Changes and Evolution in SRI Methods

The System of Rice Intensification (SRI) developed in the early 1980s in Madagascar by Fr. Henri de Laulanié has been undergoing some changes within that country and in other countries as the basic SRI methodology gets introduced and evaluated. Most of the changes are coming from farmers, something that Fr. de Laulanié would have approved of heartily.

The number of countries in which SRI has been tried with some success is now up to 15, although there is considerable variation in terms of how much yield increase is achieved with the methods. With SRI, we are not necessarily seeking to obtain the very highest yields. Rather, we want to make the greatest gains possible in the factor productivity of land, labor, capital and water. Helping subsistence farmers who now produce 2 t/ha to double their yields to 4 t/ha without having to purchase external inputs can have more merit than raising a commercial yield from 6 t/ha to 10 t/ha.

As noted above, SRI is referred to as a 'system' rather than a 'technology' because it is a set of principles based upon a number of insights into how to create the best growing environments for rice plants. This will lead to fuller realization of their productive potential, presently constrained by conventional practices, to benefit farmers and consumers.

SRI is usually communicated as a set of practices—young seedlings, transplanted carefully one per hill, with wide spacing, and no standing water during the vegetative growth phase, etc. But these practices are best understood as 'starting points' for farmers. Users of SRI methods are encouraged to experiment with variations of these practices and to evaluate them, to see what specific practices can best give effect to SRI principles.

The following discussion was prepared for conference participants to make clear that we would not be discussing and evaluating any orthodoxy—SRI is not a religion. A number of variations in SRI are reviewed below not to set any limits on what does or does not constitute SRI but to encourage evaluation of SRI as an evolving system and to encourage assessment of varying experience and insights for this process.

The practices associated with SRI have been changing and evolving since they were crystallized into a 'system' by Fr. de Laulanié in 1983, very inductively and by his own account, partly by accident. The following discussion reviews how the original practices have been changing over time and in different circumstances.

Age of Seedlings

The first recommended practice is to transplant young plants. Initially these were defined simply as plants less than 15 days old. Once Fr. de Laulanié learned about phyllochrons, he understood and explained this practice in terms of the value of transplanting before the start of the fourth phyllochron. For purposes of explaining this, farmers were advised to transplant seedlings when they still had just two small leaves, and the seed sac was still attached to the root. In general, it is recommended now to transplant seedlings between 8 and 12 days after emergence.

Using very young seedlings

Some farmers, concluding that 'younger is better,' have tried planting seedlings as young as 5 days old. A study of 108 farmers using SRI around Antananarivo and Antsirabe found a slightly negative correlation between yield and seedling age, within a range of 5 to 20 days. The difference was not great enough to be statistically significant, however (MARD/ATS 1996). Some farmers in Madagascar who have become comfortable handling really tiny seedlings and are pleased with their results, have transplanted 4-day-old seedings, and one farmer in Cambodia has started using 3-day seedlings. This seems unnecessarily young, but if farmers want to experiment with planting very young seedlings, this is fine.

At the other end of the continuum, some farmers are using other SRI practices with seedlings that are 3 or 4 weeks old. In Cambodia, the seedling age used for SRI is different between photoperiod-sensitive and photoperiod-nonsensitive varieties. For the former, older seedlings, 3-4 weeks old, are used since these can be planted several months before the monsoon begins and will not flower until after this event. The goal is to get maximum tillering before panicle initiation, so decisions about seedling age need should be adjusted to match varietal and climatic differences.

Two systematic evaluations of SRI in Madagascar, done under quite different climatic conditions, included seedling age as one of the factors to be assessed in multifactorial trials. These trials showed definite benefits from using younger seedings, other things being equal, i.e., with other cultivation practices being half SRI and half non-SRI.

- In trials at Morondava in 2000 on the west coast under tropical conditions, the average yield on 144 plots with 8-day-old seedlings was 3.96 t/ha. This was, *ceteris paribus*, 1.35 t/ha more than the average yield of 2.61 t/ha from 16-day-old seedlings on the other 144 plots, also with half SRI practices and half non-SRI (Rajaonarison 2000).
- In trials at Anjomakely in 2001, on the high plateau which has temperate conditions, the average yield for 8-day-old seedlings on 120 plots, again *ceteris paribus* with half of the plots on better clay and half on poorer loam soil, was 6.28 t/ha, compared to 3.80 t/ha on 120 plots using 20-day-old seedlings. This was a difference of 2.48 t/ha, other things being equal (Andriankaja 2001).[1]

Such data and our understanding of the physiological processes that make SRI successful provide no basis for encouraging use of seedlings beyond 15 days unless ambient temperatures are quite cool. Farmers who lack time or confidence are unlikely to be interested in transplanting any seedlings less than 8 days old, but any who are curious to try seedlings younger than this should be encouraged to do so and to evaluate the results. After a number of years of experience, the advice to start with seedlings between 8 and 12 days old remains sound; however, no specific age should be attached to "young seedlings."

[1] *At the higher elevation in Anjomakely with cooler temperatures, a 20-day-old seedling is biologically equivalent to a 16-day seedling in the warmer climate around Morondava.*

Transplanting Practices

Direct seeding

Experimentation in this area should be encouraged. There is no obvious reason why, if the germination rate is satisfactory, the other SRI practices will not work just as well with rice seeds planted directly into the field, 1 seed per hill (or 2 to give more assurance of germination), with wide spacing, etc.—as with transplanted seedlings. Some farmers in Madagascar who have tried direct seeding report no difference in yield compared to transplanting, but some saving of labor. This alternative method for plant establishment remains to be systematically investigated. It could bring important changes in SRI practice.

Tray nurseries

One variation would be, instead of planting rice seeds in a nursery, to plant them in 'plugs' of soil in plastic trays, shaped like egg cartons, as is sometimes done to establish tree or flower plant seedlings. Putting seedlings in soil plugs directly into the soil would avoid any disturbance of the root, and the root tip would be pointed downward. Since SRI requires many fewer plants per square meter, this method could be feasible for SRI rice though it would be uneconomical with denser planting, requiring 5-10 times more seedlings.

Possibly the process of transplanting this way could even be mechanized in the future. There could also be variations that use germinated seed. Direct sowing of such seed is often done now without any effort to plant in straight rows (in squares) that would facilitate subsequent weeding. Wide spacing in a square pattern to permit mechanized weeding (with soil aeration) is important for highest yields, but if herbicides were used to control weeds, square spacing of plants might be given up, trading off some yield to have lower labor costs.

Using "young seedlings" is the single most important practice in SRI according to the results of the factorial trials reported above, assessing the respective contributions of each practice. But just how this principle should be applied is not something rigid. The principle is that the young plant, especially its root, should not be disturbed and traumatized by transplanting after the fourth phyllochron. How plant establishment can be done best needs to be determined under specific conditions, considering constraints like labor availability. There can be several different ways to deal with this step in plant management.

Handling of seedlings

Careful handling of seedlings during transplanting is a central and crucial part of SRI. That seedlings should be very carefully removed from the nursery is clear, though this will not be relevant with I.B. and I.C. above. The precise techniques for careful transplanting, however, can vary. Farmers have found that using a trowel or similar implement, for example, helps to minimize trauma to the fragile seedling when it is uprooted from the nursery. Also, various methods for transporting seedlings to the field are being developed, such as portable trays.

How quickly seedlings should be gotten into the field from the nursery can vary, but it is recommended this time be no more than 30 minutes, and preferably 15 minutes or less.[2] Farmers have found this less difficult if they establish their nurseries near their fields. One alternative is to plant seedlings in shallow wooden frames that can be kept in or near the house for protection and then carried to the field, so that seedlings are uprooted only at the time of transplanting. Farmers will undoubtedly devise a number of ways to make transplanting for SRI more convenient and with minimum trauma to plants.

Trauma during transplanting can be reduced by attention to the kind of soil mixes used in the nursery and by the water management practices followed in the nursery. In Sri Lanka, for example, a nursery soil mixture of one-third soil, one-third compost, and one-third (chicken) manure has given very good results. Seedlings transplanted from such a nursery when they have two small leaves have put out their third leaves by the end of the next day, indicating that they suffered no set-back from the transplanting.

Spacing

Seedlings per hill

Fr. de Laulanié recommended planting just one seedling per hill, with the objective of avoiding competition among the plants' root systems that would inhibit the plants' growth. However, some research findings have raised the question whether two seedlings per hill might give a better yield than single seedlings. Certainly under some conditions, two-plant hills could produce more tillers per square meter than do single plants, and yet have less root competition than when three or more plants are together.

In one set of trials in Madagascar, Bruno Andrianaivo obtained a higher yield with two plants per hill compared to one. However, he also reports that a farmer using the same variety on a different field with single seedlings got a yield of 15 t/ha, suggesting how soil factors along with varietal differences can have an impact on what is the optimal plant number. One SRI evaluation at Nanjing Agricultural University in China got a higher yield with two seedlings per hill than with with one, but in Cambodia, a group of farmers who compared 1 vs. 2 seedlings found one seedling giving better results.

Such results suggest the value of approaching the question of "seedlings per hill" empirically. Farmers can easily experiment with 1 vs. 2 seedlings per hill on their own fields as this is a simple comparison to make, using single seedlings in some rows and planting two-seedling hills in other rows. The principle is to avoid plant density that inhibits root growth.

In general, we would advise farmers to start with 1 plant per hill, enabling them to see the effect that wide spacing has for more abundant tillering (they cannot see increased root growth so well). We have enough experience that 3 or more seedlings per hill will give lower yield that we would suggest evaluating differences between 1 and 2 seedlings per hill, although if farmers want to try 3 per hill for comparison as well, this is fine. SRI should not be presented dogmatically as only using just 1 seedling per hill. The option of 2 per hill should be discussed and tested under the specific soil and climatic conditions and for different varieties.

Distance between plants

The spacing between plants is always something to be optimized, rather than maximized. For best yields, one wants the largest number of tillers per square meter, not the largest number of tillers per plant. The recommendation of spacing single plants, in a square pattern, 25x25 cm, is a starting point, different from the more usual close spacing of 10-15 cm, and in rows rather than a square.

Some of the highest yields observed with SRI have come with very wide spacing, 50x50 cm. But this was not the spacing that these successful farmers began with, before their soil had been improved by SRI practices. We need to make clear that no particular spacing is recommended as the ideal for all farmers and all fields. The best spacing for particular fields, and for particular varieties, has to be established experimentally. Moreover, the best spacing can change over time. The principle is "wide spacing," but the practice needs to vary to

---

[2] *One study in Nepal found no difference in yield from transplanting times varying between 15 minutes and 1 hour.*

suit local conditions, particularly in terms of soil quality assessed in microbiological as well as physical and chemical terms.

Techniques for spacing

1. **Use of Ropes:** SRI was developed using ropes or strings tied to sticks that were stuck into the bunds of the plot to stretch transplanting lines 25 cm (or some other distance) apart in order to get precise (and wider) spacing. The ropes or strings were knotted or marked at intervals of 25 cm (or wider), and seedlings were then put into the soil at exactly this spacing. With practice, this system can become fairly efficient and quick. However, moving the sticks and managing the ropes or strings remains a chore, and it can be quite laborious.
2. **Rakes:** Some farmers in Madagascar and many in other countries are now using a wooden rake with teeth (pegs) spaced at 25 cm, or wider, intervals. This rake is drawn across the muddy field at right angles to draw lines on the surface of the field in two directions. Seedlings are then placed into the soil at the intersections of these lines. Farmers find that this speeds up the transplanting process a lot.

We would not recommend the use of strings any more, but some farmers who have mastered this technique consider it easy and preferable. Farmers should be informed about both techniques so they can choose. But general farmer preference for the rake method should be noted. A few farmers who have become very comfortable with SRI methods are now *transplanting by sight* and are achieving sufficiently regular spacing without lines or rakes. This is not for beginners, however.

Water Management

This is probably the most complicated variable in SRI. The principle is clear: rice roots should not have to grow in a hypoxic, anaerobic environment caused by continuous flooding and saturated soil. When this happens, most of the rice plant roots stay in the top 6 cm of soil, and most of them degenerate by the time of panicle initiation, when grain formation is beginning.

Daily water management

Fr. de Laulanié recommended keeping the soil moist but unsaturated during the vegetative growth period, applying just "a minimum of water," with the field dried out and left unwatered for 3-6 days for several periods of time during the growth stage. There is plenty of experience supporting this practice, which requires adding small amounts of water to the field on a regular basis, preferably in the late afternoon or early evening (unless there has been rain during the day), and then draining any excess (standing) water still on the field in the morning. This way the soil is open to aeration during the day. This way it also receives the sun's rays to warm it during the day, not having reflected most of them as happens with standing water on the field.

Alternate wetting and drying

In Madagascar a large number of farmers are now using a system of alternate wet-dry irrigation (AWDI) instead of continuous non-flooding (NF) during the vegetative growth period. We do not know whether this gives them higher yields, or just saves them labor, or both. This subject merits more systematic study than it has had thus far. It makes sense to describe to farmers both AWDI and NF approaches to water management, making sure that they understand the principle justifying the use of either method.

We will soon have data evaluating the two methods when Oloro McHugh completes his master's thesis in agricultural engineering at Cornell. He studied the practices of 108 farmers in four different locations in Madagascar who were using both SRI and standard irrigated rice methods on their farms. Among the 53 farmers who were using AWDI along with other SRI practices, there were 31 combinations of wet days/dry days during the tillering period. The average numbers were 4.4 days wet followed by 4.8 days dry, but there were almost all conceivable combinations. The range of wet days was 1 to 10 wet days, and of dry days, also 1 to 10, so there were no strongly preferred or obviously superior rotational systems.

Rather than make a specific recommendation for water management practices, we should discuss with farmers the principle of not keeping the soil continuously saturated so that rice roots are deprived of oxygen and start dying back. We should describe the alternative means to achieve this objective, letting farmers decide what is likely to work best for them. Certainly different practices are needed for clay vs. other kinds of soil.

Weeding

This is necessary for growing rice when fields are not kept continuously flooded. We recommend use of the (a) rotary weeder, as noted above. However, there are the options of (b) manual weeding, or (c) using herbicides. Some farmers in Cambodia are using (d) simple hoes, which loosen the soil as they remove weeds, and in Sri Lanka, some farmers are experimenting with (e) mulching. The latter conserves water as it suppresses weeds and possibly adds nutrients to the soil. If soil is rich in organic matter, there can be vigorous populations of earthworms and other macrofauna subsurface that contribute to soil aeration biologically, perhaps as much as could a mechanical weeder.

Weedings with a rotary hoe should begin within 8-10 days after transplanting, to get ahead of weed growth, though possibly the start can wait until 12-15 days. Farmers should understand that the purpose of such weeding is to aerate the soil as well as remove weeds. Two weedings is usually the minimum number needed. Some field conditions may require more than this. We would encourage 3 or 4 weedings even if not needed for weeding purposes becauase this contributes to soil aeration and usually results in higher yields.

In Sri Lanka, we are encouraging farmers who currently do only two weedings to do a third weeding on part of their field, along one edge, and to do a fourth weeding on half of this area. This will enable them to compare and evaluate, for their own soil and other conditions, whether a third or a fourth weeding enhances their yield enough to justify the extra expenditure of labor. It should be very easy for farmers to do this experimentation, comparing the number of tillers per plant and of grains per tiller with the three treatments.

Some research in Madagascar has found a combination of herbicides and rotary-hoe weeding gave the best results, but this could be specific to the particular soil and other conditions. This area of practice is clearly one where experimentation is called for. It should be fairly easy for farmers to test alternative treatments on just a part of their field, such as spraying a few rows with herbicide to determine what if any yield effect is associated with this practice, or doing manual weeding on a few rows to compare this with the effects of the rotary hoe.

Soil Amendments

The addition of nutrients, either organic (compost, green manure, farmyard manure, or mulch) or inorganic (chemical fertilizer), is not a requirement with SRI. Higher yields can be obtained by using SRI practices without any amendments, capitalizing on the effects of the other principles presented above. However, it is not clear for how long such high yields will be sustainable without making some contributions to soil fertility. SRI methods can be used with just inorganic fertilizer amendments, with definite enhancement of yield. However, the highest yields have been obtained with organic soil nutrient amendments, particularly with compost, making such additions very cost-effective.

SRI was developed in the 1980s using chemical fertilizers. When government subsidies were withdrawn at the end of the decade and small farmers could no longer afford fertilizer, Fr. de Laulanié began using and recommending compost. The factorial trials we have done with SRI methods show higher yields with compost than with recommended applications of NPK fertilizer, though the difference was less high-yielding varieties (HYV) are used. This is not surprising since HYVs have been developed to be fertilizer responsive.

Other things being equal, compost on average gave 0.27 t/ha more than with fertilizer, using a traditional variety in half the trials (N = 144) and an HYV in the other half (N = 144) at Morandava. The increase from using compost compared to NPK fertilizer on a combination of good and poor soils (120 trial plots of each), with all plots planted with a traditional variety (riz rouge) not bred to be responsive to chemical fertilizer, was 1.01 t/ha. This latter difference, considering the cash costs required for NPK applications, should certainly make compost a good investment.

Our observations indicate that yields with SRI methods commonly increase from year to year. A good part of this increase apparently comes from improved soil quality, assessed in biological rather than chemical terms. The plant, soil, water and nutrient management practices combined in SRI probably enrich the soil microbiologically, but this remains to be investigated and demonstrated. Probably at some point, given the high yields obtained with SRI methods, farmers will run into soil nutrient constraints, e.g., P deficiency, that will need to be alleviated by soil amendments.

Soil nutrient amendments are not recommended as a necessary part of SRI. These may not be needed, at least for some number of years. Eighty percent of the 109 farmers studied by McHugh and Barison were not using compost or NPK on their crop, and yet yields with SRI methods were about double those with standard methods. If farmers want to use chemical fertilizer instead of compost, because fertilizer is accessible and/or not very expensive, this is compatible with SRI and will give higher yields than not adding any nutrients at all.

Wherever farmers are willing to make and apply compost, we feel comfortable recommending this as advantageous in the short run and even more in the long run. Thus far, there has been little evaluation of the effect of SRI practices when used on different types of soil. Considerable analysis remains to be done.

Varietal Differences

This is another area where there has been little systematic evaluation so we do not know much about how different varieties respond to SRI practices. Obviously, varieties—whether modern or local—that have low propensity for tillering will not perform as well with SRI methods as varieties that have a high propensity to tiller. We have found that some high-yielding varieties (HYVs) respond very vigorously to SRI methods (IR-15, IR-46 and Taichung 16 in Madagascar; BG-358 in Sri Lanka), giving yields in the 12-15 t/ha range and some even in the 15-20 t/ha range.

We should encourage farmers and researchers to start looking more carefully at varietal differences in response to SRI so that in the future, recommendations can be made as to which varieties are most likely, under particular soil, climatic and other conditions, to give the most tillering, the most profuse root growth, and the greatest grain filling when optimum SRI practices are employed. Farmers can experiment with different varieties in just a few hills of their field, comparing the resulting plants and grain filling to see which varieties give the best response to the practices.

Land Preparation and Other Practices

Little has been said or studied about land preparation as an important factor in crop management. Fr. de Laulanié decided not to make any changes in land preparation practices part of SRI. This approach simplifies its extension, but it does not mean that there could not be some land preparation practices that are more advantageous than others, and more cost-effective, with SRI methods.

As the knowledge base for SRI methods expands, and as we become clearer about best practices for particular conditions, there will be a number of other matters for testing and evaluation, probably starting with land preparation. Recommendations will always need to be tailored to soil type and other soil conditions.

In-field channels

How fields should be laid out for water management was discussed by Fr. de Laulanié in some of his technical notes. Rather than do 'flood irrigation,' inundating the field from the higher point where water enters the field with flow toward other (lower) parts of the field, it has been recommended to construct a ditch around the inside of the paddy. This permits farmers to put water into the field and raised gradually the level to flood the whole paddy gradually as the level in the ditch exceeds that of the field.

McHugh, however, found only one farmer of the 109 he surveyed having made an investment in such careful water control, however, and yet most got a doubling of yield with other SRI practices and less precise water management. We think such careful field layout has advantages for getting the highest yields, but only if farmers are prepared to make substantial investment of effort to get the most benefits from SRI.

Active water aeration

Another suggestion of Fr. de Laulanié was to run the water into the paddy through a bamboo pipe so that the water falls (splashes) into the field and any standing water, thereby aerating it and making more dissolved oxygen available to the root zone. This method has not been evaluated, but it has some intuitive appeal of oxygenation is considered beneficial.

Duck-rice cultivation

Keeping ducks in the rice paddy is recommended for other systems besides SRI, for their fertilization of the field and possibly for their stimulation of meristematic tissue when hunting for insects in the culm at the base of plants, eliciting it appears deeper root growth. Bill Mollison, the founder of "permaculture," cites considerable evidence that a duck-rice system can be more productive. The principles he cites should be compatible with SRI.

Fish-rice cultivation

Combining fish and rice production is a long-standing strategy for small farmers. With SRI which does not keep the paddy flooded continuously, this needs to be modified. Some farmers in Madagascar have a fishpond in a corner of their paddy and think this gives good results. Some systematic evaluation of how to maintain fish without raising the water table so much that the root zone is continuously saturated needs to be assessed.

Raised beds

Mexican farmers have developed a wheat management system with raised beds that has several features in common with SRI: wide spacing, lower seeding rates, and furrow irrigation in place of flood irrigation (Sayre and Moreño 1997). Some research has started in India with permanent raised beds for both rice and wheat, with good results so far. One alternative to flooding fields intermittently could be raised beds that keep the root zone better aerated, with controlled applications of water in furrows (like SRI, reducing water applications by half).

Zero-tillage and green manures

In Cambodia, several farmers have begun trying "no-till" SRI by mulching the soil with stubble and then planting seeds through the mulch. Others are planting a cover crop and then cutting it to serve as a green manure and mulch, suppressing weeds. We look forward to their results. This is a very promising area for farmer and researcher experimentation and evaluation.

Ratooning

A few farmers in Madagascar let their harvested SRI crop regrow for a second crop. The yields are not as high as the first crop, but 60-70% can be obtained given the well-established root system. Since ratooning saves a lot of labor, this can be economically profitable. What are the best management practices to optimize returns on a second rationed crop? This is an interesting area for experimentation.

* * *

There will surely be many other adaptations and modifications of SRI. We want farmers in many countries to have a longer "menu" of practices to choose from. We can offer a rather simple menu to begin with, but an increasingly diverse one for farmers to consider, since one of the aims of SRI is to help farmers become more knowledgeable and skillful, not just to grow more rice. The principles underlying these practices should always be discussed, so that farmers have a good idea why they are introducing any changes in their methods.

—*Norman Uphoff*

References

Andriankaja, Andry (2002). Mise en evidence des opportunites de développement de la riziculture par adoption du SRI, et evaluation de la fixation biologique de l'azote. Memoire de fin d'etudes. Department of Agriculture, University of Antananarivo, Antananarivo.

MARD/ATS (1996). Avantages et contraintes du SRI: Enquête aupres de 108 exploitants des régions d'Antananarivo et d'Antsirabe. Rapport du Project ATS/FAC appui au développement du SRI, Campagne rizicole, 1995-96. Antananarivo: Ministry of Agriculture and Rural Development, and Association Tefy Saina.

Rajaonarison, Jean de Dieu (2000). Contribution a l'amelioration des rendements de 2eme saison de la double riziculture par SRI sous experimentations multifactorielles: Cas des sols sableux de Morandava. Memoire fin d'etudes. Department of Agriculture, University of Antananarivo, Antananarivo.

Sayre, K. D., and O. H. Moreño Ramos (1997). Applications of Raised-Bed Planting Systems to Wheat. Wheat Program Special Report No. 31. Mexico, C.F.: CIMMYT.