OPERATIONALIZING *THE SYSTEM OF RICE INTENSIFICATION* (SRI)

Revised from earlier manual/guide for explaining and undertaking SRI, based on experience in Madagascar, updated with reference to Zambia – 1/1/07

HOW SRI CAN IMPROVE A FARMER'S PRODUCTION AND LIFE

One of the first farmers to make use of SRI methods was Honoré Randrianarasana near Ranomafana in Madagascar, who started working with Tefy Saina in the 1994/95 season, planting just 25 ares (.25 ha) using SRI methods. He got a yield of 9.5 tons/ha the first year, compared to his previous yields of 2 to 3 tons/ha. The next year he expanded his SRI area to 1.25 ha and got 10.95 tons/ha, which encouraged him to expand further his use of SRI methods, to 2 hectares and then 4 hectares, with still higher yields (12.7 and 13.7 tons/ha). In 1998-99, he planted 5 hectares, but his yields were around 7 t/ha because the season was bad for all farmers in the region.

In 1999-2000, Honoré planted 8 hectares with SRI, and by this time his economic situation had improved enough to buy 9 hectares of paddy land (he started with rented land) and three houses, one of them in the regional capital of Fianarantsoa. Not all farmers will be this successful or able to manage such large extents with this method. But Honoré has shown the potential that SRI has to improve farmers' lives.

THE ZAMBIA SITUATION

SRI was introduced in Zambia by the 12 farmer-members (6 women, 6 men) of the Esek Farmers' Co-operative Society, in Solwezi, Northwest Province. They registered their cooperative in 2002 with the Ministry of Agriculture and Cooperatives. The group undertook the first SRI trial in their country in 2006, without any external funding.

The SRI activity included:

- Land selection
- Land preparation (the field was 12.5 x 12.5 m)
- Choice of variety to be planted
- Seed preparation before nursery establishment
- Nursery establishment and management
- Transplantation
- Field fertilization
- Weed control and aeration of soil
- Harvest

Results from the SRI demonstration farm were as follows:

- Period from date of planting to harvesting – 6 months
- Average number of productive tillers/hill -- 48
- Average length of panicles -- 30 cm
- Highest number of grains/ panicle – 415
- Highest number of grains/ hill – 19,920
- Average number of roots per hill – 814
- Yield harvested (dried weight) -- 96 kg (= 6.144 t/ha)

How the first SRI trial has strengthened farmers' position

- It was quite interesting and encouraging for local rice farmers to observe in the SRI demonstration plot a yield of 96 kg -- equivalent of 6.144 t/ha -- in a region where local rice yields are usually around 1 t/ha.
- The paradigm shift for rice-growing from the decades-old tradition of uncontrolled rainfed rice farming to a regime of controlled but minimum water application during the period of vegetative growth is a breakthrough.
- It has been a revelation in Zambian farming circles to learn about a new production methodology technique that does not (a) depend on introducing new varieties, or (b) rely on the need for applying chemical fertilizers, or (c) require use of agrochemicals – instead utilizing biological potentials inherent in the plants and in the soil.

How the first SRI trial has strengthened recognition in the agricultural innovation system in the country:

- The farmers' society hosted on June 30 a National SRI Launch that coincided with the first SRI harvest. This attracted over 300 persons -- farmers, officials, agriculturalists, NGO workers, and others -- many traveling hundreds of kilometers. This showed a good response and commitment to the SRI innovation.
- The Zambian Government's evident support was demonstrated through the presence of the Permanent Secretary in the Office of the President, who attended and presided at the National Launch with an encouraging speech.
- Several gifts were presented during the launch ceremony: a rotary hoe weeder shipped from Madagascar by Glenn Lines, Country Director for the Millennium Challenge Corporation; also funds were sent by David Galloway, Vancouver, Canada (Can$ 5,000) to support further SRI extension; application forms were sent from the American Embassy in Lusaka for a getting grant funds to accelerate the spread of SRI in Zambia. This represents seriousness about the promotion of SRI in Zambia
- Currently over 50 farmers have already enrolled themselves to work with SRI in the 2006/2007 growing season, and a lot more want to join and engage with SRI, having seen or heard about the results.

THE BASIC TRAINING IDEAS

The System of Rice Intensification has discovered and demonstrated some important methods for helping rice plants to achieve their real potential. This potential has been obscured by previous practices such as continuous flooding (and suffocation) of plant roots and crowding of plants together so that their roots and canopy cannot grow to full extent and solar energy cannot reach all leaves. We begin by presenting the ideas on which SRI is based.

- Farmers should first understand these ideas. Then they should choose and evaluate specific practices that are most beneficial for their own conditions. *Every farmer is -- or should become -- an experimenter.*

- SRI changes the structure of rice plants -- the density and number of their roots and tillers -- by changing the practices that are used to manage rice plants, the soil they grow in, and the water they receive through irrigation, so that the plants can become more productive. In scientific terms, this means that a different and more productive phenotype is elicited from existing genotypes.

For rice plants to be more productive, they need to have:

- More tillers per plant,
- More fertile tillers (panicles) which form from the tillers that a plant puts out,
- More grains per fertile tiller, and
- Larger (heavier) grains.

If rice plants are spread out and not planted very close together, they have more room to grow. They will get more sunshine and air and can produce more roots and tillers. More of these tillers will become fertile and produce grains of rice. With more space in which to grow, rice plants' roots become larger and are better able to draw nutrients from the soil. This enables rice plants to produce more and bigger grains, which is the reason for growing rice.

- Although it may be surprising, it is possible to get ***many more*** *grains of rice* from a field by *planting* ***fewer*** *plants* and by putting *them* ***farther*** *apart, so* that each plant is healthier and more vigorous in its growth. That "less" can be "more" seems strange, but it is true.
- For the plant to grow successfully above ground, it needs a healthy and vigorous root system below ground. The "trick" of SRI is to have both a *larger root system* for each plant below ground and *more growth* of tillers, leaves and grains above ground.

Planting rice plants densely and close together ***wastes seeds***. The individual plants will be smaller and less productive. Having more rice plants is not as beneficial as having fewer plants that are very productive. Transplanting older seedlings also wastes growth and productive potential.

- With SRI methods, you can easily get *50 tillers* on a single rice plant, and some farmers using these methods well have been able to get *over 100 tillers* from a single seedling (a single seed!).
- Farmers can get *200 grains* per fertile tiller, and good farmers get as many as *400 grains* on a tiller. One farmer in Sri Lanka has gotten even *900 grains* on a single panicle.

This is not a miracle. It results from good management of the plant and of its soil and water conditions, so that the plant's potential for growth and production gets fully expressed.

HOW CAN WE GET PLANTS TO PRODUCE MORE TILLERS?

The key to success with SRI is the ***early transplanting*** of seedlings, as explained below. This usually means transplanting seedlings before they are 15 days old, and as early as 8 or 10 days -- when only the first small root and tiller, with two tiny leaves, have emerged from the rice seed. When you plant older seedlings -- 3, 4, 5 or 6 weeks old -- they have already lost much of their potential to produce a large number of tillers.

- When seedlings are planted with *much delay* after being removed from the nursery, they suffer a lot. Once removed from their seedbed, seedlings should be replanted in the field within half an hour, and preferably *within 15 minutes.*
- When seedlings are *pushed* into the ground, rather than gently laid into the soil, they also must expend a lot of energy to resume root growth. This disturbs their development. When they are more than 1-2 cm deep in the soil, this impedes their growth and tillering.

Transplanting rice seedlings early and carefully – quickly, gently and shallow -- helps plants resume their growth in the field without reducing their potential for high yields by harvest time. But to mobilize that potential, it is especially necessary to promote strong *root growth.*

HOW CAN WE GET RICE PLANTS TO GROW STRONGER ROOTS?

(1) **TRANSPLANTING PRACTICES:** The first thing is to ***plant single seedlings***, one by one, rather than to plant them together in bunches of 3 or 4 seedlings,or even more, as is usually done.

- When several seedlings are planted together, their roots must *compete with each other.* This is a similar problem for rice plants as when they grow close together with weeds and must compete with them for nutrients, water and sunlight.
- Under some soil conditions, 2 plants per hill may give the best yield, producing more total tillers but without the root competition of having 3 or more in a hill. We recommend starting with a single seedling, but experimenting with 2 per hill to see if this gives better results because soil fertility is not very good.

(2) WIDER AND EVEN SPACING: It is important, as discussed below, that the seedlings be ***spaced wide apart,*** usually at least 25 centimeters from each other, and preferably **in a square pattern**. This facilitates weeding at the same time it gives the rice more access to sunlight and air above ground. Being equally spaced in all directions gives better, more even exposure.

- When the rice plants are set out far from each other, and if the soil conditions are good, their roots will have plenty of space to spread out into, especially when they are not competing with each other.
- With wider spacing and with single planting, there will be *many fewer plants* in a field. Indeed, there may be only 10 or 16 in a square meter instead of 50 or 100. The highest SRI yield to date has been achieved with only 4 plants per square meter, spaced 50 cm by 50 cm so the plants grow like bushes. Wide spacing

saves seed -- as much as 100 kilograms per hectare -- at the same time that it contributes *much greater production* at harvest time because SRI rice plants produce many more tillers and grains.

Planting seedlings with precise spacing can be one of the more difficult aspects of SRI at the beginning, when farmers are not used to this. Three different methods have been developed.

- Farmers can stretch **strings** across their field, tied to sticks stuck into the bund at the edge of the field, stretched across the field in parallel lines and spaced 25, 30 or more centimeters apart, with the strings *marked* (knotted or painted) at whatever interval has been chosen (25, 30, or more centimeters). Then these sticks and strings (parallel to each other) are moved across the field.

- Or a kind of **marker-rake** can be constructed simply from wood that has teeth the desired distance apart (25, 30 or more centimeters). This is pulled across the surface of the prepared muddy field, scratching parallel lines onto the surface at desired intervals. Then the rake is drawn perpendicularly across this first set of lines (at a right-angle to them), creating the desired square pattern, on which seedlings are planted at the intersections of lines. The muddiness of the soil in the field should be such that the lines are easy to make and do not disappear (which would mean that the soil is too wet, also for the new transplants).

- A third method has been developed by farmers in India, where they have constructed a large **roller-marker** from metal rods, resembling a rolling pin (used to roll out and flatten bread dough for baking). The circumference of the roller is some multiple of 25 or 30 cm (usually four multiples, making 1 or 1.2 m around). Then rods are welded at 25 or 30 cm spacing the length of the roller. When this is pulled across the field, it lays down a square grid pattern on the mud. As with the rake, the moisture content of the soil should be such that the pattern is easily imprinted on the soil and does not disappear.

The first method is easy to adapt to irregularly shaped fields, but it takes much more time. The second is quicker and saves considerable labor time. It is also very adaptable to field shape. The third method is quickest of all, but involves a little more capital cost (about $10), and is not as flexible as the rake or strings. It is better for larger fields, but is very labor-saving, and it spacing is most regular and straight.

(3) HANDLING THE YOUNG SEEDLINGS: When removing young seedlings from the nursery, it is important that their roots not be damaged or stressed in any way, since this forfeits growth potential later on. Tiny seedlings should be lifted up gently, preferably with a trowel or other implement so the plants are not pulled up. Care should be taken so that the seed sac attached to the root – the seedling's initial source of nutrition – is not separated and lost.

A very important influence on the size and health of the roots is ***how the tiny seedlings are placed into the soil*** when they are transplanted.

- When seedlings (or clumps of several seedlings) are *thrust* straight downward into the soil, the tips of their roots will become pointed upward *toward the*

surface. The shape of the transplanted seedling roots will thus become like a J, with the *root tips bent upward!*

- *The rice plant root grows from its tip.* If the tip is pointing *upward*, the root must revise its position in the soil to get the tip pointed downward before it can resume growth. This requires a lot of energy and effort from the tiny root, at a time when it is still weak after transplanting, especially if it has been allowed to dry out by delay in getting it from the nursery and into the field and is placed into a flooded environment where there is little oxygen for the root's needs. The delay in resumption of growth results in ultimately reduced tillering.

- With SRI, one does not thrust seedlings downward into the soil. Rather, each seedling is slipped *sideways* into the soil, very gently and close to the surface, so that its root lies fairly *horizontally* in the moist soil. This makes the shape of the transplanted seedling root more like an L than like a J.

- With this L shape, it is easier for the tip of the root to resume its growth *downward* into the soil. When the shape of the young transplant is more like an L than a J, *less energy is* necessary for the plant's root to begin growing (again) quickly downward and to begin putting out more roots at the same time that it is sending tillers upward.

(4) WATER MANAGEMENT: A major departure from usual rice-planting practice -- an innovation as important as the transplanting of tiny young seedlings -- is to grow rice in fields where there is ***no continuously standing water****.* The rice plant during its growth stage only needs to have ***soil that is moist, but not saturated***. Indeed, the field should occasionally be *dried* even to the point of cracking. This goes against what most people believe about rice, but it is true.

Note: Some paddy soils with heavy clay content should not be allowed to dry completely because they then become too hard for roots to grow; so farmers need to understand that water management is still more an art than a science; the objective is to ensure that plant roots – and the soil organisms living in the root zone and providing services to the plant – have both enough water and enough oxygen – too much of either means too little of the other.

- An important discovery of SRI is that *rice is not an aquatic plant.* Although it can *survive* when its roots are continuously submerged under water, it does not *thrive* in this situation. Rice does not grow as well underwater as when its roots are able to get oxygen from direct contact with air.

- Rice plants that grow in standing water will adjust to this environment. Their roots develop small air pockets (known as *aerenchyma)* that permit oxygen from above ground to reach the roots. But this is not an ideal condition for plant growth. It interferes with transfer of nutrients from the soil to the plant's tillers and leaves.

- With SRI, we have discovered that the soil only needs to be kept *moist* during the period of growth when the plant is putting out tillers and leaves, before it begins

to flower and to produce grains. During the reproductive stage that follows panicle initiation, the rice plants need at most only a thin layer of water (1-2 cm) on the surface of the soil.

- Some SRI farmers are now experimenting with continuing the minimum application of water (enough to keep soil moist but not saturated) or alternating periods of wetting and drying throughout the whole growth cycle (or until about 15 days before harvest) – with good results. SRI plants have much larger root systems so they can utilize residual soil moisture at lower soil depths than can conventionally-grown rice plants. So we are learning that even greater water savings are possible over conventional practice than was initially achieved with SRI. Farmers should determine what is the best water management practice for their soils under their local conditions.

- With many soils (but not heavy clay soils), rice plants' growth will benefit if occasionally, even once a week, the soil is permitted to dry out, at least on the surface. This permits more oxygen to enter the soil and reach the roots. When the soil is not kept saturated, the roots grow longer and deeper to seek out water. When the soil around rice plants' roots has abundant water, they can be "lazy" and need not grow very much. However, this limits their ability to acquire nutrients from the soil.

- The standard SRI advice has been that after panicle initiation, farmers should maintain a thin cover of water (1-2 cm) on the field to support grain formation, and the field should be dried completely about 15 days before harvest. This advice is being rethought since some farmers are finding that with good root growth, their SRI rice plants can perform as well or better with continuing intermittent water applications.

SRI water management strategy is based on the insight that rice plants do not grow best under continuously flooded conditions. How to implement this insight can vary considerably, depending on the type of soil that farmers have and on how much they want or need to save labor. Careful daily water management gives best results, but it takes more time and effort. Farmers who want to minimize the labor requirements with SRI have made some modification in the original recommendations, *alternately flooding their fields and then draining and drying them* for periods of 3 to 6 days. For example, they may flood their fields for 4 days and then drain them and not irrigate them for 5 days.

We do not have enough systematic information to make any recommendations for how best to practice **intermittent irrigation**. What will be best practice for a particular field will depend on soil and other conditions. Farmers wanting to reduce their labor requirements with SRI should experiment with variations in the length of alternated flooded and unflooded periods, keeping in mind the principle that the roots of the plant need to have sufficient amounts of **both water and oxygen** to achieve their best growth.

(5) WEED CONTROL: When rice fields are not kept flooded continuously with water, this will give ***weeds*** a chance to grow. So efforts must be made to keep weeds under

control, so that they do not compete with the rice plants and cannot take away nutrients and water from the rice.

- A very simple *mechanical weeder*, called a rotating hoe, pushed by hand has been developed to enable farmers to eliminate weeds easily, quickly and early. It reduces the hard labor of pulling up individual weeds by hand once they emerge. The weeder by churning up the soil destroys weeds before they absorb many nutrients. By leaving them in the soil to decompose, it returns their nutrients to the soil. But the most valuable contribution to SRI production is that this weeder **aerates the soil**, benefiting both the plant and the aerobic organisms that live in the soil and that benefit the plant.

- This weeder, which has rotating 'toothed' wheels mounted vertically in the metal plate that is pushed along the ground, is not expensive. It can cost as little as US$5-10 if locally made. It may take as much as 25 days of labor to weed a hectare of rice. However, *each weeding can add one ton or even two tons of production* to the yield, so that the payoff to the farmer from each additional weeding can be very great. This increase in production is due mostly to the beneficial effects of **active soil aeration**.

- The first weeding should be done 10-12 days after transplanting, and at least one more weeding should follow within 10-12 days. This will dig up weeds at the same time that *it puts more air into the soil* for the roots and soil organisms to utilize.

- Doing one or two additional weedings (3 or 4 weedings in all), before the plants have completed their growth and begin flowering, will provide *still more oxygen* to the soil. This is more important than removing any remaining weeds. Extra weedings can substantially increase yields.

- Hand weeding or use of herbicides to control weeds will be effective with the other SRI practices, but because these methods of weed control do not aerate the soil actively, they are less beneficial for plants and soil organisms. Indeed, herbicides can have some inhibiting effect on soil organisms.

- A super-simple weeder has been developed by a SRI farmer in Nepal, Govinda Dhakal, which can best be described as a 'rake-weeder' or 'broom-weeder.' Nails are driven into the bottom of a board about 10-15 inches wide, to which a long handle is attached, much like a push-broom. Govinda made this himself at a cost of about US 20 cents for the wood and nails. He reports that it takes about 4 days to weed 1 acre, compared with 10 days for hand-weeding 1 acre. So he saves labor time and at extremely low capital cost.

(6) FERTILIZATION: Because chemical fertilizer is often not available in villages when the farmer needs it, or is available only at a price that farmers cannot afford to pay, SRI recommends using ***compost or manure*** to add nutrients to the field. Happily, compost or manure not only requires less cash outlay from farmers but gives even higher yields with SRI methods than when using fertilizer. Alternatively, chemical fertilizer and organic nutrients can be combined, possibly for the best results. What kind of

fertilization will give highest yields with SRI needs to be determined in each farming situation.

- Because the yields from SRI methods are so great, most soils will need to be enriched by some addition of nutrients. But healthy rice plants with large roots can access much better the nutrients already in the soil as well as those added through compost or manure, and thus the plants can get more benefit from these.

- Soil that is enriched with compost or manure will usually have better *structure* so that plant roots can grow more easily in the soil. Such soil absorbs and retains water better, and also takes in and distributes more air. Because compost releases its nutrients more slowly than does fertilizer, plants get more benefit from this source of nutrients, and it does more to promote abundant and diverse populations of soil organisms.

- Making compost and working it into the soil of the field is usually a lot of work. But experience shows that this is a good investment for the farmer because the better quality soil supports better root growth and performance. Adding chemical fertilizer if it is available and the farmer can afford this can often add to yields. But fertilizer is usuall *not as productive* as adding organic material to the soil.

These are the basis ideas for transforming the production of rice. Once you understand how to help plants produce more tillers as well as how to get a larger root system, the natural result will be to produce *more and heavier grains* from your fields.

TECHNIQUES

With an understanding of the potential of rice that we want to achieve, and of the ideas behind this strategy for growing more productive rice, specific techniques make more sense. As stated in the introduction, these techniques should not be implemented mechanically. Instead, farmers should always keep in mind the ***principles*** discussed above, such as:

- Help the small seedling to achieve its great potential by getting it established in the field *at a young age -- quickly* and *in an L shape* from which the root grows easily.

- Prepare the soil so that it has a good supply of nutrients and keep the soil well-aerated. SRI soil management practices -- no flooding, and the use of compost -- help microorganisms in the soil to produce more nitrogen for the rice plants, and it is well known that plant roots require oxygen. Soil microbes also convert phosphorus that is in the soil in ‘unavailable’ forms into ‘available’ phosphorus. This applies for other nutrients as well.

- Avoid competition between rice plants so that each can grow efficiently because it has good access to air, sunlight, nutrients, and water.

The following discussion provides more detail and comment on the practices that can implement the principles on which SRI is based.

Preparing the Nursery and Starting Seedlings

Fr. de Laulanié emphasized that the nursery for growing seedlings not be regarded as a miniature field -- to be kept flooded. Rather it should be treated like a ***garden***, where the soil is kept moist but not saturated. Watering by hand is sufficient if there is not enough rainfall to maintain moisture in the soil and for the seedlings. With SRI, the nursery is quite small. It is only a small fraction of the size of the field to be planted. The following steps are recommended for a modified "dry bed" method of nursery development for SRI seedlings.

- Rice seeds should first be soaked in warm water for 24 hours. Any seeds that are irregular or float should be discarded. One technique to help separate the most viable seeds from the rest is to put the seeds into a pail of water to which salt has been added. This makes the task of removing non-viable seeds easier.
- Next, put the seeds in a sack (burlap or other) and place it in a warm compost pile or in a hole in the ground that has been warmed by fire. Cover the sack completely with either compost or soil and leave it for 24 hours for slow warming of the seeds.
- The seedbed should be prepared as closely as possible to the field that will be planted, so as to minimize transport time between seedlings' removal from the seedbed and their transplanting in the field.
- Compost should be mixed into the soil of the seedbed at a rate of 100 kg per 100 m^2 (1 are = 10m x 10m). Prior to seeding, lay down a fine layer of "ripe" compost or black soil in the seedbed to give the seeds good nutrient-rich material to begin their growth in.
- Farmers in Sri Lanka have found that building up a seedbed, about 10 cm, with lengths of bamboo, putting in a mixture of compost or animal manure (chicken manure is very good) along with soil and sand (roughly 1/3 each) gives the seedlings an excellent start and makes them easy to separate. Also, the organic nutrients are contained within the seedbed better this way.
- Broadcast the pre-germinated seeds from the sack onto the bed at a rate of about 200 grams for every 3 square meters, and then cover the seeds with a fine layer of soil.
- Water the seedbed every day in the late afternoon, or as often as needed to maintain a moderate level of soil moisture. The soil should not be saturated or kept continuously wet. If there has been rain during the day, no watering may be needed. How much water to add to the bed depends on whether the soil has become dry.
- Transplanting should be done when the seedlings have just two leaves -- and before they have more. This usually occurs between 8 and 15 days.
- Unless the field for which a nursery is intended is very small, seeds should not be sown all at the same time. Instead, appropriate batches of seed should be

sown *on successive days*, so that the plants when they are put into the field can be all the same age, all between 8 and 12 days. Enough seedlings for one day of transplanting should be sown at one time (in one seedbed, or one part of a larger seedbed).

Field Preparation

The land preparation does not require special steps, although the soil should be well worked as it would be to get the best results from any method for growing rice, breaking up large clumps or clods, for example, and removing weeds.

- Make sure that there are adequate drainage canals either through the center of the field or along the edges of the field to ensure proper water control. With SRI, one does not want to have standing water in the field or saturated soil.

In general, we have found that compost is quite sufficient as a source of nutrients. Chicken manure, for example, is very rich in nutrients, but sometimes too rich. Farmers have found that they get best results by working compost made from diverse sorts of biomass into the field *during the preceding cultivation season*, when they are growing a crop between their rice crops, such as potatoes or beans or onions. The compost applied then helps that crop grow better, and the further decomposition of the compost provides adequate nutrients for the rice crop that follows.

The steps for preparing the soil for planting seedlings are not described here, including how best to work the compost or (if available) manure into the field. SRI does not require any special preparation, only good normal preparation for having best results. Having cattle trample the soil when it has been puddled both breaks up clods and forces air into the soil for later plant use.

Leveling the field is important but need not be as precise as when one is trying to maintain a uniform layer of water on the field. It is more important to be able to ensure that all parts of the field get water that maintains a minimum of soil moisture. The soil should be well drained, which can be facilitated by constructing channels or furrows around sections within the field and around the whole field. Simply putting furrows in a fishbone pattern across the field does not evacuate water as evenly from the whole area. Keeping root zones moist *most but not all of the time* is the main requirement.

Taking Seedlings from the Nursery

Seedlings should be lifted out of the seedbed gently and **with a trowel**, rather than being pulled up. It is important that the seed sac remain attached to the infant root. Seedlings should be removed from the seedbed as one would cut sod for landscaping purposes. The sod cutting should then be moistened, and each single seedling (each with two leaves) should be gently removed from the cutting with the thumb and forefinger.

When transplanting the seedling, the root should **lie horizontally**, so that the plant's shape (including the root) is like the letter L, with the root tip able to grow downward easily and quickly. Planting the seedling with a vertical motion, plunging it into the soil in a downward movement, will leave the root tip *inverted upwards*. This will delay the

root's resumption of downward growth. Such delay must be avoided if the plant is to reach its full tillering potential.

- Seedlings should be transplanted from the nursery into the field *within half an hour*, and *preferably within 15 minutes*. The roots should never be allowed to dry out. They should also not be handled roughly or slammed or hit with the palm of the hand or against the leg (as some farmers in Madagascar do before transplanting the seedlings, to remove all soil from the roots).

Spacing Transplanted Seedlings

To plant in a uniform square pattern, with regular spacing between plants, the original SRI method was to use **strings** (or ropes) tied between **sticks** put into the soil on the edge of the field, spaced 25 cm apart -- or 30 cm, or 40 cm (or as much as 50 cm if the soil is very fertile and well managed). Other efficient methods, described below, have been developed for marking the field in a grid pattern for transplanting by farmers who want to reduce labor requirements. The string system is described first as it manifests basic SRI principles, but farmers are shifting to the use of simple, cheap implements.

Strings stretched in parallel lines across the field should be marked (or knotted) at similar intervals to match the width of the rows that are indicated by the strings. This will give uniform spacing which facilitates weeding in perpendicular directions. Alternatively, one can draw lines in a grid using a specially constructed simple **rake-marker** that has teeth spaced the desired distance apart. Or an even newer farmer innovation is the **roller-marker** that is pulled over the field's surface, imprinting a grid pattern on the muddy soil. Plants are transplanted at the intersections of the lines, 25 cm or 30 cm apart, or possibly more if the soil is very fertile.

- **Best spacing** is a variable that farmers should test and evaluate for themselves. It is advisable to start with 25 x 25 cm spacing, possibly increasing the distance between plants as farmers' gain skill and confidence and as the soil's fertility is enhanced by compost and root exudation. We have found that SRI practices improve the fertility of the soil season by season so that wider spacing gives better yields over time. Some farmers have experimented with **rectangular** or **diamond-shaped** planting patterns rather than square planting, and they think that this can enhance yield. But such results can be location-specific.

Farmers are often worried, when planting, that some seedlings will die. In fact, when SRI methods are used as recommended, there is very low mortality, maybe 2%. With mortality less than 5%, it is not worth the effort to replace them, because surrounding plants grow larger to take advantage of the open area and fill it up. Farmers who are concerned about mortality can plant some extra seedlings along the edge of the field that they can transplant into any vacant spaces at the time of the first weeding. However, few farmers make such replacement part of their SRI procedures.

Water Control

The importance of keeping the soil unsaturated so that more air gets to plant roots is evident. But how long can a field be left without water? How dry should it be allowed to become? What is the role of rainfall in providing water for field? What differences in

practice will be necessary with different kinds of soil? This is an area where more we still need more systematic experimentation and evaluation for SRI.

The addition of water to the field should occur about a week after transplanting. The first weeding (using the rotary hoe) should be preceded by a water application so that the soil is sufficiently moist for use of the weeder. If there is intermittent rain, this may be sufficient to keep the soil moist with no water additions needed. The best time to add water is before the periodic weedings.

During the growth phase, roughly the first three months, water should be applied only to the fields for weeding purposes, being left to dry out even to the point of surface cracking (if the soil is not heavy clay). This will contribute to soil aeration. Drying should be done 3 or 4 times before the phase of flowering and panicle initiation.

An increasing number of farmers who practice SRI are following an *alternating* schedule for water application. Instead of trying to keep the soil continuously moist but aerated (well-drained), with some periods of complete drying, one can flood the field for 3-6 days and then drain it and keep it dried for 3-6 days. We do not have any research to show what is the best length of time for wetting and drying under such an alternating pattern of water application, and in any case, what is best for a particular field will depend upon soil texture and other factors.

- If farmers want to save labor, they may adopt such an alternating wet-dry schedule. We do not know whether or how much this might lower yield below what is produced with moist but aerated soil. We encourage farmers and others to experiment with different water application methods, noting what serves best their plants' growth needs.

The physical design of fields for good control over water -- drainage as well as inflow -- needs to be considered, matching design to soil, water and topographical conditions, as well as methods for getting greater aeration of water, e.g., applying water to the field through a bamboo pipe that lets water fall onto the field. Farmers are encouraged to experiment with water management according to their understanding of the desirability of *ensuring aeration of the soil for better root growth and for more life in the soil.* Rather than recommend a specific schedule, we emphasize the principle for farmers to adapt to their needs.

Weeding

The justification for this has been discussed already, but the techniques need to be made clear. How does one use the weeder to get best effect for both weed removal and for soil aeration? The practice of planting seedlings in a square pattern (25 by 25 cm or wider) permits weeding in both directions, up and down rows and across them. This should be done until the growth of plants' canopy makes it difficult to pass the weeder between them.

We have seen the benefits of weeding from the yields for farmers using SRI around Ambatovaky, Madagascar, got during the 1997-98 season, considering the number of weedings done. Under the growing conditions in that area (high elevation, >1,000 m, well-drained soils), there were dramatic benefits from doing more than two weedings,

adding about 2 tons/hectare for each additional weeding. Two farmers did **no** mechanical weedings (only hand weeding) and got 6.0 tons/ha; 8 farmers did only **one** weeding and got 7.7 tons/ha while the 27 farmers who did **two** weedings got about the same, 7.4 tons/ha. The 24 farmers who did **three** weedings averaged 9.1 tons/ha, and the 15 farmers who did **four** weedings got 11.8 tons/ha. This information gives justification and encouragement for doing more than the minimum recommended number of weedings. An economic benefit-cost calculation shows about a 20:1 return on the investment of additional labor.

Pest and Disease Control

Pest and disease problems appear to be less with SRI methods, perhaps because the fields are kept less humid. Wider spacing also inhibits the growth and spread of certain pests and diseases. It is known that healthier, more vigorous plants have more capacity to resist pest and disease attacks. Farmers in Bangladesh, Cambodia, the Philippines, Myanmar and Sri Lanka, as well as Madagascar, have reported fewer pest and disease problems with this method, making use of agrochemical protection not necessary or economical. More needs to be known about how farmers using SRI can best deal with any pest or disease outbreak affecting crops. For a scientific explanation of this, according to the theory of 'trophobiosis,' see F. Chaboussou, *Healthy Crops* (Jon Anderson Publications, Charnley, UK, 2004).

Management after Flowering

SRI focuses most of its efforts on getting the rice plants well established in the soil and on encouraging their active increase of roots and tillers during the vegetative growth stage. The water management strategy can be changed once flowering begins, with a thin layer of water (1-2 cm) being maintained continuously on the field, although there can be some interruptions in this. It is recommended that farmers drain their fields about 15 days before harvesting, to let the soil dry out and encouraging the plant to transfer as much of its nutrient supply to the grains as possible. Some think that draining should come earlier or later than 15 days before harvest. Farmers are encouraged to experiment to see what works best for their crop under their soil and other conditions.

Harvest

SRI rice is harvested just like any other rice, except there should be much more rice to harvest. This makes the farmer's task more difficult, but this is the kind of difficulty everyone should wish for: a bountiful harvest. Some farmers find that the way rice grows with SRI management makes harvesting easier. For one thing, there is almost never any lodging, even with larger panicles. Also, the panicles are easier to collect because they are more uniform in size and height. Some scientists have predicted that there will be more uneven (asynchronous) ripening with SRI because of the great increase in tiller number, but this has seldom been reported by SRI farmers.

Experimentation

Throughout the whole process, farmers should be observing their rice crop and their rice field carefully, looking for any signs of stress or poor growth. Farmers should feel free to make some adjustments in practices like timing, spacing, soil preparation,

weeding, or to try any other thing they think might give their rice a better chance to grow vigorously. Innovations should be tried first in small areas rather than for the whole field.

One of the main things that needs to be evaluated by each farmer according to his or her particular field conditions, is the *spacing* of the rice plants. What density of rice plants per square meter will produce the best total yield from that area will depend on the farmer's soil, on temperature and climatic conditions, as well as the variety of rice used.

We suggest *starting* with plants set out in a square pattern 25 by 25 centimeters. Sometimes wider spacing is more productive (even with fewer plants) depending on soil structure, nutrients and drainage conditions. Sometimes narrower spacing produces more total rice, though probably plants should not be closer than 20 by 20 cm, or 25 x 15 cm. Enough space must be left for the weeder to be passed up and down the rows between plants in both directions.

With good soil and water conditions, very wide spacing is likely to be most productive -- 40 by 40 cm, or even 50 by 50 cm. Farmers can try wider spacing in one part of their field and observe whether this produces more productive tillers -- evaluated per square meter, not per plant.

Similarly, farmers who do not think they have enough labor to do more than two weedings are well advised to experiment with additional weedings on part of their field to see whether there is enough increase in rice production from those rows of plants that have a third or a fourth weeding to justify the extra cost. If a field is mostly weeded just *twice*, the usual minimum for controlling weeds, farmers are encouraged to do several rows a *third* time, and then half of these rows a *fourth* time. From this they can see whether, under their field conditions, the extra weedings stimulate enough extra grain filling to pay for their cost. We have found that such investment of labor usually pays very good returns.

Farmers are also encouraged to experiment with different ***varieties*** of rice. Sometimes certain improved varieties respond very well to these management practices, but sometimes, under other conditions, certain local varieties will produce more. We have seen some varieties in Madagascar such as x265 and 2067 perform very well at higher elevations (over 1,000 meters), producing 11 to 12 tons per hectare. But when these varieties are planted at lower elevations (400 to 600 meters) just 20 to 25 kilometers away, their yield may be only half or a third as much. (Variety 2067 produced rice at a rate of 21 tons/hectare for one farmer, Ralalason in Soatanana, Madagascar, who used all of the SRI methods to their best advantage, including excellent compost applied at a rate of 40 t/ha. He applied it to the vegetable crop that he grew between rice crops, so that it had a long time to decompose.)

- Farmers will get *greater return from their land and labor* if they can find varieties that are particularly well suited to their growing conditions. This requires experimenting and evaluation by farmers and will be more efficient if a number of farmers cooperate in evaluating varieties. If a large number of farmers operating rice fields under similar conditions test many different varieties, they can usefully share the information produced by their experience with each variety.

LABOR REQUIREMENTS

One of the main reasons cited by farmers and others for not adopting SRI methods is that SRI requires more labor. This is true in the sense that *intensification* generally requires more work and certainly more management effort. However, the increased labor requirements for SRI are not simply a matter of needing to invest more labor, and they usually reflect extra time spent in learning. Farmers are often finding that SRI requires *less labor* once they have learned the methods and gained both skill and confidence in them. Farmers in a number of countries report that SRI requires *fewer days of labor per hectare* than their conventional methods, which include time for spraying their fields with insecticides, no longer needed.

- An evaluation of SRI in West Bengal, India, by an IWMI-India research team, reported 8% less labor/ha with rainfed SRI.
- Tamil Nadu Agricultural University evaluation with 100 farmers using SRI and conventional methods on adjacent plots also reported 8% less labor with SRI.
- An evaluation of SRI in a Sichuan province village by China Agricultural University found that farmers considered labor-saving to be the most attractive feature of SRI (its use had gone from 7 farmers in 2003 to 398 farmers in 2004).
- In Cambodia, an evaluation for the German development agency GTZ, based on 500 randomly-selected farmers in 5 provinces, found no difference in total labor requirements between SRI and conventional rice cultivation, with new SRI users requiring more labor but with experienced SRI users requiring **less**.

When any new method of production is taken up, some time is required for *learning* how to use the method correctly and quickly. Some of the increased labor needed for SRI is thus simply a matter of the time required for learning. This is an investment that should be repaid within the first season.

The biggest difference in terms of labor requirements is for *weeding.* Doing the minimum of two weedings with a weeder not take much more time than two hand weedings -- and this work is much less tiresome than bending over to pull up weeds. Some farmers consider weeding with the rotating hoe for SRI to be easier than with traditional methods.

- How many weedings a farmer will do beyond this minimum is for each to decide for himself or herself. As discussed above, farmers should experiment to see how much increased yield they can get from doing additional weedings. Some farmers have been able to get 1 ton or even 2 tons more rice per hectare from each additional weeding. There can be a *very great return* from the labor invested, worth 10 times and even 20 times more than the cost. So each farmer can decide for himself or herself how much effort to invest in raising his or her production.

One big difference in labor requirement between SRI and conventional rice production can be for ***harvesting*** because yields are so much higher*.* But no farmers complain about having to bring in more rice from their fields and thresh it, since this means that

the household will get much more benefit from the labor they have already invested. Also, because the panicles are bigger and sturdier, with less dropping of rice, some farmers find that harvesting even for a larger volume of grain is quicker with SRI rice.

Some farmer households will not have enough labor to be able to cultivate the full extent of their rice fields with SRI methods. In this situation, they should experiment with SRI on a small area to satisfy themselves that this technique will increase their production by a substantial amount. We suggest that they then cultivate *only part of their available fields* with SRI, reserving the rest of their land for growing other crops at some other time when they are not limited by the amount of labor time available.

- If farmers can get *much greater returns* from their land and their labor by using SRI methods, it is **a waste of their land and their labor** to continue cultivating the whole extent of their fields with less productive methods. It will be more profitable to cultivate **just part of their land with SRI methods**, and then to grow other crops on the remaining land when time permits.
- If there is a particular operation for which a farm household does not have enough labor to use SRI methods, it will be worthwhile to hire additional labor to assist with this operation. If the household does not have enough money in hand to hire labor, it can offer to share the greater harvest with those who provide labor or to pay for the labor with rice after the harvest rather than with money.

Farmers should not let labor limitations keep them from experimenting with and using SRI methods. There should be some way that they can benefit from this new technology by making the kinds of arrangements described above. SRI is one of the few technologies that can increase simultaneously the productivity of land, of labor, and of water, as well as of capital. The goal is not so much to increase yields by several times as to **make all of the factors of production more productive**. This will enable farmers to get more return from whatever resources they have, starting with their labor, whose productivity should be maximized.

WRAPPING UP

The essential initial step toward success with SRI is to *think about the rice plant in a new and different way.* The previous ways of understanding and cultivating rice have served millions, even billions of people well for many centuries. But with some new management practices, it will be possible for farmers to get *many more grains of rice returned for every grain they plant* by doing this carefully and by providing better conditions for the growing plants.