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Village-based tropical pasture seed production in Thailand and Laos – a success story

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Abstract

Seed of 6 forage species, Mulato II hybrid brachiaria (*Brachiaria ruziziensis* x *B. decumbens* x *B. brizantha*), Cayman hybrid brachiaria (*B. ruziziensis* x *B. decumbens* x *B. brizantha*), Mombasa guinea (*Panicum maximum*), Tanzania guinea (*P. maximum*), Ubon stylo (*Stylosanthes guianensis* var. *vulgaris* x var. *pauciflora*) and Ubon paspalum (*Paspalum atratum*), is currently being produced by more than 1,000 smallholder farmers in villages in northeast Thailand and northern Laos, under contract to Ubon Forage Seeds, Faculty of Agriculture, Ubon Ratchathani University, Thailand. The seed is mainly exported (95%), with the remainder sold within Thailand. Tropical Seeds LLC, a subsidiary of a Mexican seed company, Grupo Papalotla, employs Ubon Forage Seeds to manage seed production, seed sales and export, and to conduct research on new forage species. This paper details how the development of a smallholder-farmer seed-production program in Thailand and Laos produced positive social and economic outcomes for the village seed-growers. In addition, the strong emphasis on seed quality, high purity, high vigor and high germination enabled pasture growers in more than 20 tropical countries in Asia, Africa, the Pacific and Central and South America, to establish more than 20,000 ha of pastures over the past 3 years.

Resumen

En aldeas de Tailandia y norte de Laos existen más de 1,000 pequeños agricultores dedicados a la producción de semillas de los híbridos de braquiaria (*Brachiaria ruziziensis* x *B. decumbens* x *B. brizantha*) cvs. Mulato II y Cayman; guinea (*Panicum maximum*) cvs. Mombasa y Tanzania; *Stylosanthes guianensis* cv. Ubon stylo y *Paspalum atratum* cv. Ubon paspalum, en contrato con Ubon Forage Seeds, Faculty of Agriculture, Ubon Ratchathani University, Tailandia. El 95% de las semillas producidas es exportado y el restante 5% vendido localmente. La Tropical Seeds LLC, una subsidiaria de la compañía mexicana de semillas del Grupo Papalotla, contrata a Ubon Forage Seeds para manejar la producción, venta y exportación de semilla y para conducir investigaciones en búsqueda de nuevos cultivares forrajeros. En este documento se presenta la forma cómo un programa de producción de semilla por productores aldeanos en Tailandia y Laos ha resultado en impactos positivos para los pequeños productores, desde el punto de vista social y económico. Adicionalmente, productores de forrajes en más de 20 países tropicales de Asia, Africa, la región del Pacífico y de Centro y Suramérica se han beneficiado de semilla de alta calidad, en términos de pureza, vigor y germinación, para el establecimiento de más de 20,000 ha en los últimos 3 años.

Introduction

Seed of 6 forage species, Mulato II hybrid brachiaria (*B. ruziziensis* x *B. decumbens* x *B. brizantha*), Cayman hybrid brachiaria (*B. ruziziensis* x *B. decumbens* x *B. brizantha*), Mombasa guinea (*Panicum maximum*), Tanzania guinea (*P. maximum*), Ubon stylo (*Stylosanthes guianensis* var. *vulgaris* x var. *pauciflora*) and Ubon paspalum (*Paspalum atratum*), are currently produced by more than 1,000 smallholder farmers in villages in northeast Thailand and northern Lao PDR (subsequently referred to as Laos). The seed, over 130 t in 2012-13, is mainly exported (95%), with the remainder sold within Thailand.

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Tropical Seeds LLC, a subsidiary of a Mexican seed company, Grupo Papalotla, employs Ubon Forage Seeds in the Faculty of Agriculture, Ubon Ratchathani University, Thailand, to manage seed production, seed sales and export, and to conduct research on existing and new forage species. In 2003, Tropical Seeds LLC made the business decision to come to Thailand to produce brachiaria hybrid seed, because of high forage seed quality, smallholder experience and professionalism in Thailand (Hare 1993) and Ubon Ratchathani University's involvement in forage seed production (Hare and Horne 2004; Hare 2007). The company also wanted to access the Asian and Pacific markets for forage seed. In addition, there was an expectation that seed yields of brachiaria hybrids in Thailand, where agronomic management was intensive and seed was hand-harvested from small fields, might be higher than in Brazil and Mexico, where management was extensive and seed was swept from the ground in large fields.

The Ubon Forage Seeds group in the Faculty of Agriculture at Ubon Ratchathani University, had been involved in tropical forage seed research since 1995, and had built up an international reputation for excellence in forage seed production. A Memorandum of Understanding was signed in 2004 between Tropical Seeds LLC and the Faculty to produce, for export, tropical forage seed in villages in northeast Thailand. This Memorandum was further strengthened in 2008 and 2011, with the signing of 3-year contracts between the same parties.

In this joint venture, commercial seed production commenced with Mulato II hybrid brachiaria. However, with the development of a strong export market for seed, other species are now being produced commercially, including Cayman hybrid brachiaria, Mombasa guinea, Tanzania guinea, Ubon stylo and Ubon paspalum.

In 2007, Happy Farmers, an agricultural company in Laos, started producing seed of Mulato II hybrid brachiaria in northern Laos under contract to Ubon Forage Seeds and Tropical Seeds LLC. In 2012, Mulato 2 Co. Ltd took over production from Happy Farmers.

Ubon Forage Seeds is currently the major producer of forage seeds in Thailand and contracts the Mulato 2 Co. Ltd to manage seed production in Laos. Ubon Forage Seeds is the only enterprise exporting perennial forage seeds internationally from southeast Asia. The Thailand Department of Livestock Development, which for many years produced several hundred tonnes of forage seeds, has now reduced its production due to budget restrictions. It produces mainly on government stations and sells only within Thailand. Some agricultural trading companies in Thailand buy Tanzania guinea and ruzi grass (*Brachiaria ruziziensis*) from private farmers, but this seed is generally not cleaned, and while cheap, it usually has very low germination. In addition, some small Japanese companies contract farmers to produce foundation seed of several fine-stemmed guinea grass cultivars and other minor species for the Japanese market. In southern Thailand, there is regular annual seed production of puero (tropical kudzu, *Pueraria phaseoloides*), centro [*Centrosema molle* (syn. *C. pubescens*)] and calopo (*Calopogonium mucunoides*) for use as cover crops in the oil palm plantations in Thailand and Malaysia.

This paper discusses in detail seed production of the 6 forage species listed above, and how the development of a smallholder seed-production program produced positive social and economic outcomes for the village seed-growers and enabled many smallholder farmers in other countries to receive high quality forage seed. The strong emphasis on seed quality, high purity, high vigor and high germination impacted strongly on pasture development in more than 20 tropical countries in Asia, Africa, the Pacific and Central and South America, enabling pasture growers to establish more than 20,000 ha of pastures over the past 3 years.

Mulato II and Cayman hybrid brachiaria

Seed research

Good seed yields of Mulato II and Cayman have been very difficult to achieve, although both produce sufficient inflorescences, racemes and spikelets to indicate a potential for useful seed yields. By seed harvest, there is usually a massive failure of seed set, caryopsis maturation or both, with the cleaned seed coming from fewer than 9% of the spikelets formed by the crops. Weather conditions during seed maturation (October-November) in northeast Thailand are generally suitable for seed set, with bright sunshine and no rain. The failure of seed set is probably due to pollen sterility; Risso-Pascotto et al. (2005) showed that more than 65% of pollen grains of brachiaria hybrids were sterile and that this sterility was genetic.

A series of field experiments were conducted in Thailand to try to increase seed yields through agronomic management. The experiments were mainly with Mulato II, but the results can be applied to Cayman (Pizarro et al. 2013). While Cayman produces similar seed yields to Mulato II and flowers a month earlier, its release in 2011 resulted from its stronger tolerance of waterlogging than Mulato II (Pizarro et al. 2013).

Mulato II seed crops planted at the beginning of May and June produced more seed (mean of 124 kg/ha) when

harvested in mid-November than crops planted in July and August (mean of 27 kg/ha) and harvested in late November (Hare et al. 2007a). If farmers want both forage and seed in the same year, we recommend using seedlings for planting Mulato II seed crops in Thailand as early as possible in the wet season (June), in order to produce a strong root system and to maximize the number of reproductive tillers. However, a closing date cut towards the end of July (cutting to between 5 and 10 cm above ground level) must be imposed on crops planted early (May-June), or severe lodging can occur in September before flowering. If the closing cut occurs in August and September, it will severely reduce seed yields (Hare et al. 2007b).

In practice, many Thai farmers find cutting difficult on their large areas (up to 3 ha), and there is too much forage for them to handle. These seed-producing farmers also do not need the forage, as many of them do not raise livestock. They prefer to plant in late June to mid-July as these crops do not have to be cut and do not lodge. Farmers in Laos, who plant smaller areas, have no problems in cutting their seed crops in July.

We also investigated various methods of seed harvesting. Tying light-weight nylon net bags over seed heads at anthesis to collect seed, yielded twice as much seed of Mulato II (508 kg/ha) as 3 methods of knocking seed from seed heads (252 kg/ha) without any reduction in viability (Hare et al. 2007c). Higher yields are achieved with nylon bags, because nylon bags catch all seeds as they mature and are shed from the seed heads. In contrast, with knocking, a lot of seed falls to the ground before farmers can harvest, especially if strong winds and heavy rain storms occur during the night.

Farmer seed production

Seed is produced in Nong Saeng village, Roi-et province (16° N; 130 masl) in Thailand and in several villages in Nga district, Oudomxay province (23° N; 500 masl) in Laos. The system used varies between the two countries. At the beginning of each wet season in Thailand and for the first year in Laos, each farmer receives 0.5−1.0 kg seed to plant a nursery. The farmers transplant 4- to 6-week-old seedlings into cultivated fields in Thailand in June and July. In Laos, the fields are on very steep hill slopes and so are not cultivated, and seedlings are directly planted in late May-June into small holes dug with a hoe. The time of planting in both countries depends mainly on available soil moisture. In Thailand, seedlings are planted in rows 80–90 cm apart and at spacings of 50−60 cm within the rows, while in Laos, farmers plant at wider spacings of 1−1.25 m between rows and 60−70 cm within rows. Farmers in Thailand replant Mulato II each year, because Mulato II seed crops in Thailand are grown on very poor soils and produce uneconomic seed yields in the second and subsequent years, even with fertilizer. In Laos, on richer soils without fertilizer, many farmers have produced consistently good yields (250−280 kg/ha) for 6 years.

For seed harvesting in Nong Saeng village, Thailand, the farmers allow the seed to fall to the ground. In late December-January, they cut all vegetation to ground level and remove it from the field. Seed on the ground is swept up, along with lots of sand, soil, leaves and other litter. The seed is firstly cleaned in the field through screens and then winnowed in cane trays back at their houses or cleaned through small seed cleaners provided by Ubon Forage Seeds.

In second-year and older seed crops in Nga district, Odumxay province, Laos, farmers cut Mulato II plants to ground level in July to prevent them growing too tall and lodging before flowering in October. In September, the leaves of each plant are tied together to make an upright bunch, and in late October the process is repeated with the stems just before anthesis to make living sheaves (Kowithayakorn and Phaikaew 1993). The seed is knocked into cane trays or baskets every 1−2 days, dried slowly in the shade for 1−2 weeks and then sun-dried for 4−5 days before cleaning and winnowing using cane trays. The seed is dried again prior to sale to reach 10% seed moisture.

In January, the Mulato 2 Co. Ltd purchases the seed from the Laos villages and trucks it through Laos, across the Mekong River, to Ubon Forage Seeds at Ubon Ratchathani University, Thailand, a distance of nearly 1,500 km. In February, the seed from Nong Saeng village, Thailand, is purchased. At the University, all seed is treated with sulfuric acid to remove the lemma and palea husks to improve seed germination, and is then washed, dried and re-cleaned before packaging for sale and export.

After acid-scarification, Mulato II and Cayman seeds average 88−91% viability (tetrazolium test), 70−90% germination and over 99.5% purity. Without acid-scarification, the seed fails to exceed 30% germination, and even long-term storage will not increase germination, owing to the physical dormancy imposed by the tightly bound lemma and palea husks (Hare et al. 2008).

In Thailand, production of Mulato II seed has increased steadily since first harvests in 2004 (Table 1). From 2004 to 2009, farmers harvested Mulato II seed by tying seed heads and knocking seeds out into large baskets. However, yields were low, averaging only 196 kg/ha. These farmers generally were disappointed with

Table 1. Mulato II seed production in Thailand.

Year	No. farmers	No. villages	Province	Area (ha)	Production (kg)[1]	Seed yield (kg/ha)
2004-05	60	2	Ubon	11	2,070	188
2005-06	127	2	Ubon	16	1,292	81
2006-07	128	15	Ubon, Amnart	11	2,597	236
2007-08	200	20	Ubon, Amnart Mukdahan, Lamphang	48	12,202	254
2008-09	49	8	Roi-et, Ubon, Amnart	27	6,778	251
2009-10	45	1	Roi-et	26	9,959	383
2010-11	59	1	Roi-et	33	16,169	490
2011-12	58	1	Roi-et	33	10,829	328
2012-13	103	1	Roi-et	80	27,040	338

[1]Clean seed but not acid-scarified.

Table 2. Mulato II seed production in Laos.

Year	No. farmers	No. villages	Province	Area (ha)	Production (kg)[1]	Seed yield (kg/ha)
2007-08	155	9	Oudomxay	16	2,205	138
2008-09	252	16	Oudomxay	25	4,492	180
2009-10	300	16	Oudomxay	40	7,437	186
2010-11	381	16	Oudomxay	50	12,073	242
2011-12	510	12	Oudomxay	90	21,595	240
2012-13	508	11	Oudomxay	84	23,381	278

[1]Clean seed but not acid-scarified.

the low yields, which they said did not cover their costs. In addition, harvesting of pasture seed coincided with rice harvesting, which taxed the labor force on the farm. As a result, many farmers ceased producing Mulato II seed altogether. Even though collecting seeds in nylon bags produced the highest seed yields in our trials, bags were considered too expensive by farmers (US$0.30−0.50/bag).

Since 2009 in Thailand, seed of Mulato II has been produced only in the village of Nong Saeng in Roi-et province, where farmers sweep the seed from the ground after the rice harvest is complete. Some farmers are now obtaining yields of more than 600 kg/ha, considerably better than yields from our research plots. Production has increased from about 10,000 kg in 2009/10 (45 farmers) to 27,040 kg in 2012/13 (103 farmers). The method of harvesting has been a major contributing factor towards increasing seed yields, with ground-harvesting producing far higher seed yields than knocking. The Roi-et farmers prefer ground-harvesting, but farmers in the other villages refuse to ground-harvest saying either it is too time-consuming for them or they cannot prepare even seed-beds because their land is on hill slopes.

In Laos, seed production has increased from 2,205 kg in 2007/8 (155 farmers, 9 villages) to 23,381 kg in 2012/13 (508 farmers, 11 villages) (Table 2).

Seed yields in Laos are lower than for Thailand, owing to plant and tiller death from rats eating the plants in the field, mice eating emerging seed heads, lack of fertilizer, wide row and plant spacings, and harvesting by tying and knocking seed heads. Average annual yields have ranged from 138 to 278 kg/ha (Table 2).

Mombasa and Tanzania guinea grasses

Seed research

Tanzania seed research conducted by the Department of Livestock Development studied flowering patterns, seed development and method of harvesting (Kowithyakorn and Phaikaew 1993). From these studies the hand-tying of seedheads into living sheaves and knocking the ripe seed out evolved. Current trials at Ubon Ratchathani University are studying the effects of crop age, plant spacing, fertilizer, liquid trace elements and seed storage on Mombasa and Tanzania seed production and seed quality.

Farmer seed production

In 2008, Ubon Forage Seeds started producing Mombasa guinea seed for Tropical Seeds LLC, mainly for export back to Mexico, since Mombasa guinea seed produced

in Central and South America was often contaminated with common varieties. Under the intensive management system in Thailand, farmers can remove any varieties that are not Mombasa guinea. As Mombasa is a large, leafy and very productive grass, a strong market has recently developed for Mombasa in Asia.

In 2010, Tropical Seeds asked Ubon Forage Seeds to produce Tanzania guinea seed for export to Central America, because they wanted seed of uncontaminated lines. We adopted the practices, developed by Phaikaew et al. (1995) and used by farmers for production of Mombasa seed, to produce Tanzania seed for several years. Tanzania is called Sri Muang (purple) in Thailand and TD58 in some other countries in Asia. For farmers in Mukdahan, Amnart Charoen and Ubon Ratchathani provinces, seed production of these 2 guinea cultivars is relatively easy. Activities fit in well with village management, as the seed crops can be planted quite late in the season (July-early August), and harvesting is in October before the rice harvest commences. Both cultivars are treated as annual crops and are replanted each year.

Farmers plant seed in nurseries in May-June, and transplant seedlings into their fields from July to early August, but different villages use different planting patterns. In Mukdahan, an inter-row spacing of 1 m is used, and within rows groups of 4 plants (50 cm apart) are planted at 1 m intervals. This planting pattern allows seed heads to be tied together in groups, enabling hand-knocking at seed harvesting. Some farmers plant only 3 plants per group. In Amnart Charoen and Ubon Ratchathani, the same inter-row spacing is used, but plants are 50 cm apart within the rows and the seed heads on each plant are tied together for harvesting.

Strong winds in October can be a major problem in all villages, blowing much good seed to the ground. It is estimated that nearly 40% of seed was lost from strong winds in 2009 and 2010. Farmers who produce guinea grass seed do not sweep fallen seed from the ground, because ground-sweeping requires thorough field preparation before planting to produce a relatively flat seedbed, and it is difficult to separate the soil granules from the small guinea seeds. In the past, there has been a problem with too many empty seeds in guinea seed purchased by the University from farmers and re-cleaning at the University was necessary. In some instances, the trash removed amounted to 20% of the purchased weight. Farmers were not able to winnow strongly enough by hand to remove empty seeds. To overcome this problem, small seed cleaners with a strong air flow were manufactured in 2010 and provided free to the seed-growers. Farmers are now able to clean their seed to >99.5% purity, with a high thousand-seed weight (Mombasa 1.54 g; Tanzania 1.20 g). No further cleaning is required for sale and export.

Mean seed yields of Mombasa guinea ranged from 312 kg/ha in 2011 to nearly 500 kg/ha in 2012 (Table 3). The main factors preventing higher seed yields have been: strong winds during seed harvest knocking seed to the ground before harvest (2009); and wet, overcast weather during the growth phase before stem elongation preventing maximum tillering and inflorescence development (2011).

Tanzania seed yields are usually higher than those of Mombasa, averaging 766 kg/ha in 2009 (Table 4). However, bacterial leaf blight in 2010, wet weather during reproductive development in 2011, and low rainfall in 2012 substantially reduced seed yields.

Table 3. Mombasa guinea seed production in Thailand.

Year	No. farmers	No. villages	Province	Area (ha)	Production (kg)	Seed yield (kg/ha)
2008	126	8	Ubon, Mukdahan, Amnart	23	7,318	318
2009	135	9	Ubon, Mukdahan, Amnart	64	28,570	446
2010	225	8	Mukdahan, Amnart	82	36,024	439
2011	166	7	Mukdahan, Amnart	68	21,269	313
2012	266	15	Mukdahan, Amnart, Ubon	116	57,137	493

Table 4. Tanzania guinea seed production in Thailand.

Year	No. farmers	No. villages	Province	Area (ha)	Production (kg)	Seed yield (kg/ha)
2009	60	3	Ubon, Mukdahan	14	10,726	766
2010	56	4	Ubon, Mukdahan	13	7,050	542
2011	47	4	Ubon, Mukdahan	11	2,435	221
2012	125	11	Mukdahan	37	13,699	369

Ubon paspalum

Seed research

We first received seed of Ubon paspalum in 1994, and after research trials showed its tolerance of waterlogging (Hare et al. 1999a; 1999b), a demand for seed developed within Thailand. Immediately, we encountered problems with low seed yields and implemented a series of seed-production field trials.

Seed crops of Ubon paspalum established by sowing seed in mid-May produced no seed at all in the establishment year (Hare et al. 2001a). Planting rooted tillers, divided from second-year plants, or transplanting 2-month-old seedlings, grown in plastic bags, into the field also in mid-May, produced the highest seed yields in the establishment year, though not as high as yields of second-year crops. Seed crops, planted with rooted tillers at the beginning of May, produced 132 kg/ha seed 5 months after sowing in one trial and 331 kg/ha seed in a second trial. It is important to plant in May, as planting tillers or seedlings in June and July severely reduces seed yields.

Timing of the final closing cut is quite critical. Seed crops of Ubon paspalum cut in August and September produced little or no seed at all, and crops closed in May were susceptible to lodging (Hare et al. 1999c). Cutting and closing crops in June produced the highest seed yields.

To obtain an explanation for the poor seed yields from late plantings and late closing cuts, a plant growth chamber study on flowering was conducted at Ubon Ratchathani University. Ubon paspalum was confirmed as a long-short day plant exhibiting a quantitative response to long days followed by a qualitative response to short days (Hare et al. 2001b). In order to flower in September, plants must be at least 60 days of age before the summer solstice (June 22), explaining why crops sown with seed or planted late do not flower profusely in the year of establishment. Plants cut close to ground level after the summer solstice also do not receive enough long days subsequently to flower well and produce good seed yields in the same year. The study also confirmed that no juvenile phase exists in Ubon paspalum (Hare et al. 2001b).

While the correct planting time can ensure that good seed set occurs, the harvesting method can significantly affect recovery of seed. Hand-knocking mature Ubon paspalum seed from seed heads into bags each day produced 230 kg/ha, more than twice the amount produced by threshing or sweating seed heads (Hare et al. 1999c). Using this method, farmers in villages achieved yields in excess of 600 kg/ha (Hare *e*t al. 2001a). Even higher yields (1,108 kg/ha) were obtained on a research station by covering seed heads with nylon bags (Phaikaew et al. 2001).

Farmer seed production

In March 1997, 20 farmers were contracted to grow Ubon paspalum seed. Each received 300 g of seed at that time and was instructed to sow the seed in a nursery and transplant strong plants to the field in May-June. The maximum area per farm was 1,600 m^2. Fields planted in May and June averaged 315 kg/ha and 65 kg/ha, respectively, whereas fields planted in July produced no seed at all (Hare et al. 2001a). Harvesting from the same fields in 1998 and 1999 produced mean seed yields of 632 kg/ha and 651 kg/ha, respectively (Hare et al. 2001a). Hand-knocking mature seed from tied seed heads into bags each day, followed by slow drying in the shade and winnowing on cane trays, produced high seed yields, with a purity of 99% and an average germination of 80%.

Even though seed production in Ubon paspalum is well synchronized, with flowering occurring predictably in September and hand-harvesting taking place over 7−10 days in early October, some difficulties can be experienced. Heavy thunderstorms frequently occur during the late September-early October flowering and harvesting period, causing seed to shed. Foraging birds may also dramatically reduce seed yields and farmers use nets to capture the birds for sale or install bird-scaring devices, such as scarecrows and tins filled with stones. Some farmers resort to sleeping in their fields in order to chase away birds, which usually forage in the early morning.

Seed production of Ubon paspalum has not expanded in recent years, because the market demand for seed is very small. We plan to produce no more than 10,000 kg per year.

Ubon stylo

Seed research

Perennial stylo cultivars have been harvested for seed in Thailand for over 30 years starting with Endeavour, Cook, Schofield and Graham. Anthracnose disease destroyed these cultivars, but fortunately cultivar CIAT 184 (called Tha Phra stylo in Thailand) became available and has been produced for seed by the Thailand Department of Livestock Development for more than 15 years. In 1999, Dr Bert Grof provided seed of a new stylo blend of lines derived from *S. guianensis* var. *vulgaris* x

var. *pauciflora*, which had very strong resistance to anthracnose (Grof et al. 2001). This stylo has been released in Australia as cultivar Nina; however, in Thailand, farmers growing seed and forage call it "Ubon stylo" and we have continued to use this name. To identify optimum strategies for growing Ubon stylo, experiments were conducted in Thailand during 2004-5 to determine optimum times for cutting (Hare et al. 2007d).

Ubon stylo (959 kg/ha) produced 2.6 times the seed yield of Tha Phra stylo (365 kg/ha) in a field trial at Ubon Ratchathani University, and closing stylo seed crops in September doubled seed yield over closing in October (Hare et al. 2007d). We recommend cutting tall dense seed crops in September, but not crops which are sown late or are growing very slowly.

Germination tests on 1-year-old stored Ubon stylo seed (Hare 2007) showed that hot water and machine-scarification significantly increased germination and reduced the percentage of hard seed. Seed germination was less than 10% without scarification, while scarifying the seed 4 times through a machine significantly increased speed of germination at 7 days compared with hot water treatment (81.9 vs. 67.3%). However, after 14 days, there was no difference in total germination between hot water treatments and scarifying 4 times through a machine (88.0 vs. 89.9%).

Today, all Ubon stylo seed sold is acid-scarified because this operation is relatively easy to perform, and very high germination rates (99%) can be achieved (Table 5). Large quantities (over 1 t) can be scarified daily, and the resulting seed has far higher germination than machine-scarified seed.

Table 5. Effect of sulfuric acid scarification on germination of Ubon stylo seed.

Treatment	Germination (%)		Hard seed (%)
	7 day	14 day	
No acid	21	24	76
Acid 5 minutes	99	99	1

Farmer seed production

In Thailand, Ubon stylo seed is produced in only a single village, Bark Kud Waay, in Ubon Ratchathani province. Farmers receive 500 g of seed in April to plant a nursery and in July plant seedlings into raised seed-beds in 1 m x 50 cm rows. They prefer to delay planting until July, because this precludes imposing a closing date defoliation. Seed crops flower and set seed from November to January. All crops are thoroughly hand-weeded during the growing season to remove any chance of weed-seed contamination during ground-sweeping of the Ubon stylo seed.

At seed harvest in late January, farmers use sticks to beat plants to dislodge any remaining seed that has not fallen from the seed heads, before the vegetation is cut to ground level and removed. Fallen seeds are swept from the ground and cleaned by farmers in the field.

In March the seed is purchased by the University. It is then acid-scarified to remove soil and seed coats, which improves seed purity and overcomes hard-seed dormancy, thereby improving seed germination. Farmers produce high seed yields (Table 6), and in March 2012, 17 farmers harvested average seed yields of 1,040 kg/ha.

Profitability of smallholder forage seed production in Thailand and Laos

In Thailand, forage seed crops are grown on upland soils previously planted to cassava, or on upland rice paddies, which are only marginally productive for rice, because they are not inundated with water each year. Farmers usually hire contractors to plough their fields and hire additional labor for weeding, harvesting and cleaning. More and more rice is now machine-harvested and threshed by contractors.

Table 6. Ubon stylo seed production in Thailand.

Year	No. farmers	No. villages	Province	Area (ha)	Production (kg)[1]	Seed yield (kg/ha)
2005-06	10	1	Ubon	3	2,070	690
2006-07	15	1	Ubon	9	5,590	621
2007-08	30	1	Ubon	12	7,500	625
2008-09	30	1	Ubon	9	6,400	711
2009-10	30	1	Ubon	3	1,950	650
2010-11	26	1	Ubon	9	6,265	696
2011-12	17	1	Ubon	7	7,290	1,041
2012-13	30	1	Ubon	12	9,000	750

[1]Before acid-scarification.

Costs of production were gathered from forage seed-producing farmers and rice farmers over 2 years (2011−2013) by holding informal discussions whenever possible. Further costs were obtained from data supplied by the agricultural economics division of the Ministry of Agriculture.

Forage seed crops are far more profitable than rice in Thailand (Table 7), but forage seed crops cannot be planted on the low-lying, waterlogged paddies, where only rice can be grown. Mulato II is the most profitable forage seed crop, but these yields and costs are from Roi-et, where high seed yields (500−650 kg/ha) are achieved using seed recovered from the ground. Roi-et farmers are the only farmers in Thailand and Laos who harvest Mulato II seed in this way.

Cassava is the main competitor with forage seeds for land in Thailand, particularly seed crops of Mombasa, Tanzania and Mulato II. Cassava is relatively easy to grow and, with the tubers in the soil, there is minimal risk of losing the crop from climate variations as with grass seed crops. Farmers usually look at the gross income they receive and not net income. If cassava prices increase to more than US$0.10/kg, many farmers would prefer to grow cassava. If the cassava price drops to US$0.08/kg, farmers will plant more forage seed crops. Decision making by farmers in our seed villages appears to be based on return to land ($/ha) and not on return to labor ($/hour).

Farmers in Mukdahan, Amnart Charoen and Ubon, who produce Mombasa and Tanzania guinea grass seed, currently harvest by tying seed heads and knocking, considering it is too difficult to ground-sweep seed, given the small seed size and the need to carefully prepare even seed-beds, which is difficult on hill slopes. On the other hand, the Roi-et farmers ground-sweep Mulato II, as they do not like tying seed heads and daily knocking seed into bags. Their fields are on flat land and it is not difficult for them to cultivate and produce even seed-beds. Another consideration is that Mulato II harvesting occurs at the same time as rice harvesting and farmers must harvest rice for their families for food security. With ground-sweeping Mulato II, they can let the seed fall to the ground during rice harvesting and after the rice harvest is completed, they can turn their attention to harvesting Mulato II seed. However, they will not consider growing guinea grass for seed, because they consider the seeds are too small to sweep and separate from the soil collected during harvest. If nylon net harvesting was introduced, the risk of losing seed from hand-knocking would be greatly reduced and seed yields could increase to over 700 kg/ha for Mombasa, over 800 kg/ha for Tanzania (Phaikaew et al. 1995) and over 800 kg/ha for Ubon paspalum (Phaikaew et al. 2001). In this situation, the price of nylon bags, currently deemed too expensive at US$0.30−0.50/bag, would need to be factored into the calculations.

In Thailand, additional benefits from forage seed crops can arise from the sale of fresh forage or its use to feed the farmer's own cattle and buffalo. However, farmers often do not seem to consider these aspects, when deciding which cash crop to plant.

Farmers in Nga district, Laos, do not hire outside labor for their agricultural production. Crops are sown by hand, seed is free, no fertilizers, insecticides or herbicides are used, cultivation is by hand and no machinery is hired or used. No costs are incurred except for family labor and time, which are common to all these crops. Seed production of Mulato II is very profitable

Table 7. Estimated costs and gross and net income* (US$/ha) from rice, cassava and forage seeds in northeast Thailand in 2013.

	Rice	Cassava	Ubon paspalum	Mulato II	Ubon stylo	Mombasa
Direct Costs						
Cultivation	125	125	125	125	125	125
Raising furrows		125			125	
Fertilizer	375	415	210	210	210	210
Labor for weeding		125	65	125	125	65
Labor for harvesting	125	210	125	335	335	125
Hire digger to dig up tubers		125				
Labor for cleaning/threshing	125	125	65	335	335	65
Transport	80	105				
Total Direct Costs	830	1,355	590	1,130	1,255	590
Sale price (US$/kg)	0.50	0.09	3.00	6.00	3.35	3.35
Yield (kg/ha)	2,500	25,000	565	500	810	500
Gross Income	1,250	2,250	1,695	3,000	2,714	1,675
Net Income*	420	895	1,105	1,870	1,459	1,085

*Net income: farm gate return.

Table 8. Estimated yield and net income from rice and Mulato II seed in Nga district, Oudumxay district, Laos.

	Rice	Cassava	Maize + Soybean		Mulato II
			Maize	Soybean	
Sale price (US$/kg)	0.25	0.05	0.08	0.30	4.00
Yield (kg/ha)	1,500	25,000	3,500	1,500	278
Net Income (US$/ha)	375	1,250	280	450	1,112

compared with upland glutinous rice grown on steep hillsides, producing 6 times the income (Table 8). However, rice is produced mainly for household consumption and sales are rare.

Net incomes for upland rice, cassava and maize grown in Nga district can be increased, if other crops such as peanuts, soybeans and sesame are inter-row planted in the same fields. However, these crops are relatively bulky and villages producing Mulato II are remote and poorly serviced by roads, often having only walking tracks, which make transport expensive. Therefore, seed production of Mulato II is still the most profitable enterprise for village farmers. The major advantages of Mulato II seed are its relatively high value per kg and lower bulk, which reduce transport costs from remote areas like Nga district to Thailand. Some remote villages export Mulato II seed by boat, down the Mekong River to Luang Prabang, where Mulato 2 Co. Ltd loads the seed on to trucks to transport to Thailand.

In Laos, Mulato II is proving a sustainable and environmentally friendly agricultural crop in Nga district for the following reasons: it prevents erosion by providing a dense vegetative cover on the hill slopes; and it grows for many years, while upland rice and maize die after seed harvest and do not provide a ground cover. Some of the material cut after harvest of Mulato II and at closing is fed to cattle, while the rest is used as mulch, providing additional control against erosion and preventing weeds from growing. Mulato II seed crops planted in 2007 are still producing consistently good yields, averaging 278 kg/ha. How long these yields will be maintained is a matter for conjecture but, in Mexico, Mulato seed crops receiving 150 kg N/ha/yr produced 500 kg/ha of pure seed in year 5 and 900 kg/ha in year 8 but only 140 kg/ha in year 9 (Esteban Pizarro personal communication). On this basis, Mulato II seed crops in Nga district should continue to produce good seed yields for 10 years or longer.

Export

Ubon Forage Seeds has achieved an international reputation for very high quality tropical forage seed, emphasizing high purity, high vigor and high germination.

Acid-scarification considerably improves seed germination of hybrid brachiaria cultivars and Ubon stylo and, to achieve high germinations in Mombasa, Tanzania and Ubon paspalum, the seed must be stored for at least 4−5 months to remove embryo dormancy before it is sold and exported (Hare et al. 1999c).

During the past 3 years, nearly 140,000 kg of seed has been exported to 22 countries and 6,000 kg has been sold within Thailand. The main markets have been in Central America (84,000 kg), Asia (32,000 kg) and the Pacific region (23,000 kg). Africa is becoming an emerging market. As 95% of seed produced is sold, the industry is highly dependent on maintaining and expanding these markets.

Conclusion

Experience in northeast Thailand and northern Laos has shown that forage seed production can be an economically viable and sustainable cash crop for more than 1,000 smallholder village farmers. Over the past 5 years, production has increased exponentially, with 136 t of seed being produced by hand-harvesting and hand-cleaning methods in 2013. However, the future viability of this industry depends on reliable markets for the seed. To date, dairy and beef cattle smallholder farmers in other tropical countries in Asia, Africa, the Pacific and Central and South America have been the primary outlet. The future of the industry will depend on efforts to expand on export markets plus local sowings as well as the development of additional pasture species.

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