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Feed Options for Ruminants in the Tropics

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[Editor's Note: This article marks the fourth and final installment of a series of on-farm animal feed creation articles written by Keith Mikkelson at Aloha House Orphanage and Sustainable Farm in Puerto Princesa, Philippines. Keith's prior articles include AN #20 Fish Feed, AN #25 Hog Feed, and AN #28 Poultry Feed. These articles have shown how utilizing on-farm products for animal feed can reduce dependency on external (often costly) inputs, thereby increasing sustainability and profitability.]

Introduction

The amazing multi-stomached ruminant comes in many forms, with varied nutritional requirements. Ruminants are even-toed, cloven-hoofed, four-legged, cud-chewing mammals of the suborder Ruminantia (within order Artiodactyla). Cattle, water buffalo, goats, and yaks are some of the ruminants found in Southeast Asia.

Ruminants are able to digest and extract nutrients from plant-based food by fermenting it in a specialized stomach with the aid of beneficial microorganisms, prior to digestion (Figure 1). After the initial fermentation, the fermented cud is regurgitated and chewed again. The process of re-chewing the cud (to further break down plant matter and to stimulate digestion) is called rumination. The waste from ruminants is valuable as a fertilizer for better production of the forage they eat. Manure should be used on the farm to maintain soil fertility. One of the benefits of integrated livestock will be better plant health and yield owing to the recycling of nutrients on the farm.

Many options are available for feeding ruminants on the small farm. Before selecting a feeding strategy for your situation, be sure that the benefits outweigh the disadvantages. Every farm is unique, and farmers must determine the most appropriate and cost-effective techniques for their needs.

Optimum Health of Ruminant Herds

Sunshine and grass are some of the best sources of nutrients for cattle and sheep, but may not provide a complete diet for

***Figure 1**: A tethered cow wades in to graze on a barge of Gotu Kola and Salvania.*

Featured in this AN

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Table 1: *Nutritive quality of hay, silage, and natural pasture in South Western Nigeria (*Ojo *et al.* 2013).

Treatment	CP	Ash	NDF	ADF	ADL	GV (ml/0.2 gDM)	C_g (ml/hr)	ME (MJ/kg DM)	OMD (%)	SCFA (µmol)
Hay	92.0 b	79.0 b	589.0 b	436.3 a	174.7 b	34.33 a	0.09	8.6 b	45.1 b	0.5 b
Silage	108.0 a	106.0 a	574.4 c	363.8 b	128.1 c	33.67 a	0.07	10.7 a	55.4 a	0.7 a
Natural pasture	59.0 c	71.0 c	705.2 a	440.6 a	184.4 a	13.67 b	0.08	5.3 c	32.8 c	0.2 c
±SEM	7.24	5.32	20.73	12.51	8.71	3.44	0.01	0.82	3.29	0.07

Means in the same column with different letters are significantly different (P<0.05). CP: Crude Protein; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; ADL: Acid detergent lignin; GV: Gas volume; C_g: Rate of fermentation; ME: Metabolizable energy; OMD: Organic matter digestibility; SCFA: Short-chain fatty acids. SEM- Standard error of mean. Natural grazing land composition during the dry season: *(Pennisetum purpureum, Andropogon gayanus, A.tectorum, Panicum maximum, Sorghum almum, Stylosanthes hamata, Calopogonum mucunoide, Centrosema molle)*

other ruminants. However, all ruminants will benefit from some grassland when properly managed, perhaps integrated with other feedstocks, such as legume shrubs or even azolla. The bulk of this article will discuss two of the three topics listed above in Table 1 (hay and natural pasture). We will not be covering silage or feedlot grains except to point out in Table 2 their advantages and disadvantages and with one reference below.

Cattle

Native beef and dairy cows in Southeast Asia are hardy breeds that thrive in a variety of environments from the high Himalayan mountains to the humid tropics. Some breeds were introduced by European settlers or migratory peoples. In the Philippines, the "native" cow was actually introduced by the Spanish; they brought several varieties to their newly claimed colony over 400 years ago. Many countries have old-line breeds that have cross-bred for centuries and that have adapted to the local climate and context. We will look at beef cattle feed options first and then suggest ways to increase milk yields for a dairy herd.

Water and Mineral Salt

Water must be available throughout the day to maintain herd health. Salt (sodium chloride, NaCl) is also an essential nutrient for cattle. On average, cattle should consume 11 to 15 grams of salt per day to meet nutritional requirements. Both sodium and chloride can be consumed by cattle in relatively high amounts without negative effects, but dietary levels of NaCl should not exceed 8 percent of the daily diet by weight (Ward and Lardy 2005). In areas where imported mineral blocks are too costly, sea salt can be given as "free choice" (i.e. salt is left out and animals are free to eat as much as they need). According to Troy Smith, the sodium in salt is the only mineral about which animals exhibit "nutritional wisdom"; he says they will take only as much as needed when offered free choice, without over-consuming (2008).

We make a stabilized rammed earth salt block that is still highly experimental. It consists of various quantities of on-farm red clay sub soil, 2 to 3 kilos jagged "plastering" sand, 100 to 500 grams molasses, 100 to 200 grams Epsom Salt, and 1 kilogram hydrated lime or Portland cement with 3 kilos sea salt. We are still analyzing the performance of these blocks, but they do have some research basis (Liu *et al.* 1995). Although many urea blocks are promoted, please note that our block is urea-free. There is a proven inability of the rumen microorganisms to synthesize sufficient quantities of all amino acids needed to prevent deficiencies or imbalances which may be a major factor responsible for the lowered animal performance obtained with urea diets (Chalupa 1968).

Pasture

Sustainable pasture development is possible with some advanced planning and the use of keen observation. The "Pasture Picker" is a good starting point to determine which tropical grasses are likely to succeed. The interactive "Pasture Picker" site is based on the book *A guide to Better Pastures for the Tropics and Subtropics* by L. R. Humphreys and I. J. Partridge (1995);

Table 2: *Management, advantages, and disadvantages of various feeding strategies for ruminants.*

Feed Type	Management	Advantage	Disadvantage
Pasture	Moving animals	Access to rapidly growing green shoots	Overgrazing, parasites
Cut & Carry	Gathering greens and distributing them to animals	Legume trees can continually produce; free of parasites	Takes time to cut and carry; good forage species must be available
Hay	Gathering greens and distributing them to animals	Can be stored for drought/ snow fall	Can spoil; some waste occurs
Silage	Buying grains or gathering greens and fermenting them	Can be stored for drought/ snow fall	Can spoil; some waste occurs; may cause acidosis
Grain	Feed lot	Can be stored for drought/ snow fall	Can spoil; poor nutrition; can cause acidosis

it allows you to input your conditions to get the best recommendations (Figure 2). [Editors' Note: please also see AN #23 and a follow-up article in AN #25 about the potential of some of these fodder species to become weeds. When introducing new species to an area, please use caution and try them yourself first to ensure that the "solution" doesn't become another problem!]

Cut and Carry Grasses and Legumes

The Aloha House grows a biodiverse spectrum of fodder crops that we bring to our goats and cows as "cut and carry." Humans are more adept than trampling livestock at carefully harvesting tall grass species, trees, and shrubs when they are at their prime. According to Martin (1993), "about 75% of forage consumed in the tropics is grass." Grasses can be gathered and fed to livestock if an efficient method is employed.

We grow *Chrysopogon zizanioides* (Vetiver) for slope stabilization and swale management in our water harvesting system. In addition helping reduce erosion, vetiver is also a palatable fodder species (Figure 3). We can harvest the young Vetiver with some frequency during the rainy season and maintain forage nutritional value (Table 3).

We have also utilized *Pennisetum purpureum* (Napier) as a fresh cut forage for goats and cattle. Cows will readily eat it when we carry it to them in marginal pastures to supplement what is there. Napier is great because it can be vegetatively propagated (i.e. asexually propagated through cuttings). We are training three cooperatives in our region to use a variety of propagation techniques to see which are most effective for their dairy buffalo project—stay tuned! You can direct-plant napier cuttings or, if the dry season is pronounced, use some kind of nursery/cup starts and then transplant them into soil during the rainy season. We treat two- or three-node cuttings with Effective Microorganisms (EM1) and then dip them in a diverse blend of Vesicular-Arbuscular Mycorrhiza (VAM) inoculant, which is available from University of the Philippines, Los Banyos.

Figure 3: *Goats happily devour young vetiver leaves on an elevated feed rack.*

Table 3: *Nutrition quality of vetiver at various lifecycle phases.*

	Young Vetiver	Mature Vetiver	Old Vetiver
Energy [kcal/kg]	522	706	969
Digestibility [%]	51	50	-
Protein [%]	13.1	7.93	6.66
Fat [%]	3.05	1.30	1.40

The Aloha House has also utilized the Sloping Agricultural Land Technology (SALT) system since 2001. This system incorporates contour soil stabilization with legume trees and shrub perennials, as well as annual alley crops. The legume trees and shrubs can provide a nice forage option for ruminants; the legumes contribute protein for fermented feeds and contain vitamins as well as enzymes that boost feed digestibility (Watson 1985). Over the years, we have been able to save seed from prolific leguminous perennials. We have established stands and contours of *Desmodium rensonii* (Local name: Ticktrefoil), *Flemingia congesta* (Malabalatong), *Indigofera, Gliricidia sepium* (Kakawate or Madre de Cacao), *Leucaena leucocephala* (Ipil-Ipil), and *Mangium acacia.* These species are all well-suited for the SALT approach and are valuable legumes for goat feeds (Elvitch and Wilkinson 2008).

Pasture Picker Go Back

Pasture Species	Tolerance to				Minimum Rainfall (mm)	Clay?	Loam?	Sand?
	Frost	Drought	Water Logging	Heavy Grazing				
Couch, green (*Cynodon dactylon*)	P	P	P	VG	0	✓	✓	✓
Couch, Indian (*Bothriochloa pertusa*)	F	F	F	VG	600	✓	✓	✓
Elephant (*Pennisetum purpureum*)	F	G	F	P	850	✓	✓	✓
Guinea (*Panicum maximum*)	F	F	F	P	900	✓	✓	✗
Hamil (*see under Guinea Grass*)	?	?	?	P	0	✓	✗	✓
Humidicola (*Brachiaria humidicola*)	P	F	G	VG	1000	✓	✓	✓
Pangola (*Digitaria eriantha subsp. Eriantha*)	F	F	G	VG	1000	✓	✓	✓
Para (*Brachiaria mutica*)	P	P	VG	F	1000	✓	✓	✗
Plicatulum (*Paspalum plicatulum*)	F	G	G	F	800	✓	✓	✓
Signal (*Brachiaria decumbens*)	P	F	F	VG	1000	✓	✓	✓

P =poor, F =fair, G =good, VG =very good

Figure 2: *Pasture Picker pasture species guide. Available: https://www.tropicalgrasslands.asn.au/pastures/pasturepicker.htm.*

Prevention of Parasite Issues with Cut and Carry

In most pastoral areas, cattle do not face a threat of parasite infestation from the environment because they are immune to some of the common tropical pests that plague goats. Goats, however, are prone to certain parasites and are best grazed on dry pasture after the dew has evaporated or rains have dried, because barber pole worm infestation is aided by wet grass (Figure 4). Cut and carry legumes are always available to our goats and can be fed without risk of the parasite re-infecting the goats because the intestinal worm only lives in wet grasses. It is worth the management of cut and carry to protect against this parasite in most tropical areas.

Planned Grazing, Holistic Farm Management, Keyline Sub-Soiling, and Movable Electric Fences

P.A. Yeomen developed a concept called Keyline planning, based on the natural topography of the land; it uses the form and shape of the land to determine the layout and position of dams, irrigation areas, roads, fences, buildings, and tree lines (Ecologia 2012). His innovative Keyline plow has the ability to work subsoil without inverting the soil profile (Figure 5). Over a period of several months to a year, grasslands can be improved by pulsing the soil with successively deeper plowings ranging from 10 cm to 20 cm to 30 cm. With air and root matter being incorporated into the soil following deeper rips, greater microbial activity in pastures can be maintained through planned grazing. Abe Collins has documented his journey and published his findings through various avenues. His Keyline improvements are discussed in simple terms in an article he wrote with Darren Doherty (2009).

Collins has seen farmers add organic matter in pasture soils for many successive years, increasing organic matter by up to 7.3%. He utilizes complex mixtures of cover crop seeds—commonly between 7 and 20 varieties of seed in a single mix—to achieve multiple soil-health, production, and profit goals, usually in no-till farming systems (Collins 2013).

Figure 5: *Keyline plow for working the subsoil without inverting the soil profile.*

Although tractors and Keyline subsoil plows are utilized in developed countries, we have innovated a modified Keyline method for small farms that does not require fancy machinery. With the use of an off-contour triangle "A-Frame," we are able to plant slightly downhill from the gullies to the ridges, drawing moisture to the ridges from otherwise over-hydrated gullies and thus increasing water availability throughout the year (Figure 6). By planting on the marked lines determined by the A-frame, we are able to draw more moisture through the root system and produce forage well into the dry season.

Electric Fence vs. Tethering

Combining aggressive pasture development with intensive grazing, we are able to increase stocking density and move our livestock frequently, often 2 to 3 times per day. With the help of a movable electric fence, our grazing cows can simulate the activities of the wild herds; historically, the wildebeest or great bison herds would graze in a tightly packed group (to keep the herd safe from predators), trampling the soil and adding manure. They would then move together to a fresh area when needed. Alan Savory modeled his herd management on this insight, as documented in his writings and TED talk.

When properly utilized, a movable electric fence allows farmers to move their herds in a dense grouping without overgrazing, so that all herbaceous plants are consumed and manure is spread evenly. When left to their own devices and free choice, ruminants will preferentially eat the most palatable greens and concentrate manure in a few areas. The least palatable species (often weeds) then prosper, shifting the pasture composition over time to these less palatable greens. Using planned grazing, Abe Collins has seen first year animals become very effective at managing aboveground pasture biomass while increasing root matter and biology below ground (2006).

Joel Salatin is another successful advocate of intensive managed grazing; he calls his method "Salad Bar Beef." He keeps

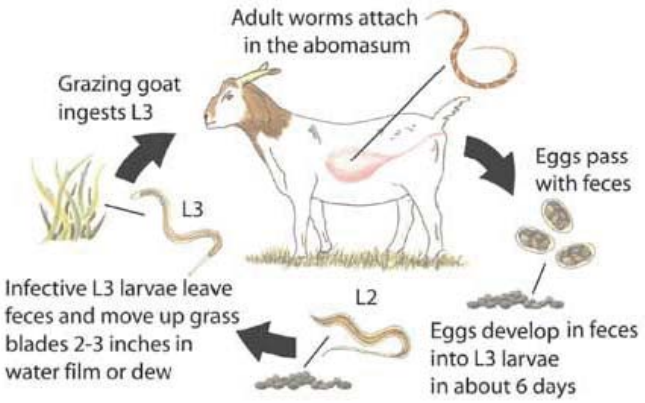

Figure 4: *Barber Pole Worm Life Cycle. Available: https://www.pinterest.com/pin/452541462542767238/*

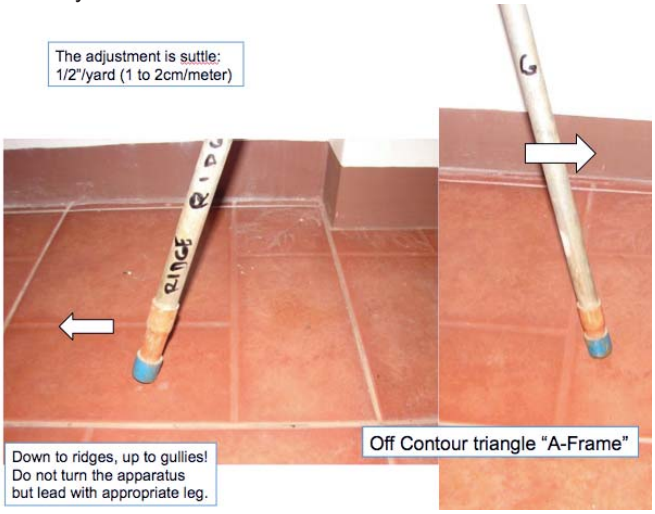

Figure 6: *Off contour triangle "A-Frame." An overview of this innovation is available for more study at this Slideshare set.*

his cows on perennial polyculture, being careful not to let the cattle overgraze on juvenile greens. Each pasture species has an "S" curve growth rate. If animals are allowed to graze an area too soon, plants will not have had enough time to recover. If animals are kept away too long, grasses will have reached a "geriatric" stage during which they turn dormant and lignify, providing less nutrition (Figure 7). Grazing should take place during the adolescent stage of a grass when optimum nutrition is available to the animal. For more information, see this video from Joel Salatin.

Movable electric fences may be too expensive for many farmers. Instead, small-scale farmers can tether their cows on a movable stake system. We were able to renovate old stands of *Imperata cylindrica*, commonly known as cogon grass, kunai grass, or blady grass, by tightly stocking and moving the herd according to observation of the needs of the pasture and the cows. We started by immediately grazing the new shoots after the natural seasonal burn-off that is common where cogon grass grows. (Do not feed the old standing dry cogon to your animals, because it is poor forage of low quality due to its maturation and lignification (see Figure 7). For cattle, we supplement the sub-standard graze of cogon with freshly cut and carried *Pennisetum purpureum* (Napier). Cows will readily eat Napier grass when it is carried out to marginal pastures in order to supplement their nutritional needs. Any Napier that is not eaten is trampled and left as mulch. Over a period of only 2 seasons in the tropics, we've seen the native turf grasses and *Brachiaria humidicola* take over these depleted pastures and biologically exclude the cogon!

Dairy Breeds

Here at Aloha House, we milk "native" cows, probably of Jersey descent, as well as Holstein and Brahman (or Brahma), which is a breed of Zebu cattle (*Bos indicus*). We recommend starting small with breeds that are locally available before you start investing money in exotic breeds. Thailand has a large national dairy center, in partnership with the Dutch Government in Saraburi; it is a great resource for large and small farmers alike. As farmers gained experience in managing dairy herds, the breeding plan of the center shifted from 75 percent Holstein-Friesian to 87.5 percent Holstein-Friesian crosses. These exotic breeds are now readily available to local farmers, as they have become "common." Thai farmers are also milking Zebu cows, and a Thai-Friesian breed has also been developed and tested (Chungsiriwat and Panapol 2009) (Figure 8). In Bangladesh, commercial dairy herds were most successful with Holstein breeds, compared to Jersey crosses, where success was measured by milk yield and herd health/adaptability (Azam *et al.* 2012).

Hay as Feed

In Chiang Mai, Thailand, we were able to visit a dairy cow co-op that trains and supplies farmers with Napier hay as well as other inputs. In Sri Lanka, small-scale farmers using semi-intensive management systems depend on tethering and stall-feeding as their main source of animal feeding; by contrast, farmers in extensive management systems rely on grazing and tethering as the main source of animal feed. Animals are usually tethered and allowed to graze on paddy lands (bunds and harvest stubble and stover) (Figure 9), public spaces, and under rubber and coconut trees in estates. The average milk production under extensive management systems was 3.9 l/AU (Animal Unit)/day, while milk production under semi-intensive management systems was 5.4 l/AU/day, showing that the extra management may be worth the boost in production for small farms (Saraiva *et al.* 2014). Similar results were reported by Zemmelink *et al.* (1999) and Premaratne *et al.* (2013) in the mid-country wet zone of Sri Lanka. Lower average milk yields in extensive management systems may be due to poorer feeding and cattle management.

Figure 8: *My wife inspects a dairy herd in Thailand fed Napier hay.*

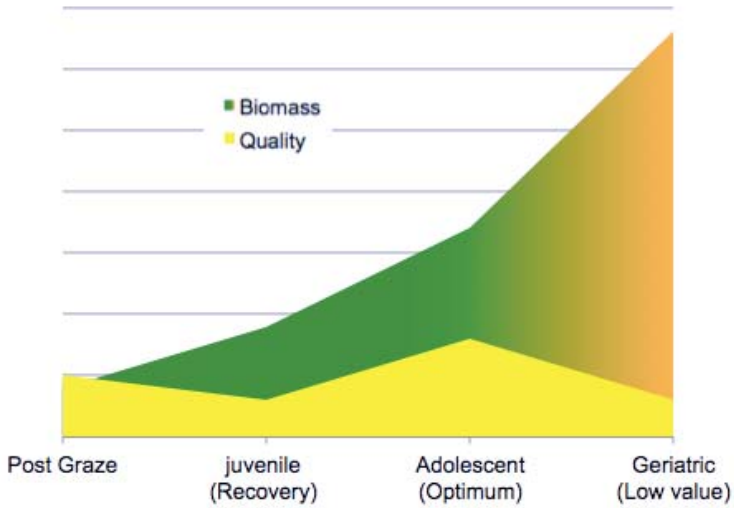

Figure 7: *The effect of time on pasture biomass and quality.*

Figure 9: *Typical low-management cattle pasture: bunds and rice stubble.*

The Great Grain Debate

Tim Wightman, author of the *Raw Milk Production Handbook* (2005), addresses the question, "Should pasture-fed dairy cows get any grain?" Typical "grain-fed" dairy cows receive a large portion of their diet in the form of grain, resulting in high milk production but with lower milk quality and with a reduced lifespan for the cows. Pastured dairy cows with access to high-quality pasture and high-quality hay alone should be able to produce large quantities of milk. However, giving cows a small amount of grain can provide starch to feed the microorganisms in a cow's rumen that help the cow convert forage into body mass, milk, and energy. According to Wightman, "The rule of thumb, in order to manage rumen activity in cows, is to feed no more than one percent of body weight per day as grain." We use a blend of rice bran and copra meal at 1:1 ratio with a drizzle of molasses at the end of a day of grazing.

Azolla Successes and Failures as Ruminant Feed

Azolla (*Azolla caroliniana*) is a fast-growing floating fern with a reported protein range of 19-30%. We grow it intensively, and feed it to chickens, ducks and fish (See AN #20-Fish Feeds, AN #25- Hog Feeds, and AN #28- Chicken Feeds)(Figure 10). Due to our abundance of napier and pasture, we are not currently using it for ruminants. Also, we have a finite supply of azolla and feed it to our hogs and poultry. However, experiments conducted by the Vivekananda Kendra-Natural Resources Development Project (VK-NARDEP) in Kanyakumari district, Tamil Nadu, indicated that the quantity and quality of milk yield of cattle went up when they were fed with azolla to supplement marginal pasture (Prabu 2007).

Azolla was introduced as an alternative feed for dairy cows by an NGO in India. In contrast to the VK- NARDEP study above, the pilot program was found to have very poor results (Tamizhkumaran and Rao 2012). This highlights the importance of testing innovations before promoting a community "solution," to ensure that a new technique or idea will work in your particular environmental and cultural context.

In experimental trials comparing *Lemna minor* (common duckweed), *Ipomoea reptans* (kang kong or morning glory), *Trapa natans* (water caltrap), and *Salvinia cucullata* (often mistaken for azolla) in India, both duckweed and morning glory had higher feed conversion ratios and high protein: 28% and 32% respectively (Kalita *et al.* 2007; Biswas and Sarkar 2013). These excellent fodder crops can be grown in an aquaculture system, but should be kept away from the fish so as to ensure a regular harvest (otherwise the fish would eat them). I wish that azolla had been included in the India study. We feed available azolla (after it has satisfied the need for fish, chicken, and hog feed production) to cattle by placing it in the evening feeder with our rice bran and molasses.

Figure 10: *At our 15 degree latitude, azolla with 40-80% shade does better than azolla in full sun.*

Figure 11: *A deep fryer basket works well for lifting the azolla while draining water.*

With floating water plants such as azolla and salvinia, a farmer must be careful not to overharvest, so that sustainable production can be maintained. A general rule of thumb (under ideal conditions) is to harvest no more than half of the floating biomass per week (or 1/7 of the total biomass per day). The trick is to keep it in the rapid vegetative stage, so farmers should monitor which way of harvesting is more productive in their system. Azolla tolerates moving water better than duckweed. Salvinia is the fastest growing, but can be invasive. At Aloha House, our best interns in charge of azolla production averaged 194 grams/sq. meter. A deep fryer basket works well for lifting the azolla while draining water (Figure 11). We harvest in the morning and let the plants drip dry for 24 hours before weighing them (Mikkelson 2017).

Moringa Forage Can Improve Milk Production

According to Lowell Fuglie (2000) in EDN 68, "New Uses of Moringa Studied in Nicaragua," when moringa leaves constituted 40-50% of dairy cows' feed, milk yields increased by 30%. The article shared: "The high protein content of moringa leaves must be balanced with other energy food. Cattle feed consisting of 40-50% moringa leaves should be mixed with molasses,

sugar cane, young elephant grass, sweet (young) sorghum plants, or whatever else is locally available."

Feeding Other Ruminants

Water Buffalo

The tamaraw, or Mindoro dwarf buffalo, is a water buffalo endemic to the island of Mindoro in the Philippines. It is the only endemic Philippine bovine; the species is endangered, with fewer than 500 animals remaining, and they are no longer used as draft animals. Most buffalo in the Philippines are much larger than the tamaraw. The Murrah is a domestic breed of water buffalo *(Bubalus bubalis)*, originally from the Punjab and Haryana states of India, that is kept for dairy production. Some areas in India specialize in buffalo dairy for the production of authentic Italian mozzarella cheese.

Draft animals may require less premium feed, depending on their workload. Napier grass is good to have available and readily transported as cut and carry to the work site. All traction animals require ample water and plenty of calories for the workload. Some molasses can supplement their energy requirements at 1-5% of daily feed ration. According to EDN 53, if you work with animal traction, you should also know about Tillers International. They have specialized information and training for a wide variety of working animals in developing countries. They even have draft animals in Madagascar ripping and sub-soiling on contour for water harvesting! See this link for more details.

Oxen, yaks, camels, llamas, alpacas, and reindeer are ruminants for someone else to write about, but think through the browse and graze needed before you buy feed. Often these native ruminants can be fed with proper planning from the bounty you develop on or around your farm!

Alternative Feeds For Goats

Goats are browsers, and need a different diet than can be provided by most pastures available to a smallholder farmer. Cut and carry legumes can round out goats' diet, but do not rely on a pure legume diet. When goats overeat lush, damp feeds such as clover, alfalfa, or cut and carry legumes, tiny bubbles of gas can get trapped in the rumen, causing bloat. It is a life-threatening condition; the foamy bubbles of gas are impossible for a goat to belch up. Protein levels vary from crop to crop but a rule of thumb is no more than 2/3 legumes and 1/3 grass and other forage should be given to goats.

Besides limited amounts of grass, shrubs, and cut and carry legume shrubs, we feed our goats a variety of palm leaves, bamboo, and neem. The neem is offered free-choice along with plenty of other greens, because it is a natural de-wormer and the goats will nibble as needed. It is reported to be very effective on sheep as well (Chandrawathani *et. al.* 2006).

Fresh coconut is another option for goat feed. Coconut farmers in our area drop the mature nuts and split them open with a machete for their goats. An American on our island has observed excellent results in his goats' overall health and weight gain and reduced his pastoral management on sandy soils by offering coconut to his goats on a daily basis. Research shows that copra meal (dried coconut meat) increases dietary intake of protein for cattle, goats, and sheep. Copra meal is a valuable feed for ruminants and can be used as a protein supplement for grass-fed animals (Manikkamani 2011). If you use coconut by-products such as copra meal, be sure to avoid the second extraction using hexane. The chemical residues can be undesirable (Heuze V., *et al.* 2015).

By way of example, in North Sulawesi, Indonesia, a budding goat production system intercrops Napier grass (*Pennisetum purpureum*) under coconut groves. Their Crop Livestock System (coconut-forages-goat) also uses legumes such as Leucaena and Gliricidia. This is another example of an integrated and sustainable practice that helps with "the scarce supply of good forages (grass and legume) to support the feed requirements of goats." Of course, the manure from the feed is converted to organic fertilizer. It is a way to achieve better growth of both pasture and coconut yeild (Polakitan *et al.* 2001).

Sheep

Many straggly sheep wander the tropics, surviving but rarely thriving. Goats might be a better entry way for the novice, but lamb and sheep can have a niche in the right climate under good management. Sheep are prone to deheydration and only drink clean water from still ponds or drink pails. Moving water, streams, and rivers will not help in your watering program. They are also in need of protection from predators. Sheep are more suited for cooler climates because they can get heat stroke easily. The good news is that although there are important differences between lamb breeds, research in Brazil found that sheep can be finished exclusively on tropical pasture (Poli *et al.,* 2013).

Silage for Ruminants

We utilize fermented feeds quite a bit for our fish, hogs, and poultry. However, we do not ferment or ensile any of our grasses, grains, or legumes for our four-stomached friends. We find that, on a small farm, the added labor and management negate any savings. E. coli can be problematic, because acidosis (too much acidity in the body) can result from fermented feeds and E. coli will flourish in the rumen under those conditions. Feed lots struggle with high E. coli counts because the bacteria survive the high acid (low pH) environment and multiply. The fermented feed does not culture E. coli, but rather the cows, goats, etc. produce high levels in their waste stream. The manure and feed yard are the disease vector. According to the Reference Advisory Group on Fermentative Acidosis of Ruminants (RAGFAR): "Rumen pH starts to decline immediately after feeding concentrates or silage. Concentrates such as grain, soy, or corn can cause even a more rapid decline in rumen pH than silages" (RAGFAR 2007). We are a raw dairy operation and avoid silage altogether. We do not pasteurize our milk. To keep our milk safe, we eliminate exposure to E. coli by avoiding concentrates and silage and feeding our ruminants our grass/greens; therefore, we have a lower risk for E coli contamination than a feedlot using grains only. You can read about our silage for hogs in AN #25 and adapt it for ruminants, but be careful to substitute legumes for fishmeal and to avoid soy meal. In India a technique has been demonstrated for cattle feed fermentation.

Documented Problems with Soy

At Aloha House, we do not feed soy to any of our livestock, due to soy's detrimental health effects. Soy contains phytoestrogens and enzyme inhibitors that are problematic for both livestock and humans (IEH 2000). My concerns with soy have been previously summarized in AN #28. We at Aloha House also choose to avoid genetically modified organisms (GMOs).

Conclusion

Farmers feeding cows, goats, sheep, and buffalo should attempt to keep purchased inputs to a minimum. Farmers must balance the dietary needs of their animals with safety, comfort, and security from theft. No matter how ideal your goals for your ruminant herd, make sure you carefully plan and manage for the overall benefit of the animals and the farmer. Most small farms in SE Asia would do well to develop and manage some amount of pasture for ruminants, combined with a cut and carry strategy. Manure should be incorporated on the farm to maintain soil fertility for the forages and plants, and tighten nutrient cycling loops so that the benefits of integrated livestock will translate into more economical and sustainable food production.

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Creating a Low-Cost Seed Dryer for Use in Local Seed Banks

by Abram J. Bicksler, Ph.D., Director of ECHO Asia Impact Center

Introduction and Background

Saving your own seeds can be a cost-effective way to access crop seed for future planting and to help maintain the planet's plant biodiversity. Whether you plant your own saved seeds, give them away to friends and neighbors, or distribute them through your organization, the ability to effectively harvest, clean, prepare, dry, and store seeds is important to help maintain seed germination and viability. This note will focus on the importance of drying seeds to proper seed moisture content, and will provide details about two low-cost seed dryers that we have built and use at the ECHO Asia Impact Center Seed Bank.

Definitions

- **Orthodox seeds** are tolerant to desiccation and are storable in this condition.
- **Recalcitrant seeds** lose germination capacity rapidly when exposed to dry air, in most cases within ten days of harvest.
- **Seed moisture content** is the amount of water in a seed; usually expressed as a percentage (%).
- **Seed moisture content determination** is done using either equilibrium moisture content predictions (see next term), or by the use of a seed moisture meter, or through destructive sampling (i.e. using an oven to burn off all water in the seed). See Rao *et al.* 2006 for more information.
- **Equilibrium moisture content** refers to the way seeds left in ambient environmental conditions will equilibrate with the relative humidity in the environment, changing their seed moisture content (expressed as a %).
- **Seed drying** is the reduction of seed moisture content to recommended levels for seed storage, using non-destructive methods. Seeds dry at an exponential rate until the equilibrium moisture content is reached.
- **Seed viability** is a measure of the percentage of seeds that will germinate after storage. The greater the viability of your seeds, the fewer seeds will be needed to establish a desired number of plants in the field or nursery.

Figure 1: *Outdoor pre-drying area for seeds utilizing opaque plastic to prevent sun damage while keeping seeds dry.*

Optimum Drying Conditions

Orthodox seeds that are sufficiently dried will retain their viability for longer periods of storage in seed banks. In general, orthodox seeds should be dried to between 3% and 7% moisture content for long-term storage, although some seeds (such as soybeans) may experience reduced viability at moisture contents below 8%. Realistically, we at the ECHO Asia Impact Center Seed Bank are rarely able to dry seeds below 10% moisture content during the rainy season, owing to relative humidity levels of 70-80%.

Recalcitrant seeds, which include a large number of tropical tree and fruit species, should not be dried or exposed to dry air, and therefore, are beyond the scope of this note. Determining seed moisture contents for orthodox seeds is also beyond the scope of this note, but many good online resources exist to help ascertain targeted seed moisture content for a particular species, as well as how to scientifically calculate the actual seed moisture contents.

Figure 2: *Pre-drying shelves used to pre-dry seeds in a controlled environment before they go into the seed dryer.*

See FAO's excellent *Manual of Seed Handling in Genebanks*, Chapters III and IV, for more information (Rao *et al.* 2006).

Please note that seeds can become damaged during drying if they are dried too quickly or at too high a temperature. In general, ensure that the drying temperature does not exceed 41ºC (105ºF) for tree or high-oil seeds, and 54ºC (130ºF) for most other orthodox seeds. Pre-drying in a slightly shaded environment that is protected from wind and rain can help reduce the time seeds need to spend in a seed dryer. Figures 1 and 2 show ECHO Asia's pre-drying areas, under opaque plastic and in a custom-built screened pre-drying cabinet.

ECHO Asia's Experience with Seed Banking Best Practices

ECHO Asia began experimenting with seed storage best practices for the tropics when our seed bank was established in 2009. Little work had been done on appropriate, low-cost techniques for the tropics and sub-tropics, so we began to conduct our own research. After several peer-reviewed articles and lots of staff input and observations, we have established best practices that are relevant for NGOs and organizations with seed banks that are an intermediate step between community-level seed banks and international seed or gene banks. Many of these best practices are summarized in ECHO's Technical Note #63 (Motis 2010). We recommend that you:

- Start with healthy soils and healthy plants, which are better able to resist insect pests and diseases and are more likely to produce healthy seeds for future generations
- Ensure that seeds are mature and fully developed before harvesting
- Harvest seeds continuously when they reach full development, to avoid pests, shattering, disease incidences, or loss due to other unforeseen events
- Clean all seeds thoroughly to remove chaff, insects, pods, etc. which can harbor insects and diseases
- Remove all damaged or diseased seeds
- Dry seeds to the recommended seed moisture content
- Immediately store seeds in vacuum-sealed containers (see ECHO Asia Note #14- Croft *et al.* 2012; Croft *et al.* 2013; and Lawrence *et al.* 2017)
- Store vacuum-sealed seeds in low-temperature conditions (See ECHO Asia Note #14- Croft *et al.* 2012)

This note describes how to create a low-cost seed dryer to remove seed moisture content and thereby increase stored seed viability. However, if you are going to invest the time and money to dry seeds, once they are dried you must immediately store them in vacuum-sealed or hermetic containers. If left out, dry seeds will again pick up moisture from the outside air. Seed viability and germination remain highest when seeds with low moisture content are stored in vacuum-sealed containers at low temperatures.

Building a Seed Dryer

An effective seed dryer will include a heating source, a way to moderate the heating source, a container or box for maintaining the heat, screens on which to place seeds, a fan to circulate air (optional), and a vent for releasing moist air (optional). Basically, heated air from a heating element flows upward due to convection or is circulated around an enclosed space using a fan; this heating element is set to a specific temperature so as not to damage seeds. As the warm air moves through the chamber, seeds release moisture because warm air holds more moisture than cold air. If the chamber is very air-tight, your seed dryer will be more efficient with a vent to give off the warm, moisture-laden air, since seeds will equilibrate to the ambient relative humidity.

Drying times and ability to reduce seed moisture content will vary depending on the efficiency of your dryer, the heating source, the quantity of seed being dried, the types of seed being dried, and the ambient conditions. During the rainy season in northern Thailand, we find it difficult to dry seeds even with a seed dryer, but during very dry periods of the hot season, a seed dryer is hardly necessary. Learning how to dry seeds properly requires trial and error, and is both an art and a science. With time and experience, the ECHO Asia Seed Bank Staff have developed a keen finesse for drying seeds and approximating seed moisture content.

Depending on the type, seed dryers can play additional important roles on a Small Farm Resource Center or in a seed bank. When a thermostat is used along with a sealed, insulated chamber, the dryer can become a seed germination cabinet. Seed dryers with sufficient airflow and heat can be used to dry other biomass for research or commercial purposes (e.g. our Seed Dryer #3, which is a modified seed germination cabinet, can also be used to dry moringa and other plant materials for research purposes or to powder for nutrient supplements). With a little creativity, a seed dryer can be built from commonly available materials and can serve many concurrent purposes!

ECHO Asia has built three seed dryers over the past eight years. Below we look at each one of them in depth. In general, a seed dryer requires five or six main components. **1. A heating source**, can either be a heating element or light bulbs. Incandescent light bulbs give off the most heat, but fluorescent bulbs can be used. Electricity will be needed to power the bulbs. **2. The way to moderate the heating source** can either be with a thermostat or with a simple electric timer. The thermostat is the preferred method, as it can accurately regulate temperatures; however, a timer can be used, assuming that you spend the

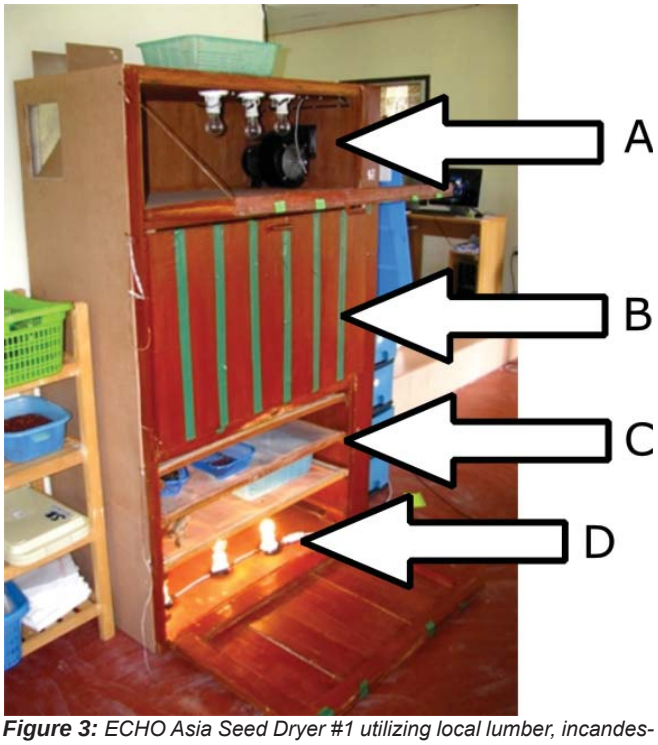

Figure 3: *ECHO Asia Seed Dryer #1 utilizing local lumber, incandescent bulbs, custom-built shelves, squirrel fan, and heating chamber. A. Drying compartment with additional lights and fan; vent is on far left. B. Additional seed drying compartment. C. Seed drying compartment using screen shelves. D. Incandescent light bulbs provide heat.*

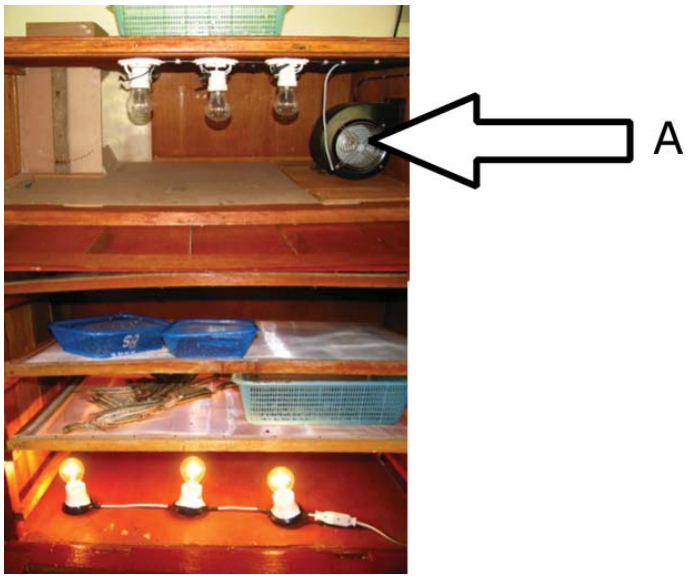

Figure 4: *Close-up of ECHO Asia Seed Dryer #1 utilizing local lumber, incandescent bulbs, custom-built shelves, squirrel fan and heating chamber. A. Drying compartment with additional lights and fan; vent is on far left.*

Figure 5: *Close up of shelves and large seed pods drying in Seed Dryer #1.*

Figure 6: *ECHO Asia Seed Dryer #1 showing custom made shelves, light bulbs, and squirrel fan for air flow before addition of vent. The fan blows heated air from the top to the bottom via a false wall to help recirculate heated air.*

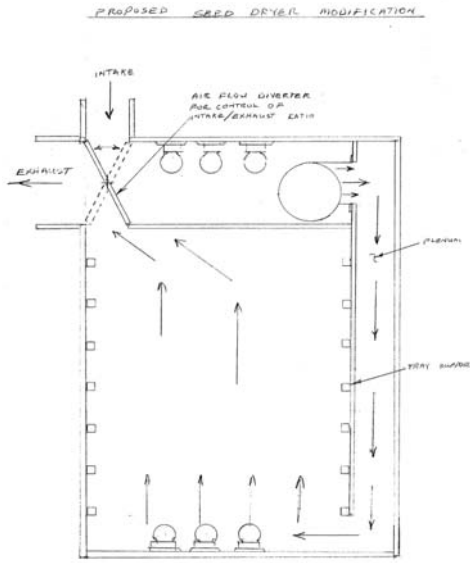

Figure 7: *Plan of modifications for the Seed Dryer #1, including the addition of an airflow intake and exhaust.*

necessary time and effort to measure temperature inside the seed dryer and to adjust the bulbs' heating/cooling cycle through the on/off function of the timer and pay attention to changing ambient temperature conditions. **3. A container or box** that will store the seeds and will contain the heat is essential to ensure that seeds are not re-equilibrating to ambient air moisture and that the heating elements are being used efficiently. **4. Screens** work well to hold the seeds inside the container. Any material that allows for airflow can work; we have successfully made removable screens out of screen door material. The screens should be arranged to allow for maximum airflow through the chamber. Stacking screens in layers like shelves has worked well for us. Spread seeds no more than one layer thick on the screen material, to allow for good air circulation and to maximize drying. **5. A small fan** that circulates the warm air can help to speed up drying times, maximize efficiency, and ensure more uniform drying; you might use an AC fan connected directly to a mains power source, or a DC computer fan connected to a DC converter. Although helpful, a fan is not absolutely necessary if the heating element is below the screens and convection can carry the warm air up through the successive layers of screen shelves. **6. A vent** that can be opened and closed is not absolutely necessary (especially if your cabinet or box is not too air-tight), but it can be helpful if your seeds have a very high moisture content. As warm air picks up moisture from the seeds, it loses its ability to hold more moisture, and makes the inside of the chamber moist. Opening a vent periodically allows moist air to escape and replaces it with fresh air. If you don't have a vent, this can also be accomplished by opening the chamber door or shelves every so often.

Figure 8: *ECHO Asia Seed Dryer #2 with all shelves closed. A. Thermostat and ventilation fans. B. Drying shelves.*

Figure 9: *Looking down into Seed Dryer #2 at heating source. Not all light bulbs are necessary to create the desired amount of heat.*

Figure 10: *Showing hardware for removable shelves of Seed Dryer #2.*

Figure 11: *Close up of thermostat, fans, and removable shelves of Seed Dryer #2.*

Figure 12: *Close up of shelves using screen material in Seed Dryer #2.*

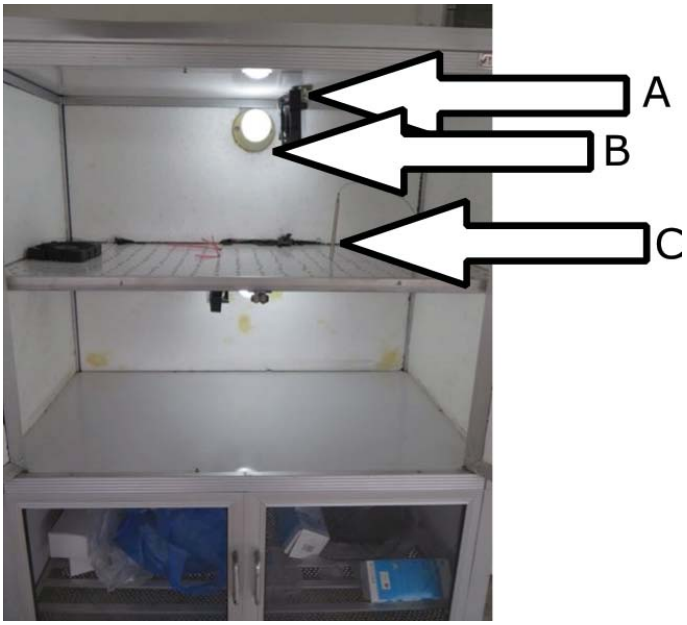

Figure 15: *Seed Dryer #3 showing: A. Fans for air circulation. B. Light bulbs for heating. C. Thermostat.*

Figure 13: *Modular Seed Dryer #3 with original design based around ECHO Asia's Seed Germination Chamber.*

Figure 14: *Thermostat to control heating temperatures inside Seed Dryer #3.*

ECHO Asia Models of Seed Dryers

The first ECHO Asia Seed Bank dryer (we'll call it Seed Dryer #1) is a very large, custom-built wooden box with shelves spaced about 8 inches (17 cm) apart (Figures 3, 4, and 5 on pages 11 and 12). It uses incandescent light bulbs in the bottom and at the top to heat the air (Figure 3). The dryer is quite rugged, but heavy, and has developed cracks in the walls over time, due to the use of local lumber that was not kiln-dried. We later modified it to include a ventilation system (which we rarely use), a thermostat to better control temperatures, and a squirrel fan, along with more incandescent light bulbs to try to circulate more air (Figure 4) from the upper part of the chamber down into the lower part of the chamber. This design also incorporates a separate heating area at the top to heat and exchange air (Figures 6 and 7 on Page 12).

The second ECHO Asia Seed Bank dryer (Seed Dryer #2) was built six years after the first. We used the same principles, but with modifications to make it more compact and efficient (Figure 8 on Page 12). While the first dryer was built using local lumber prone to splitting, this dryer was built using kiln-dried wood and plywood. We also used heavier-duty hardware and more closely-spaced shelves (to make the design more compact). Like the first dryer, this one has light bulbs for heating (Figure 9), a thermostat, and DC-computer fans to circulate the air (Figure 10). Whereas Seed Dryer #1 is unmovable, this dryer has caster wheels that allow us to move it where needed. Hardware is high quality (Figure 11) and provides for smooth operation, but is somewhat difficult to remove from the cabinet for cleaning (Figure 12).

We have built a third design (Seed Dryer #3), but have not yet used it widely. It is a modular design, based off of a seed germination cabinet (Figure 13) that ECHO Asia built and has been promoting (see EAN #8 (Bicksler 2011) as well as our YouTube video). This seed dryer is essentially a seed germination cabinet with a thermostat (Figure 14) to precisely control temperatures, a vent to allow for release of saturated air, DC-computer fans to circulate air within the cabinet (Figure 15), and a number of holes drilled into the pre-existing shelf in the chamber to aid in airflow (Figure 16). Advantages of this design are that: 1) it can double as a seed germination cabinet, and 2) with pre-existing insulation, is extremely heat efficient. A drawback is that it is limited in size to the pre-existing size of the kitchen cabinet that was used in its construction.

Staff Feedback About the Designs

ECHO Asia Seed Bank staff members provided the following feedback on the designs and operability of Seed Dryer #1 and Seed Dryer #2. They also shared their parameters for an ideal seed dryer (Table 1). We would like to combine some of the

best features of both to create a new seed dryer in the future.

Conclusion

A high-quality and highly effective seed drying cabinet can be built from local materials with very low financial and labor inputs. Using such a seed dryer helps to reduce seed moisture content, improving the viability of seeds and the effectiveness of seed storage techniques. Improved seed storage and viability can reduce the need to purchase seed, improve the self-sufficiency and sustainability of farmers and communities, and help in the fight to protect the planet's crop seed biodiversity.

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Figure 16: *Close up of light bulbs, fans, and thermostat in Seed Dryer #3.*

Rao, N. K., J. Hanson, M. E. Dulloo, K. Ghosh, D. Nowell, and M. Larinde. 2006. Manual of Seed Handling in Genebanks. Handbooks for Genebanks Number 8. Rome: FAO. *Available:* http://www.bioversityinternational.org/e-library/publications/detail/manual-of-seed-handling-in-genebanks/

Table 1: *Staff feedback about the pros and cons of Seed Dryers #1 and #2, as well as their parameters for creating an ideal seed dryer in the future.*

Seed Dryer #1	Seed Dryer #2	Ideal Seed Dryer
Pros:	**Pros:**	
Fan doesn't seem to be necessary for drying seeds	Constructed out of light, durable wood	Constructed out of light, durable wood
Custom-built shelves are easy to remove	Easy to move	No need for a fan
Easy to clean	Good for the final stage of cleaning and drying	Heating elements at bottom of cabinet
Wide shelves spaced far apart make it easy to put containers or seed pods into the dryer		Easy to move
Bulbs at bottom provide enough heat without fan		Some wide shelves spaced for apart and close together to allow for options (seeds and seed pods)
		Access area in bottom, to enable easy cleanup of debris that falls
		Removable top lid to aid in any repairs
Cons:	**Cons:**	
Heavy- doors and entire cabinet	Difficult to clean debris that falls to bottom	
Diffcult to move	Difficult to remove shelves	
Fan is loud	Expensive (German) hardware	
Shelves are a bit flimsy	Unable to put large seed pods in (because shelves spaced closely together)	

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Our conference theme **"Improving Lives"** expresses our desire to partner with you as we train, equip, and grow our network to impact the lives and livelihoods of farmers and their families across Asia.

Speakers will share practical solutions to agricultural challenges, personal experiences, and strategies for improving the lives of millions who daily face the threat of starvation. The event offers an open exchange of information, connecting the people and ideas that can make a real and sustainable difference.

Come join us for 3-days of plenary speakers, workshops, coffee cupping, paper proceedings, a poster session, and a seed exchange followed by a 1-day site visit!Go to **AsiaConference.ECHOcommunity.org** to register and to learn more about what our conference seeks to offer.

Now accepting applications for poster and paper submissions! We are pleased to announce an opportunity to submit posters and/or research papers for publication and distribution to our network. This will provide conference attendees to share and exchange information with one another.

Posters: consider creating a poster for display at the conference venue. Your poster can then be viewed by other conference delegates at their leisure, as well as during designated times for poster presenters and other conference attendees to interact.

Papers: please consider submitting a paper summarizing some of the research you may have conducted in recent years. We hope that in this way, any interesting research findings from within our network may be shared in a more formal manner with practitioners throughout the region.

There will also be an opportunity, during a late-afternoon or evening session, to give a five-minute oral summary of your paper/poster. To learn more, go to our conference website or go directly to the application page to learn specifics on how to submit your proposal.

Conference Packages in USD/THB if registering before 31 August 2017

- Day Package (conference only, no lodging): $150USD/ 5,250THB
- Shared Room (conference and 4 nights shared room) Package: $200/ 7,000THB
- Single Room (conference and 4 nights single room) Package: $250/ 8,750THB
- Spouse Package (4 nights lodging, no conference): $60/ 2,000THB
- Contact us at echoasia@echonet.org to learn about scholarships!

Early Bird Deadline is 31 August. Register today to take advantage of lower package price and to secure your place!

For more information and to register email us at echoasia@echonet.org or go to:

AsiaConference.ECHOcommunity.org

New Publications Available

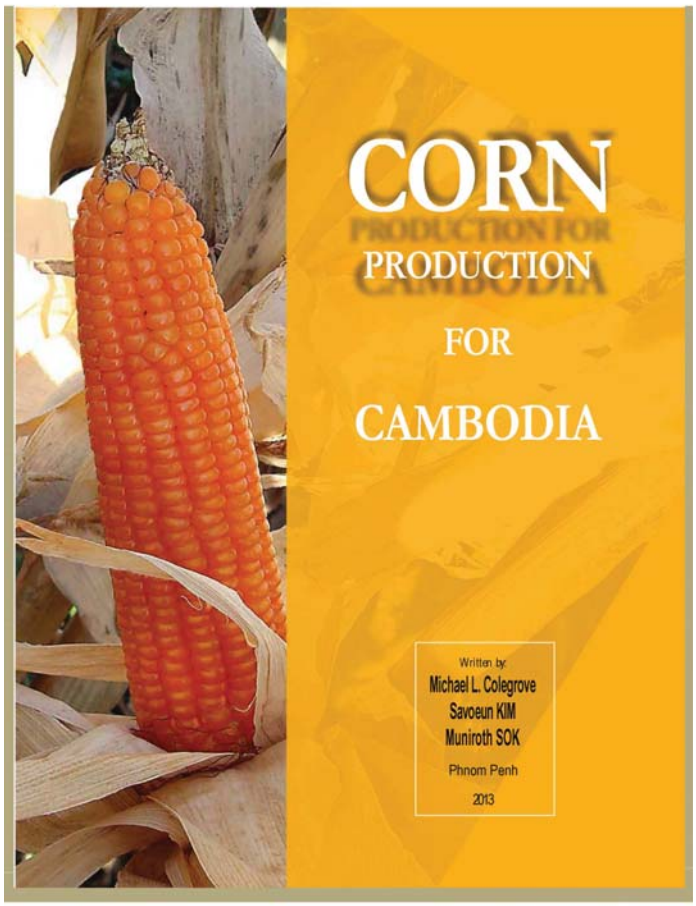
ECHO Asia is pleased to make these two resources on **water treatment systems** available from Aqueous Solutions and Pun Pun.

Both booklets describe multi-step water filtration using:

- A gravel roughing pre-filter
- A slow sand biofilter
- And a biochar adsorber at the 300L per day and 2,000L per day scale

The PDFs are available in our ECHO Asia Technical Documents section on ECHOcommunity as well as for sale in hardcopy in the office in English, Thai, and Burmese.

We think these water treatment systems can have positive implications for improved sanitation and health in communities.



Corn Production for Cambodia, written by Michael L. Colegrove, Savoeun Kim, and Muniroth Sok, offers a comprehensive look at corn and its agronomics and economics in the developing world of Southeast Asia.

Although originally written for a Cambodian context, its 216 pages are broad-ranging and applicable to many corn-growing regions in the tropics and will be found to be a useful companion to anyone growing corn or working with those who are.

Available in print form from the ECHO Asia Office.

Opportunities from the Network

Call for Papers Related to Shifting Cultivation

This is an invitation to contribute to the final publication of an encyclopaedic trilogy on shifting cultivation in the Asia-Pacific region.

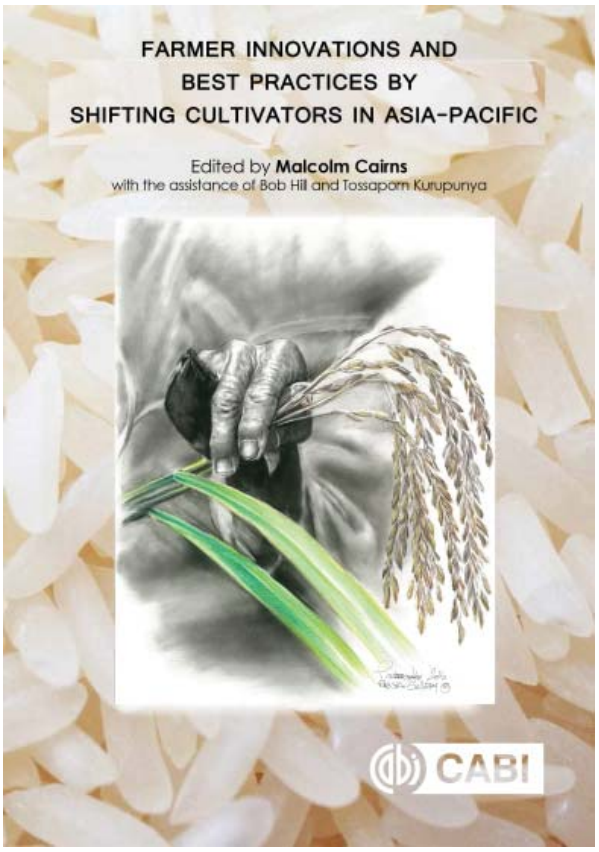
Edited by Dr Malcolm Cairns, **Volume One, Shifting Cultivation and Environmental Change: Indigenous People. Agriculture and Forest Conservation** (Earthscan, 2015), has already received wide acclaim. **Volume Two, Shifting Cultivation Policies: Balancing Environmental and Social Sustainability**, enlisted contributions from many of the world's leaders in the field, and will be published by CABI Publishing in the UK in mid-2017.

Now Dr Cairns and his team are working on **Volume Three, Farmer Innovations and Best Practices by Shifting Cultivators in Asia-Pacific**, and are casting a wide net in order to gather the best contributions. Much like its predecessors, Volume Three will be a 1,100-page collection supported by an online Addendum, aiming to make this trilogy essential reading for scientists, students, policy-makers and extension workers around the world.

We would warmly welcome inquiries at **mfcairns@gmail.com**. Papers to be submitted before December 31, 2017.




All photos by M. Cairns.



Call for Articles & Insights

We are delighted that you receive and read our ECHO Asia Notes. We hope that the information contained here within is useful to you and most importantly, useful to those whom you serve. I wanted to highlight a few things that you may find add value to your free membership to ECHOcommunity.org and can help you be more effective.

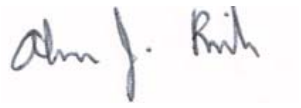
1. Please do remember that a "Development Worker" membership entitles you to 10 free trial packets of seed per year, so be sure to take advantage of this! If you would like more seed packets or larger quantities of some seeds (especially green manure/cover crops), we do have additional seed packets and bult seeds for sale, and our Seed Bank catalog is available online!
2. Please also know that besides being written in English, our ECHO Asia Notes are translated and available for free download on ECHOcommunity.org in Thai, Khmer, Burmese, Hindi, Mandarin, Bahasa Indonesia, and Vietnamese languages.
3. Additionally, we have a special place in the Asia section of ECHOcommunity for additional technical resources, free book downloads, and presentations from past ECHO Asia events and workshops.
4. If you have never joined us for an event, please consider doing so- our Biennial conference is happening in Thailand this October and other upcoming events will be posted to ECHOcommunity.org soon.

In addition to using our information, we strongly encourage you to provide feedback to us in order to better know how to serve you and help us to refine our resources and delivery.

In the future, we hope to have an automated feedback system, seed evaluation system, and better monitoring and evaluation so that we can better equip workers. We encourage you to share success stories, lessons learned, insights, Facebook posts, etc. with us to keep us abreast about what you are trying and what is working in your context.

Additionally, if you have any ideas or would like to write an article for an upcoming ECHO Asia Note, we invite you to do so! Thank you for reading, and please do stay in touch!

Best regards,



Abram J. Bicksler, Ph.D.
Director, ECHO Asia Impact Center

ECHO ASIA IMPACT CENTER