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By Dawn Berkelaar

We recently learned about a method of raising rice that produces substantially higher yields with the planting of far fewer seedlings and the use of fewer inputs than either traditional methods (i.e., water) or more “modern” methods (chemical fertilizer or agrochemicals). It involves using different practices for plant, soil, water and nutrient management. This system of rice intensification has been successfully used in a number of countries (although so far mostly in Madagascar).

What is SRI?

SRI involves the use of certain management practices which together provide better growing conditions for rice plants, particularly in the root zone, than those for plants grown under traditional practices.

SRI was developed in Madagascar in the early 1980s by Father Henri de Laulané, a Jesuit priest who spent over 30 years in that country working with farmers. In 1990, Association Tefy Saina (ATS) was formed as a Malagasy NGO to promote SRI. Four years later, the Cornell International Institute for Food, Agriculture and Development (CIIFAD), began cooperating with Tefy Saina to introduce SRI around the Ranomafana National Park in eastern Madagascar, supported by the U.S. Agency for International Development. It has since been tested in China, India, Indonesia, the Philippines, Sri Lanka and Bangladesh with positive results.

The results with SRI methods are remarkable (see Table 1). In Madagascar, on some of the poorest soil to be found and where yields of 2 tons/hectare were the norm, farmers using SRI are now averaging over 8 tons/hectare, with some getting 10 to 15 tons/hectare. A few farmers have even gotten over 20 tons/hectare. In other parts of the country, over a five-year period, hundreds of farmers averaged 8 to 9 tons/hectare.

	Traditional Methods		SRI Methods	
	Ave.	Range	Ave.	Range
Clump/m ²	56	42-65	16	10-25
Plants/clump	3	2-5	1	1
Tillers/clump	8.6	8-9	55	44-74
Panicles/clump	7.8	7-8	32	23-49
Grains/panicle	114	101-130	181	166-212
Grains/clump	824	707-992	5,858	3,956-10,388
Yields (t/ha)	2.0	1.0-3.0	7.6	6.5-8.8
Root strength (kg)	28	25-32	53	43-69

Table 1: Comparison of rice grown with traditional vs. SRI methods. Data for traditional methods were calculated from measurements on five adjacent fields. Data for SRI methods are averages and ranges from 22 test plots. Data are from a master's thesis by Joel Ibarison, 1998.

SRI methods have at least doubled the yields of any variety of rice that has been tried. No external inputs are necessary for a farmer to benefit from SRI. The methods should work with any seeds that are now being used. However, you do need to have an open mind about new methods and a willingness to experiment. With SRI, plants are treated as the living organisms that they are, rather than as machines to be manipulated. The potential within plants is drawn out by giving them the best possible conditions for their growth.

At first, the practices that constitute SRI seem somewhat counterintuitive. SRI challenges assumptions and practices that have been in place for hundreds, even thousands of years. Most rice farmers plant fairly mature seedlings (20-30 days old), in clumps, fairly close together, with standing water maintained on the field for as much of the season as possible. Why? These practices seem to reduce the risk of crop failure. It seems logical that more mature plants should survive better; that planting in clumps will ensure that some plants will survive transplanting; that planting more seedlings should result in more yield; and that planting in standing water means the plants will never lack water and weeds will have little opportunity to grow.

Despite this reasoning, farmers have not found that using SRI practices puts their crops at any more risk than do traditional methods. Four “novel” practices in particular are key in SRI:

1. **Seedlings are transplanted early.** Rice seedlings are transplanted when only the first two leaves have emerged from the initial tiller or stalk, usually when they are between 8 and 15 days old (see Figure 1). Seedlings should be grown in a nursery in which the soil is kept moist but not flooded. When transplanting seedlings, carefully remove them from the nursery bed with a trowel, and keep them moist. Do not let them dry out. The seed sac (the remains of the germinated seed) should be kept attached to the infant root, because it is an important energy source for the young seedling. Seedlings should be transplanted as soon as possible after being removed from the nursery--within half an hour and preferably within 15 minutes. When placing seedlings in the field, carefully lay the roots sideways in the soil with a horizontal motion, so that the root tip is not inadvertently left pointing upward (this happens when seedlings are plunged straight downward into the soil). The root tip needs to be able to grow downward. Careful transplanting of seedlings when they are very young reduces shock and increases the plants' ability to produce numerous tillers and roots during their vegetative growth stage. Grains of rice are eventually produced on the panicles (i.e. the “ears” of grain above the stalk, produced by fertile tillers). More tillers result in more panicles, and with SRI methods, more grains are produced on each panicle.

Figure 1: With SRI, seedlings are planted when they are 8 to 15 days old, when there are just two leaves. The plants at the right are eight days old. With traditional methods, seedlings are planted when they are several weeks old. The seedlings below are 31 days old. Photos by Joshua Harber.



2. **Seedlings are planted singly rather than in clumps.** Seedlings are transplanted singly rather than in clumps of two or three or more. This means that individual plants have room to spread and to send down roots. They do not compete as much with other rice plants for space, for light, or for nutrients in the soil. Root systems become altogether different when plants are set out singly, and when the next practice is followed:
3. **Wide spacing.** Rather than in tight rows, seedlings are planted in a square pattern with plenty of space between them in all directions. Usually they are spaced at least 25 cm x 25 cm (see Figure 2). Feel free to experiment with the spacing, because the optimum spacing (producing the highest number of fertile tillers per square meter) depends on soil structure, soil nutrients, temperature, moisture and other conditions. The general rule is that plants should have plenty of room to grow. If you also use the other practices mentioned here, seldom will the best spacing be closer than 20 cm

but the increase in yield means that the work will more than pay for itself.

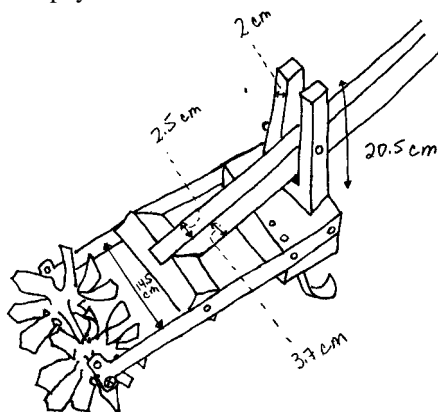


Figure 3. One example of a mechanical weeder with vertical rotating toothed wheels, often used with SRI. Plans are available at ECHO for this weeder and for a larger weeder with five wheels. Sketches of weeders by Paya deMarken, Peace Corps Volunteer in Madagascar.

The first weeding should be done ten to twelve days after transplanting, and the second weeding within fourteen days. At least two or three weedings are recommended, but another one or two can significantly increase the yield, adding one to two tons per hectare. Probably more important than removing weeds, this practice of churning the soil seems to improve soil structure and increase aeration of the soil.

6. **Organic inputs.** SRI was developed initially with chemical fertilizers to increase yield on the very poor soils of Madagascar. But when subsidies were removed in the later 1980s, recommendations switched to use of compost, and even better results were observed. The compost can be made from any biomass (e.g. rice straw, plant trimmings and other plant material), with some animal manure added if available. Banana leaves can add more potassium, cuttings from leguminous shrubs add more nitrogen, and other plants such as *Tithonia* and *Azadirachta indica* may be high in phosphorous. Compost adds nutrients to the soil slowly and can also contribute to a better soil structure. It seems fairly intuitive that some form of nutrient input is necessary on poor soils if chemical fertilizer is not added. With huge yields of rice being harvested, something needs to be returned to the soil!

Why does SRI work?

The concept of **synergy** appears to help explain why SRI works so well. In this context, synergy means that practices used in SRI interact in positive, reinforcing ways so that the whole is more than the total of its parts. Each of the management practices used in SRI makes a positive difference in the yield, but the real potential of SRI is seen only when the practices are used together.

When used together, SRI practices result in a rice plant structure that is different from what results when traditional practices are followed. Rice plants under SRI have many more tillers, greater root development, and more grains per panicle. In order to tiller, plants need to have enough root growth to support new growth above ground. But roots require certain conditions of soil, water, nutrient, temperature and space for growth. Roots also need energy from the photosynthesis that occurs in tillers and leaves above ground. Thus the roots and shoots depend on each other. In addition, when growing conditions are optimized, there is a positive relationship between the number of tillers per plant, the number of tillers that become fertile (panicles), and the number of grains per tiller.

SRI fields will look terrible for a month or more after transplanting, because the plants are so thin and small and widely spaced. In the first month, the plant is preparing to tiller. During the second month, serious tillering begins. In the third month, the field seems to “explode” with rapid tiller growth. To understand why, you need to understand the concept of **phyllochrons**, a concept that applies to members of the grass family, including cereals like rice, wheat and barley.

A phyllochron is not a thing. It is the period of time between the emergence of one phytomer (a set of tiller, leaf and root which emerges from the base of the plant) and the emergence of the next (see Table 2). The length of phyllochrons is determined particularly by temperature, but it is also affected by things like day length, humidity, soil quality, exposure to light and air, and nutrient availability.

If conditions are good, phyllochrons in rice are five to seven days long, though they may be shorter at higher temperatures. Under very good conditions, the vegetative growth phase of a rice plant may last as long as 12

	Phyllochrons											
	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 th
New Tillers	1	0	0	1	1	2	3	5	8	12	20	31
Total Tillers	1	1	1	2	3	5	8	13	21	33	53	84

Table 2: The increase in number of tillers that can be produced by the rice plant in successive phyllochrons (from De Laulanie 1993). The first and later tillers send out more tillers which send out still more tillers. By the end of the series, plant growth becomes exponential rather than additive.

phyllochrons before the plant begins initiating panicles and starts its reproductive phase (see Table 2). This is possible when the rate of biological growth is speeded up, so that many growth intervals are completed before panicle initiation.

Conversely, under poor conditions, phyllochrons last longer, and fewer of them will be completed before the flowering phase begins. Here is the most important consideration: only a few tillers are put out during the early phyllochrons (and none at all during the second and third phyllochrons), but during each successive phyllochron after the third one, each tiller already growing puts out a new tiller from its base (with a lag time of one phyllochron before this process starts) (see Table 2). During the latter part of the vegetative growth period, with ideal growing conditions, the plant's production of tillers becomes exponential rather than additive. (It corresponds to what is known as the Fibonacci series in biology.) Instead of a "maximum period" of tiller production being reached some time before panicle initiation (PI), as happens with standard cultivation practices, with SRI both PI and the maximum production of tillers coincide.

This is why it is best to transplant seedlings during the second or third phyllochron, so as not to disrupt the rapid growth which begins in the fourth phyllochron. Seedling roots are traumatized when they are exposed to the sun and dry out; when they are plunged into an airless environment; and when feeder roots, put out from the first root, are lost or damaged during late transplanting. This trauma slows subsequent growth, and not as many phyllochrons are completed before PI. Most current transplanting methods (and timing) set plant growth back by one or two weeks and also slow subsequent growth. For maximum tillering, you want plants to complete as many phyllochrons as possible during their vegetative phase. If seedlings are three or four weeks old when transplanted, the most important (late) phyllochrons when tiller growth is multiplied will never be reached.

Contrary to popular expectation, more tillering does not mean less panicle formation or grain filling. With SRI, there is not a negative correlation between the number of tillers produced and the number of grains produced by each fertile tiller. All yield components—tillering, panicle formation, and grain filling—can increase under favorable growing conditions.

This sounds too good to be true. What is the catch?

SRI requires more labor per hectare than traditional methods of growing rice. When farmers are not familiar and comfortable with transplanting tiny seedlings with fairly exact spacing and depth of planting, this operation can initially take twice as long. But once farmers are comfortable and skilled with the technique, transplanting

takes LESS time because there are so many fewer plants to put in.

With SRI, more time is spent applying water carefully than when fields are kept flooded all the time. This means that fields should initially be constructed with appropriate irrigation systems that allow water to be "put on" and "taken off" the field at regular intervals. Most rice fields are not set up like this (i.e. they were designed to hold the maximum amount of water), so some reconstruction of fields may be necessary before initiating SRI production systems.

Weeding takes more time if there is no standing water. However, the yields may be increased several-fold due to the increased soil aeration which results from weeding with the rotary push-hoe. The extra yield more than pays for the extra expense of weeding.

At first, SRI can take 50 to 100% more labor (and more skilled and exacting labor), but over time, this amount is reduced. Experienced SRI farmers say it can even require less labor once techniques are mastered and confidence is gained. Since yields can be two, three, and even four times more than with current practices, the returns to both labor and to land are much higher, justifying the greater investment of labor.

Some farmers are skeptical of SRI's benefits. It seems almost like magic at first, though there are good scientific reasons to explain each part of the process. These farmers should be encouraged to try the methods out in a small area, to satisfy themselves about the benefits and to start gaining the skills on a small scale.

Planting and weeding are initially the most labor-intensive part of SRI. Many families are constrained by the amount of labor that is available, either within the household or for hire. If someone does not have enough labor available to plant and tend all the rice fields using SRI, he or she can cultivate just part of the land with rice using SRI methods, getting higher returns for both labor and land. Then other crops can be planted on the remainder of the land at times when labor is available.

Is SRI sustainable? How can you get such high yields?

Scientists are not certain, and many are very skeptical, about how such high yields can be obtained on such poor soil as that found in Madagascar. Fortunately, SRI methods have been found to produce much improved yields in other countries (China, India, Indonesia, the Philippines, Sri Lanka and Bangladesh), so we know that it is not a methodology with success limited to one country.

Little systematic evaluation has yet been done by plant or soil scientists. However, here are a few proposed

explanations for which there is some basis in scientific literature:

- 1) Biological nitrogen fixation (BNF). Free-living bacteria and other microbes around the roots of rice may fix nitrogen for the plants. The presence of such bacteria has been documented for sugar cane, which is in the grass family along with rice. Where nitrogen fertilizer had not been applied (since this suppresses production of the enzyme nitrogenase required for BNF), microbial action fixed 150-200 kilograms of nitrogen per hectare for the cane. However, less nitrogen fixing occurs where chemical fertilizers have previously been applied. It is known that about 80% of the bacteria in and around rice roots have nitrogen-fixing capability, but this potential will not be realized where inorganic N has been applied, or possibly in anaerobic, water-logged soil.
- 2) Other research suggests that plants can grow very well with extremely low concentrations of nutrients, as long as those nutrients are supplied evenly and consistently over time. We know that compost furnishes a low, steady supply of nutrients.
- 3) Plants with extensive root growth have better access to whatever nutrients exist in the soil. Extensive root growth can result when the roots of young seedlings have lots of space and oxygen, and when water and nutrients are scarce enough that roots need to “go looking” for them. Such extensive roots may be able to extract more balanced nutrients from the soil, including some scarce but necessary micronutrients.

Much more remains to be studied about and learned from SRI, but scientists are starting to take an interest in it as reports of superior yields increase. SRI should be seen not as a technology to be applied mechanistically, but rather as a methodology to be tested and adapted to farmers’

conditions. Farmers need to be good observers and good learners to make the best use of the insights that SRI provides.

In summary, the main elements of SRI are as follows: Transplant young seedlings to preserve their potential for tillering and root growth while they also benefit from other favorable growing conditions. Provide the plants with wide spacing, without competition either in hills or between hills. Keep the soil well aerated but sufficiently moist, so that the roots can “breathe”; for this, use both water management and weeding practices that aerate the soil. Finally, provide nutrients that feed the soil as well as the plant, so that a rich and healthy soil gives plants the nutrients and positive environment needed for best growth and performance.

For More Information

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Sebastien Rafaralahy, President, and Justin Rabenandrasana, Secretary. Association Tefy Saina; B.P. 1221, Antananarivo, Madagascar. (Tel: 01-261-222-0301; e-mail: tefysaina@simicro.mg). If you can communicate in French, please do so; Tefy Saina can read and write English fairly well, but communication is easier en français.

Special thanks to Norman Uphoff for helpful comments on the manuscript, and to Association Tefy Saina for editing. Thanks to Glenn Lines for editing and for sending us diagrams of the mechanical weeder.

ECHOES FROM OUR NETWORK

Rice Hulls Revisited

Tom Kalb, AVRDC

Last issue’s article about Smoked Rice Hull began with the statement that ordinary rice hulls make a poor planting medium. We were curious to know why, so we contacted AVRDC in the Philippines. Here is what training specialist Tom Kalb had to say:

“Rice hulls may contain disease. They will not hold much water. Rice hulls are slow to decompose, and

thus cannot supply many nutrients to growing seedlings. We smoke the rice hulls to kill fungi and bacteria. The smoked hulls have a consistency that can hold onto water and supply nutrients to plants.”

Ash from Cocoa as a Substitute for Lime in Ponds

Will Leschen, Ghana

Will Leschen, VSO Fisheries Advisor from Ghana, wrote the following: “Before stocking (and restocking) fish ponds it is well known that fish farmers remove the

layer of organic mud and silt from the bottom of their ponds and can then use this mud as a very rich source of manure in order to grow vegetables on the banks/dikes of their ponds. They then lime the ponds’ bottoms and sides prior to stocking, usually using a locally available form of slaked lime--CaO, CaOH, etc. However, in inland areas the availability of this lime is often limited and the cost is prohibitive, particularly for fish farmers with larger ponds.

“Rather than using lime, farmers in Volta, Western and Central regions

of Ghana are substituting ash from dried and burnt pods of cocoa. This ash is used already in rural areas for soap making, is readily available in large quantities and is a strong alkali. Recent trials using it show no adverse effects on the fish (tilapia, catfish) and the resulting algal blooms generated in the pond water from its use tend to be sustained a lot longer than using expensive inorganic fertilizers such as NPK and

triple phosphates. I would be interested to know if any of your other readers have experience using locally available substitutes for liming and thus increasing the productivity of fish ponds.”

The International Center for Aquaculture and Aquatic Environments at Auburn University write in their bulletin “Chemical Fertilizers for Fish Ponds” that

liming a pond is important because it helps neutralize acidity where ponds are filled by rainwater.

Apparently cocoa plants can be very useful in fish pond systems! We previously wrote in EDN 66 about using powdered cocoa fruit husks as an addition to fish food.

BOOKS, WEB SITES & OTHER RESOURCES

New From ECHO: Books on CD-ROM

By Stephen Lackey

About a year ago ECHO began a new program that we believe will be of great benefit to our network for years to come. Many very helpful and practical books for agriculture and development work are no longer in print. The potential number of buyers of specialty books is often so small that for-profit companies do not bother reprinting them. Non-profit groups that give away their books sometimes run out of money for printing or postage and let their titles go out of print. ECHO plans to republish on CD-ROM many of the best books that are out of print, when copyright allows. Any new ECHO books will be published as a CD-ROM version, perhaps without even printing an actual book (which costs thousands of dollars more to publish and costs more for you to buy).

We are delighted to announce that we have just released our first three books on compact discs (CDs). To use them, you will need a PC or a Macintosh Power PC with a CD-ROM or DVD drive. All the information on these CDs is in a PDF format and requires Adobe Reader or Adobe Acrobat in order to view it—but each CD has a copy of the Adobe Reader software on it for you to install on your machine.

We have designed the CDs to be easy to use. The information they contain can be read on-screen or printed on your printer. A search engine allows you to type in a word or phrase and go directly to the places where it is found. These CDs will be much easier and less expensive to ship, and should hold up in a tropical environment better than a paper book would (though they should still be kept in as cool, dry, and dark a place as possible).

These CD's will be available from our online bookstore and our physical bookstore, and you can write in and request them. All overseas network prices include shipping. Here are our first three titles:

Ideas for Growing Food Under Difficult Conditions

This is a compilation of several ECHO publications. The CD contains *Amaranth to Zai Holes* (which itself is a compilation of EDN issues 1-51); EDN issues 52 to present; EDN in Spanish issues 58 to current; and 45 technical notes (with more to be added soon). This CD will be available for \$29.95 (\$19.95 for those working in developing countries).

Fruits of Warm Climates

Julia Morton's classic 504 page reference book on tropical fruits will be out of print as soon as ECHO sells the remaining stock of about 300 books. The book has entries for 124 fruits,

giving extensive information on the more common ones. It also has listings of local and alternate names for many of the fruits. This is probably the most used reference book at ECHO. This CD will be available for \$49.95 (\$25 for those working in developing countries).

Palms for Development.

This is a new publication by Frank W. Martin and Bryan Brunner. It introduces the reader to the fascinating world of palms with an emphasis on their use and potential for incorporation into development projects. It includes instruction on cultivating palms and an extensive listing of multi-purpose palms and their possible uses. This CD costs \$15.

Because this is our first venture into electronic publishing, we will greatly appreciate your comments. We especially need to know of ANY problem you have using the CD-ROM. We will publish only a few at a time, so that if you alert us to a problem we can get it corrected before the next person buys a CD. We will offer free technical support. These CDs were produced totally in-house, and much was learned in the making of this initial batch. We will be publishing many other titles on CD-ROM, so if you have any suggestions of helpful, out-of-print books that we could make available on CD-ROM, please write to us. (We are also interested in books in other common languages.)

FROM ECHO'S SEEDBANK

***Sesbania sesban*, var. 'Mount Cotton' Available**

By Daniel Sonke

Many of our readers are familiar with *Sesbania sesban*, a nitrogen-fixing shrub used for organic matter and fodder that is widely promoted in the humid tropics. ECHO now has seed of *Sesbania sesban* var *nubica*, cultivar "Mount Cotton". *Sesbania sesban* regrows vigorously after being cut, producing high yields of fodder and organic matter. Widely adapted, it tolerates drought, waterlogging, and soil acidity, alkalinity, and salinity. In University of Queensland studies, 'Mount Cotton' was shown to have

outstanding forage yields at five locations in Queensland, superior to that of other accessions of *Sesbania sesban* and to *Leucaena leucocephala* cv. Cunningham. In other studies at the University of Queensland, *Sesbania sesban* was shown to have high nutritive value (28% crude protein) and high dry matter digestibility (86%). Those working for an NGO in developing countries may request one packet from ECHO for free. All others please pay US\$4.00 for a packet, including shipping. If you need larger quantities, you can contact: Agroforester Tropical Seeds P.O. Box 428 Holualoa Hawaii 96725

USA

Tel: (808) 324-4427

Fax: (808) 324-4129

E-mail: seeds@agroforester.com

Website:

<http://www.agroforester.com>



Sesbania sesban. Drawing by Mary Anne Cotter. Reprinted with permission from Agroforester Tropical Seeds.

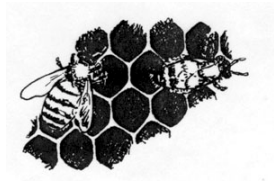
UPCOMING EVENTS

Arbeitsgemeinschaft für Mission und Landwirtschaft (Third Agricultural Missions Conference)

January 22-26, 2001

Near Stuttgart, Germany

This agricultural missions conference encourages networking of ideas and resources among German-speaking missionaries and development workers. For more information, contact Karim Sahyoun at nellnetz@hotmail.com



Apimondia 2001: Apiculture Meets Africa

September 2-6, 2001

Durban, South Africa

Apimondia is an international beekeeping congress organized by the International Federation of Bee-Keepers Associations. It is based in Rome, Italy, and specializes in all sectors of bee-keeping. Apimondia 2001 will be the 37th Congress, and the first ever to be held in Africa.

The Congress includes seven standing commissions, among them apitherapy, bee pathology, beekeeping for rural development, and beekeeping economy.

Apimondia also involves an ApiExpo trade show with international displays of beekeeping products and equipment.

Registration fees for Apimondia are US\$350 before June 10. For visa requirements, contact your nearest travel agent or South African Diplomatic Mission. For more information, contact: Apimondia 2001, Conference Planners P.O. Box 82 (66 Queen Street) Irene 0062 South Africa Phone: +27 (0) 12 667-3681 Fax: +27 (0) 12 667-3680 e-mail: confplan@iafrica.com Website: www.apimondia2001.com

THIS ISSUE is copyrighted 2001. Subscriptions are \$10 per year (\$5 for students). Persons working with small-scale farmers or urban gardeners in the third world should request an application for a free subscription. Issues #1-51 (revised) are available in book form as *Amaranth to Zai Holes: Ideas for Growing Food under Difficult Conditions*. Cost is US\$29.95 plus postage in North America. There is a discount for missionaries and development workers in developing countries (in the Americas, US\$25 includes airmail; in Europe, Africa, and Asia, \$25 includes surface mail and \$35 includes air mail.) The book and all subsequent issues are available on CD-ROM for \$19.95. Issues 52-70 can be purchased for US\$12, including air postage. ECHO is a non-profit, Christian organization that helps you help the poor in the third world to grow food.