 m above sea level. The district has two rainy seasons, March–May and August–September. The mean annual rainfall is 1250–1300 mm and the mean annual maximum temperature is 30–32.5°C. The district is heavily inhabited with a population density in excess of 280 people per square kilometre. Much of the original vegetation has been destroyed and the landscape converted to small scale farmland. The district is dominated by small scale farms and papyrus swamps.

Methology

Phenology

We observed the flowering and fruiting of *Capparis tomentosa* ($n = 5$), *Psorospermum febrifugum*

($n = 35$), *Sarcocephalus latifolius* ($n = 3$) and *Securidaca longipedunculata* ($n = 27$) in Nawaikoke every second week from November 2006 to November 2007; *Hallea rubrostipulata* ($n = 30$) and *Warburgia salutaris* ($n = 6$) from May 2006 to November 2007 in a tropical wet forest reserve in Sango Bay in south-western Uganda (Table 1). One of the *W. salutaris* trees died during the time of monitoring due to severe debarking. The trees were given scores from 0 to 5 for flowering and fruiting stages (Okullo et al., 2004). Zero was scored for individuals where no flowering or fruiting was observed and 5 for withering flowers and end of fruiting (75% of fruits harvested or fallen).

Seed collection and germination

We used a slightly modified FWS method, where we tested for germination traits as described by Blakesley et al. (2002), but without using a replicated experimental design. We raised seedlings for 4–12 months, planted the seedlings in three plots in Kaliro district and monitored them for survival and growth broadly as described by Elliott et al. (2003) although we monitored for 13 months instead of 17 and we did not monitor weed cover. The tree seedlings were raised in a nursery established for this purpose in Nawaikoke from March 2007 to April 2008. Most of the seeds were collected in the neighbouring farms and fallows.

The seeds were cleaned and between 20 and 200 seeds of each species were sown in polyethylene pots or germination trays and placed under shade net that removed 70% of the light. Some very small seeds, like those of *Sarcocephalus latifolius* and *Milicia excelsa* were sown in greater number and directly in seedbeds. The seeds were not pre-treated and were sown in a medium of 50/50% mixture of river sand and forest soil. We added two introduced species (*Calliandra calothyrsus* and *Leucaena leucocephala*) which fix nitrogen and improve soil quality, and some *Senna* species which grow fast and are wanted by the population for firewood (Tabuti et al. 2009). All the species are growing in the area and have proved not to be invasive.

Germination was recorded every third day. As the seedlings grew they were pricked out and transplanted to bigger polyethylene pots. The transplanting medium contained less sand, and some composted cow dung was added. The plants were watered when necessary in the dry season. The seedlings were hardened by exposing them to gradually more sun and less watering in the last 1–2 months before planting.

Planting and monitoring of growth

Three groups of Traditional Healers provided land and management of the seedlings after planting. One healer in each group arranged to have a medicinal tree garden on their own land. After a meeting and discussion we developed a written agreement, describing rights and responsibility of each party. Most importantly we agreed that the trees were not to be harvested during the first year while we monitored growth, but that afterwards the healers could harvest as they pleased. We provided seedlings and money for ploughing and fence material, while the groups of healers prepared land, put up the fence, planted the seedlings and weeded the plots three times during the first rainy season.

In March 2008 three experimental plots were selected, two in Nawaikoke and one in Gadumire. Each plot measuring 40×40 m and was prepared as described above. Holes (0.5 m in diameter and 0.5 m deep) for planting were dug and seedlings transported to the plots just before the rainy season.

Two weeks after the rain had started a mixture of 27 indigenous and some introduced seedlings (*Calliandra calothyrsus* and *Leucaena leucocephala*) were randomly planted in each plot. Depending on seedling availability, we planted from 4 to 30 seedlings of each species in each plot at a spacing of 1.8 m. Seedlings of ten more species were planted, but because less than 3 seedlings were available for each plot, we decided to not include them in this paper. Watering was only done during planting. Beans were planted between the lines during the first rainy season to provide some short term benefit and increase motivation for weeding. This also resulted in improved soil fertility by nitrogen fixation.

Sub-samples of seedlings (maximum ten of each species in every plot, 813 trees altogether) were randomly selected and labelled for subsequent monitoring. All labelled trees were monitored after 2 weeks and thereafter once every month for height, crown width, root collar diameter and health. Health was recorded on a score of 0–3 (0: dead; 3: completely healthy).

To assess the species' performance as framework species, we used the criteria advocated by Elliott et al. (2003), but modified their methods by monitoring growth for a shorter period of time. In addition the rainfall in Elliot's area was much higher than in Kaliro (2095 mm and 1275 mm respectively). According to Elliott et al. (2003), potential framework species should be assessed for germination percentage, mean length of dormancy (MLD), synchrony of germination (number of days from the first to the last seed germinated) and seedling survival, height and crown width after planting in the field. Germination is regarded to be good if 60% or more of the seeds germinate and low if less than 20% germinate. The MLD, i.e. the number of days when 50% of the seeds have germinated, is considered to be rapid if seeds take 21 days or less to germinate and slow if they take 84 days or more. Germination is defined as synchronous if all seedlings of a species emerge within 21 days, and highly asynchronous if they take more than 84 days (Blakesley et al. 2002).

The survival rate is considered to be excellent when 70% or more seedlings of any species survive after 17 months; acceptable when 50–69% survive, and marginally acceptable when 45–49% of the seedlings survive.

The crown width was monitored as an additional measure of growth and to establish the species' ability to form a closed canopy. A closed canopy will suppress weeds and create a cooler, more shady and moist environment, where forest tree seedlings can establish more easily. A crown width of 1.4 m after 13 months was considered as excellent, 1–1.39 m as acceptable and less than 0.6 m as not acceptable. We considered a mean height of 1.6 m after 13 months as excellent, 1–1.59 m as acceptable and 0.6–0.99 m mean height as marginally acceptable for woody species in this dry area.

The number of saplings of each species monitored 13 months after planting ranged from 3 to 29. This variation in number was due to variation in availability of seeds/seedlings, seedling mortality in the nursery prior to planting and survival in the plots (Table 2).

Results

Phenology

Sarcocephalus latifolius portrayed a bi-modal fruiting pattern, producing fruits during December, and from February to August. A similar trend was observed for *Warburgia salutaris*, where fruits were produced in September and March. *Securidaca longipedunculata* had produced seeds in November–December during the first year of monitoring, but in the subsequent year fruits did not develop as the flowers were destroyed by a hailstorm in May. *Psorospermum febrifugum* only had one long fruiting period of 7 months (Table 1). *Capparis tomentosa* did not produce flowers or fruits during the time of observation.

Germination

Germination ranged from 7 to 100% among the 27 species of mainly indigenous trees and shrubs in the experiment (Table 2). Nearly half of the species (*Artocarpus heterophyllus*, *Calliandra calothyrsus*, *Callistemon citrinus*, *Canarium schweinfurthii*, *Capparis tomentosa*, *Carica papaya*, *Carissa spinarum*, *Erythrina abyssinica*, *Eugenia jambos*, *Leucaena leucocephala*, *Maesopsis eminii*, *Markhamia lutea*,

Table 1 Phenology data recorded every second week for some indigenous medicinal trees in Uganda

Species	Flowering	Fruiting
Sarcocephalus latifolius	Not observed	Fruited in December 2006. Fruited again in February through to mid August 2007
Securidaca longipedunculata	18 of 26 trees flowered at the beginning of April. All flowers were destroyed by a hailstorm on the 1st of May 2007.	8 of 27 trees fruited in November–December 2006.
Psorospermum febrifugum	Flowered from April to July 2007	Fruited from April to November.
Warburgia salutaris	June–August 2006	Peak fruiting was recorded in September 2006 and March 2007.

Table 2 Seed germination data for potential framework tree species in East Uganda

Scientific name	Local name	Family	Major use	Seed collection month	% germination	MLG	Synchrony of germination	Germination and synchrony categories
Acacia macrothyrsa	Muwologoma	Mimosaceae	M	September	18	12	7	RG/S
Albizia coriaria	Musita	Mimosaceae	T, M, Ch	May	56	9	21	RG/S
Annona squamosa	Mustaferi	Annonaceae	F, M	November	43	33	24	IG/IS
Artocarpus heterophyllus	Fene	Moraceae	F	July	61	21	27	RG/IS
Calliandra calothyrsus	Calliandra	Mimosaceae	SI, Fod	Seeds from NTSC	57	12	21	RG/S
Callistemon citrinus[a]	Bottle brush	Myrtaceae	Fw, M	April	80	15	38	RG/IS
Calpurnia aurea	Lumanyo	Rabaceae	M. Fw	September	19	15	27	RG/IS
Canarium schweinfurthii	Mpafu	Burseraceae	T, F, M	October	100	50	39	IG/IS
Capparis tomentosa	Muzingani	Capparidaceae	M	August	100	10	14	RG/S
Carica papaya	Papali	Caricaceae	F, M	July	88	17	12	RG/S
Carissa spinarum	Mutyoga	Apocynaceae	F, M	August	68	38	6	IG/S
Ceiba pentandra	Mufamba	Bombacaceae	M, Fod	June	8	45	21	IG/S
Entada abyssinica	Musambamadhi	Mimosaceae	M	April	46	27	1	IG/S
Erythrina abyssinica	Musitisiti	Fabaceae	M	April	60	23	21	RG/IS
Eugenia jambos	Muzabibu	Myrtaceae	F	April	60	na	na	na
Ficus natalensis	Mukosi	Moraceae	M, S, bark cloth	Cuttings	na	na	na	na
Ficus sycomorus	Mukunyu	Moraceae	S, M	July seeds/ cutting	7	20	1	RG/S
Leucaena leucocephala	Lusina	Mimosaceae	Si	March	83	31	18	IG/S
Maesopsis eminii	Musizi	Rhamnaceae	T, M	March	100	31	18	IG/IS
Markhamia lutea	Musambya	Bignoniaceae	T, Th, M	March	65	11	10	RG/S
Milicia excelsa	Muvule	Moraceae	T, Hc	March	60	24	14	IG/S
Sarcocephalus latifolius[c]	Mutamatama	Rubiaceae	M	December	60	15	15	RG/S
Senna siamea	Gassia seed	Caesalpiniaceae	M, Fw	May	39	47	16	IG/IS
Senna grandis	No local name	Caesalpiniaceae	Fw	May	16	29	93	IG/AS
Senna spectabilis	Gassia kibiliti	Caesalpiniaceae	Fw, Ch, Th	April	39	8	30	RG/IS
Terminalia schimperiana	Mukonge	Combretaceae	M	April	32	na	na	na
Warburgia salutaris[a,b]	Balwegira	Canellaceae	M, T	March	32	33	67	IG/IS

M medicine, *Ch* charcoal, *F* food, *T* timber, *Fw* firewood, *Si* soil improvement, *S* shade, *Fod* fodder, *Th* tool handles, *Hc* house construction, *RG* rapid germination, *IG* intermediate germination, *SG* slow germination, *S* synchronous, *IS* intermediate synchrony, *AS* asynchronous

[a] Sowing experiment at National tree seed centre, [b] Tree growing in tropical wet forest, [c] laboratory experiment (Stangeland et al. 2007)

Table 3 Survival, mean tree height and mean crown width 13 months after planting of tree species

Scientific name	No. of trees planted	Initial number monitored	% survival	n[a]	Mean height (cm)[b]	Mean crown width (cm)[b]
Acacia macrothyrsa (TS 214)	13	13	23.1	3	98 (36)	109 (36)
Albizia coriaria (TS 119)	60	28	75	21	64 (5)	57 (4)
Annona squamosa (TS 365)	39	23	17.4	4	74 (8)	35 (6)
Artocarpus heterophyllus (JRST 459)	60	30	80	24	127 (9)	59 (8)
Calliandra calothyrsus (TS 352)	15	14	92.9	13	257 (14)	192 (26)
Callistemon citrinus (TS 344)	45	30	73.3	22	185 (18)	112 (11)
Calpurnia aurea (TS 219)	45	27	25.9	7	125 (18)	78 (14)
Canarium schweinfurthii (JRST 538)	36	24	12.5	3	59 (11)	54 (14)
Capparis tomentosa (TS 5, 9, 10, 118)	57	27	74.1	20	47 (4)	42 (5)
Carica papaya (JRST 506)	20	16	75	12	204 (14)	203 (16)
Carissa spinarum (TS 348)	60	30	93.3	28	147 (8)	160 (7)
Ceiba pentandra (TS 202)	60	28	100	28	235 (9)	149 (8)
Entada abyssinica (TS 349)	45	29	62.1	18	129 (18)	76 (12)
Erythrina abyssinica (JRST 26)	30	29	72.4	21	75 (8)	53 (8)
Eugenia jambos (TS 204)	60	28	78.6	22	71 (4)	53 (5)
Ficus natalensis (JRST 477)	21	19	42.1	8	77 (11)	29 (7)
Ficus sycomorus (JRST 472)	33	28	92.9	26	168 (10)	127 (9)
Leucaena leucocephala (TS 360)	60	29	93.1	27	222 (12)	157 (13)
Maesopsis eminii (TS 355)	30	20	10	2	132 (52)	134 (67)
Markhamia lutea (TS 398)	60	30	93.3	28	144 (11)	82 (7)
Milicia excelsa (JRST 500)	60	30	86.7	26	108 (4)	75 (5)
Sarcocephalus latifolius (TS1, 3, 16)	90	29	96.7	29	211 (15)	264 (18)
Senna siamea (JRST 262)	45	28	92.9	26	319 (18)	257 (24)
Senna sp.(TS 362)	30	30	60	18	120 (16)	115 (19)
Senna spectabilis (TS 343)	12	12	83.3	10	409 (48)	230 (41)
Terminalia schimperiana(TS 351, 354)	18	18	100	18	155 (7)	147 (8)
Warburgia salutaris (TS 109)	60	26	42.3	11	84 (9)	63 (7)

[a] Subsamples of surviving trees

[b] Values in brackets represent SE of mean

Milicia excelsa and *Sarcocephalus latifolius*) had a germination of 60% or higher which is regarded as good for this kind of nursery production. Five of the species (*Acacia macrothyrsa*, *Ceiba pentandra*, *Ficus sycomorus*, *Calpurnia aurea* and *Senna grandis*) had low germination of less than 20%. For dry forest species like these, even less than 20% germination can be acceptable. Since we wanted to explore the germination traits of the different seeds, we did not pretreat them. Seeds of both *Capparis tomentosa* and *Warburgia salutaris* are known to lose viability quickly after harvesting. Seeds of *C. tomentosa* were sown immediately after collection and achieved 100% germination while seeds of *W. salutaris* were not sown until 2 weeks after collection (for logistical reasons) and only 32% germinated.

Mean length of germination across all species varied between 8 and 50 days and synchrony of germination varied between 1 and 93 days (Table 3). Thirteen of the species had rapid germination (≤21 days), only one, *Senna grandis*, had asynchronous germination while the rest had intermediate germination (between 21 and 84 days).

Survival

Of the 27 species of trees planted, 18 or 67% had excellent survival rates ranging between 72 and 100%

13 months after planting (Table 2); these species are *Albizia coriaria*, *Artocarpus heterophyllus*, *Calliandra calothyrsus*, *Callistemon citrinus*, *Capparis tomentosa*, *Carica papaya*, *Ceiba pentantra*, *Carissa spinarum*, *Erythrina abyssinica*, *Eugenia jambos*, *Ficus sycomorus*, *Leucaena leucocephala*, *Markhamia lutea*, *Milicia excelsa*, *Sarcocephalus latifolius*, *Senna siamea*, *S. spectabilis* and *Terminalia schimperiana*. Seven species had unacceptable survival rates between 13 and 42%.

Growth

Nine of the species planted (*Calliandra calothyrsus*, *Callistemon citrinus*, *Carica papaya*, *Ceiba pentandra*, *Ficus sycomorus*, *Leucaena leucocephala*, *Sarcocephalus latifolius*, *Senna siamea* and *S. spectabilis*) showed excellent growth of 1.6 m or higher (Table 4), eight displayed acceptable height of 1 m or more, four species had marginally acceptable growth

Table 4 Summary of framework species classification based on field performance

Species	% germination[a]	Survival[b]	Growth[c]	Crown width[d]	Overall classification
Acacia macrothyrsa	L	U	M	M	M
Albizia coriaria	M	E	U	M	A
Annona squamosa	M	U	M	U	R
Artocarpus heterophyllus	G	E	A	M	E
Calliandra calothyrsus	M	E	E	E	E
Callistemon citrinus	G	E	E	A	E
Calpurnia aurea	L	U	A	M	M
Canarium schweinfurthii	G	U	U	M	M
Capparis tomentosa	G	E	U	U	M
Carica papaya	G	E	E	E	E
Carissa spinarum	G	E	A	E	E
Ceiba pentandra	L	E	E	E	A
Entada abyssinica	M	A	A	M	A
Erythrina abyssinica	G	E	U	M	A
Eugenia jambos	G	E	U	M	A
Ficus natalensis		M	M	U	M
Ficus sycomorus	L	E	E	A	A
Leucaena leucocephala	G	E	E	E	E
Maesopsis eminii	G	U	A	A	A
Markhamia lutea	G	E	A	M	E
Milicia excelsa	G	E	M	M	A
Sarcocephalus latifolius	G	E	E	E	E
Senna siamea	M	E	E	E	E
Senna sp.	L	A	A	A	M
Senna spectabilis	M	E	E	E	E
Terminalia schimperiana	M	E	A	E	E
Warburgia salutaris	M	M	U	M	M

E excellent, *G* good, *L* low, *A* acceptable, *M* marginally acceptable, *U* unacceptable, *R* rejected

[a] G > 60%, M = 20–59.9%, L < 20%

[b] E > 70%, A = 50–69.9%, M = 40–49.9%, U < 40%

[c] E > 1.6 m, A = 1.0–1.59, M = 0.6–0.99, U < 0.59

[d] E > 1.4 m, A = 1.0–1.39 m, M = 0.6–0.99 m, U < 0.6 m

of 0.6 to 0.99 cm, and six species had unacceptable growth of less than 0.59 m.

Crown width

Nine of the species had excellent crown width of 1.4 m or more 13 months after planting, only four had acceptable crown width of 1–1.39 m; while eleven had marginal (0.6–0.99 m) and three had unacceptable crown width of less than 0.6 m (Table 4).

Discussion

This study quantifies for the first time germination traits and field performance of 27 woody species growing in Uganda. Botanic Gardens Conservation International regards five of these species to be medicinal trees of conservation concern (*Albizia coriaria*, *Carissa spinarum*, *Erythrina abyssinica*, *Markhamia lutea*, and *Warburgia salutaris;* Hawkins 2008). Another two species, *Sarcocephalus latifolius* and *Markhamia lutea* are very rare or rare and decreasing in Nawaikoke, Uganda (Tabuti et al. 2009). *Capparis tomentosa* was the top priority for a group of healers in Gadumire when selecting important medicinal plants that are becoming increasingly difficult to find. *C. spinarum* and *S. latifolius* are both important medicinal plants, but harvesting practices have been detrimental since few trees are left and mostly bark and roots are used (Tabuti et al. 2009).

Phenology studies are important during domestication of woody species because they facilitate seed collection and give information on the best sowing procedures. Phenology data on five important medicinal woody species are presented here for the first time. The low number observed for three of them (*C. Tomentosa*, *S. latifoilius* and *W. Salutaris*) reflects how rare they are, no more individuals were found in the areas studied. We did not observe flowering of *S. latifolius* probably due to a very ephemeral flowering phenophase, but during the time of monitoring we recorded two fruiting periods for both *S. latifolius* and *W. salutaris*. Germination success, mean length of dormancy and synchrony of germination are regarded as important traits for species raised in nurseries for use in tree planting and reforestation. In this study 48% of the trees studied had good germination (higher than 60%). This contrasted with observations by Elliott et al. (2003), where 80% of the species had good germination. African tree species may thus have lower germination success or greater need of pre-treatment than Asian species. Further work should focus on establishing seed pre-treatments that improve germination. Several *Acacia* and *Senna* species have thick seed coats and achieve higher germination success when pretreated (Katende et al. 1995). Nevertheless, survival was satisfactory as 63% species planted had an excellent survival rate of 70% or more, even though Kaliro district suffered a severe drought in 2009, and the rains did not start until the beginning of April. This is in line with Elliott et al. (2003) where they planted seedlings in two succeeding years. Of the seedlings planted in 1998 eighty % had an excellent survival, while for the seedlings planted in 1999 only 28% of the species had excellent survival, probably due to dry weather after planting.

Eleven of the 27 tree species planted (*Artocarpus heterophyllus*, *Calliandra calothyrsus*, *Callistemon citrinus*, *Carica papaya*, *Carissa spinarum*, *Leucaena leucocephala*, *Markhamia lutea*, *Sarcocephalus latifolius*, *Senna siamea*, *S. spectabilis* and *Terminalia schimperiana*) proved to be excellent framework species (Table 3). Eight species qualified as 'acceptable' FWS (*Albizia coriaria*, *Ceiba pentranta*, *Entada abyssinica*, *Erythrina abyssinica*, *Eugenia jambos*, *Ficus sycomorus*, *Maesopsis eminii* and *Milicia excelsa*), while six species were ranked as 'marginally acceptable' (*Acacia macrothyrsa*, *Canarium schweinfurthii*, *Capparis tomentosa*, *Ficus natalensis*, *Senna* sp. and *Warburgia salutaris*). *Annona squamosa* was the only species rejected since both germination and survival was low.

We started to raise seedlings 1 year before planting, but we experienced that this was early. Probably we needed between three and 6 months to raise many of the species, as they were growing rapidly in nursery, and would probably have performed better if planted when smaller.

Capparis tomentosa, *Albizia coriaria* and *Warburgia salutaris* grew slowly in our experiment. The first two are dry land or dry forest species and may be slow growing when they establish naturally as well. Even if they do not qualify as FWS, it is important to include them in these tree gardens as they are important medicinal plants and are becoming rare.

W. salutaris is a wet forest species, and probably suffered from the drier climate in Kaliro. A cultivation experiment in South Africa has proved that a key to success for planting medicinal plants is that the species are located in a similar site to their natural habitat (Mander et al. 1996).

There is a debate as to whether cultivation is the best way of conserving medicinal plants and securing supply. It has been argued that collection from the wild will continue to be the best option, simply because it costs less money and is time efficient (Schippmann et al. 2002). However, small-scale cultivation that requires low economic inputs could be a good way of responding to decreasing local stocks, generating income and supplying local and regional markets. Nevertheless, cultivated medicinal plants are regarded as less valuable in some cultures; it is believed that they 'lose power' if cultivated (Wiersum et al. 2006). Scientific studies partly support this belief. The medicinal effects of plants usually depend on the presence of secondary metabolites which the plants produce to protect themselves against enemies such as bacteria, fungi, insects and other herbivores. The quantity of compounds produced is related to the hazards of the natural environment. Large scale cultivation with the addition of fertiliser and water will reduce stress and thereby probably reduce the production of secondary metabolites (Schippmann et al. 2002).

The minimum acceptable performance standards proposed in this paper should not be regarded as absolute; they must be used with flexibility and the methods used adjusted to each area, as recommended by Elliott et al. (2003).

Conclusion

We found the Framework species method to be a useful tool to test which medicinal trees can be cultivated. In Uganda mainly *Eucalyptus* and *Pinus* species are planted both for timber production and restoration of forests. We believe that the FWS method is a good way of finding alternative candidates for community forests and restoration in a way that can satisfy different needs of the population and minimise the threat of habitat degradation and species extinction.

We propose planting a mixture of local medicinal tree species in a multipurpose tree garden, since this will probably not influence the chemical content of the planted species as much as planting in monocultures. However this will have to be tested in further work. At the same time, the tree garden would provide people with a wide variety of products needed such as food, fodder, fire-wood and building material in addition to medicinal plants.

In our research we tried to target problems experienced by traditional healers and the rural population. The healers received training, information about results, the nursery was handed over to them and they were left with around 1000 trees to manage and harvest. We believe that establishing community forests or private multipurpose tree gardens are good ways of securing the rural poor with much needed forest products, and counteract the deforestation; efforts needed in most African counties. We found the framework species method to be a useful tool to establish multipurpose community forests. However, support from governments or NGOs to provide knowledge and funding to establish small tree nurseries are needed.

Acknowledgments We thank Uganda National Council for Science and Technology (NS 202) for granting research permit for this project. Voucher specimens are stored at Makerere University Herbarium (MHU) and at the University in Oslo (O). We thank the NGO Compass that funded some of the fieldwork, Sebastian Walaita from Uganda National Tree Seed Centre for giving valuable advice in the establishment of the nursery and collection of seeds, and Charles Wambuzi for lending us land for the nursery. The authors are especially grateful to all the Traditional Healers in Bulamogi Traditional Healers Organisation that shared their knowledge and took part in the work; and all the field assistants including Rose Akello (RIP), Juliet Kawudha, Lillian Budjiri, Joseph Solomon Kalule and Dennis Ssebugwawo.

References

Adjanohoun JE, Ahyi MRA, Aké Assi L, Amai CA, Gbile ZO, Johnson CLA, Kakooko ZO, Lutakome HK, Morakinyo O, Mubiru NK, Ogwal-Okeng JW, Sofowora EA (1993) Contribution to ethnobotanical and floristic studies in Uganda. Scientific, Technocal and Research commission of the Organisation of African Unity (OAU/STRC)

Blakesley D, Elliott S, Kuarak C, Navakitbumrung P, Zangkum S, Anusarnsunthorn V (2002) Propagating framework tree species to restore seasonally dry tropical forest: implications if seasonal seed dispersal and dormancy. For Ecol Manage 164:31–38

Chhabra SC, Mahunnah RLA, Msiu EN (1987) Plants used in traditional medicine in Eastern Tanzania. I. Pteridophytes and Angiosperms (Acanthaceae to Canellaceae). J Ethnopharmacol 21:253–277

Cole D (2003) The impact of certification on the sustainable use of devil's claw (*Harpagophytum procumbens*) in Namibia. Paper prepared for FAO, Non-wood forest programme, p 34

Elliott S, Blakesley D, Chairuangsri S (2008) Research for restoring tropical forest ecosystems: a practical guide. www.forru.org. Accessed 2 February 2009

Elliott S, Navakitbumrung P, Kuarak C, Zankum S, Anusarnsunthorn V, Blakesley D (2003) Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. For Ecol Manage 184:177–191

Geissler W, Harris SA, Prince RJ, Olsen A, Odhiambo RA, Oketch-Rabah H, Madiega PA, Andersen A, Molgaard P (2002) Medicinal plants used by mothers and children in Bondo district, Kenya. J Ethnopharmacol 83:39–54

Hamilton AC (2004) Medicinal plants, conservation and livelihoods. Biodivers Conserv 13:1477–1517

Hawkins B (2008) Plants for life: medicinal plant conservation and botanic gardens. Botanic Gardens Conservation International, Richmond, UK

Heine B, Heine I (1988) Plant concepts and plant use. An ethnobotanical survey of the Semi-Arid and Arid Lands of East Africa. Part I. Plants of the Chamus (Kenya). Kölner Beiträge zur Entwicklungsländerforchung, vol. 6. Breitenbach Publishers, Saarbrücken & Fort Lauderdale

Katende AB, Birnie A, Tengnäs B (1995) Useful trees and shrubs for Uganda. Regional Soil Conservation Unit (RSCU), Kenya

Kisangau DP, Hosea KM, Joseph CC, Lyaruu HVM (2007) In vitro antimicrobial assay of plants used in traditional medicine in Bukoba rural district, Tanzania. Afr J Trad, Compl Altern Med 4:510–523

Kokwaro JO (1976) Medicinal plants of East Africa. East African Literature Bureau, Nairobi

Krog M, Falcao MP, Olsen CS (2006) Medicinal plant markets and trade in Maputo, Mozambique. Forest & Landscape Working Papers No 16-2006, Danish Centre for Forest, Landscape and Planning, KVL, Denmark

Lye KA, Bukenya-Ziraba R, Tabuti JRS, Waako PJ (2008) Plant medicinal dictionary for East Africa. Makerere Herbarium handbook no. 2. Makerere University, Kampala, Uganda

Mander M, Mander J, Breen C (1996) Promoting the cultivation of indigenous plants for markets. Experiences from KwaZulu-Natal, South Africa. In: Leakey RRB, Temu AB, Melnyk M, Vantomme P (eds) Domestication and commercialization of non-timber forest products in agroforestry systems. FAO (Non-wood forest products 9), Rome, pp 104–109

NEMA (National Environmental Management Authority) (2002) State of the environment report for Uganda 2002. National Environmental Management Authority, Kampala, Uganda

Neuwinger HD (1996) African ethnobotany. Poisons and drugs. Chapman & Hall, Weinheim

Okullo JBL, Hall JB, Obua J (2004) Leafing, flowering and fruiting of *Vitellaria paradoxa* subsp. *nilotica* in savanna parklands in Uganda. Agrofor Syst 60:77–91

Schippmann U, Leaman DJ, Cunningham AB (2002) Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues. Inter-department working group on biology diversity for food and agriculture. FAO, Rome

Ssegawa P, Kasenene JM (2007) Medicinal plant diversity and uses in the Sango Bay area, Southern Uganda. J Ethnopharmacol 113:521–540

Stangeland T, Tabuti JRS, Lye KA (2007) The influence of light and temperature on the germination of two Ugandan medicinal trees. Afr J Ecol 46:565–571

Tabuti JRS (2007) The uses, local perceptions and ecological status of 16 woody species of Gadumire Sub-county, Uganda. Biodivers Conserv 16:1901–1915

Tabuti JRS, Lye KA, Dhillion SS (2003) Traditional herbal drugs of Bulamogi, Uganda: Plants, use and administration. J Ethnopharmacol 88(1):19–44

Tabuti JRS, Ticktin T, Arinaitwe MZ, Muwanika VB (2009) Community attitudes and preferences towards woody species and their implications for conservation in Nawaikoke Sub-count, Uganda. Oryx 43(3):393–402

Ticktin T (2004) The ecological implications of harvesting non-timber forest products. J Appl Ecol 41:11–21

Tucker NIJ, Murphy TM (1997) The effects of ecological rehabilitation on vegetation recruitment: some observation from the wet Tropics of North Queenland. For Ecol Manage 99:133–152

van Wyk B-E (2008) A broad review of commercially important southern African medicinal plants. J Ethnopharmacol 119:342–355

Walter S (2001) Non-wood forest products. In: Africa: a regional and national overview. FAO working paper. FOPW/01/1

Wiersum KF, Dold AP, Husselman M, Cocks M (2006) Cultivation of medicinal plants as a tool for biodiversity conservation in the Amatola Region, South Africa. In: Bogers RJ, Craker LE, Lange D (eds) Medicinal and aromatic plants. Springer, Netherlands, pp 43–57